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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

<u>ATTACHMENT 1</u>

Zwick, P. (1992) Stream Habitat Fragmentation—a threat to biodiversity. Biodiversity and Conservation 1, 80-97.

Biodiversity and Conservation 1, 80–97 (1992)

Stream habitat fragmentation – a threat to biodiversity

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Biodiversity is undisturbed rhithral streams in central Europe is high, with about 1000 resident metazoan species; over 600 insect species occur in the Fulda river (Germany). Longitudinal downstream shift of dominance from rheobiontic to rheophilous and finally to ubiquituos rheoxenic taxa in the potamal is described. Present downstream importance of ubiquituous species probably results from replacement of original potamal communities, present faunas being surrogates. Species losses through human impact are well documented for fish. The case of Plecoptera (10 potamal species either altogether extinct, extinct in Central Europe or extremely endangered) suggests that potamal invertebrates suffered as severe losses as did fish.

Human impact on major rivers was so severe also because they occur at distances beyond average dispersal capacity of the fauna, i.e. are widely separate ecological islands, with known risk of species losses. In contrast, faunal exchange between adjacent headwater streams in mountains with intact stream nets is easy, certainly for amphibious insects. However, damage to rhithral streams is becoming increasingly frequent. This fragments stream nets, turning also upper parts of drainage systems into ecological islands, with danger of extinctions. Rhithral biodiversity is thought to be much more endangered by human impact than is presently recognized.

Keywords: streams; biodiversity; ecological island; Plecoptera; human impact

Introduction

Streams represent the most widespread type of surface freshwater habitat in Central Europe. They are the central part of the global watercycle, interconnecting all of its compartments, fresh as well as saline. Even though at any given moment in time the amount of water contained in streams may be relatively small, a very large proportion of the available freshwater passes through streams during time. Streams drain and irrigate the landscape, which is largely shaped by the power of flowing water. Conversely, the quality of the landscape also affects streams. Conditions in streams affect both the quantity and quality of our most vital resource, clean fresh water.

A typical stream network resembles a tree, with a large, widely spread-out root-like base eventually leading to a single, major trunk. The stream water body exhibits universal coherence and physical continuity, and naturally there is also regular (Illies, 1961) or even continuous (Vannote *et al.*, 1980) longitudinal change of ecological conditions. However, ecological continuity has in many cases been disrupted by human action. Due to the hierarchical nature of stream networks, discontinuity in any given river continuum fragments the stream network, disconnecting upper subordinate sections of the catchment system and turning them into separate island-like systems. Even outside

Europe, only few streams maintain their original natural state, for a recent synopsis see Benke (1990).

Methods

Data on biodiversity in streams discussed were largely drawn from the literature (see legend to Table 2). In view of their importance, one would expect streams to be well-known ecosystems, but this is not so. Available comparative data only measure diversity by counting numbers of species present.

The longitudinal organization of stream topography, changes of abiotic and biotic factors along the river, have profound effects on, or have corresponding counterparts in, almost every aspect related to running waters, be they abiotic factors like stream flow, sediment composition, temperature regime, solute or particular freights, or be they biotic, i.e. flora and fauna (e.g. Vannote *et al.*, 1980). These changes probably also affect biodiversity, but there are no synoptic studies of this subject. Still, studies related to an earlier European attempt to describe stream ecosystems (Illies, 1961; Illies and Botosaneanu, 1963) provided useful species lists because the approach is based on faunal assemblages and species replacement. These lists concern the Fulda river in central Germany. Illies' main study object.

There are several studies of biodiversity for selected taxa in small streams, or in sections of moderately large streams, but biodiversity (of the same selected taxa) has been studied over the entire (220 km) length of only one major European river, the Fulda (Hesse, Germany). There seems to be only a single small stream in Europe, the Breitenbach, for which the entire biodiversity, not only of selected taxa, is fairly well known; only the fauna will here be considered.

Biodiversity in near-to-natural rhithral streams

The small Breitenbach (near Schlitz, Hesse, Germany) is inhabited by over 1000 species of metazoa, reported from a 2 km stretch (Table 1). The two species of *Gammarus* contribute about half the animal biomass in this stream, insects contribute most of the other half. Most of the species concerned are typical stream dwellers and absent from other bodies of fresh water.

The remaining stream invertebrates, except the few large-bodied Crustacea and Mollusca, are very small metazoa contributing small amounts of biomass, like in other streams. Many of these small non-insect invertebrates possess resistent eggs, cysts or other stages in which they are passively dispersed, mainly wind-blown, over large distances. They are hence widespread in many bodies of fresh water, instead of being restricted to streams.

Several insect groups have also been studied in other rhithral streams in central Europe. These streams are located in distant, geologically and climatically distinct areas, and hence cover the spectrum of near-to-natural European foothill streams adequately. Species numbers for given groups are very similar in all streams compared (Table 2). Clearly, the Breitenbach is not exceptional but its diversity is within the general range for the insects considered. It is a legitimate assumption that the Breitenbach also resembles the other streams in the diversity of non-insect taxa not actually studied in the streams compared. Accordingly, about 1000 metazoan species can be expected to live normally in ecologically healthy Central European rhithral streams.

Table 1. Numbers of metazoan species in the Breitenbach near Schlitz (Hesse, Germany) as of 1989*.

Fauna	Number	Insecta	Number
Plathelminthes	50		
Gastrotricha	6	Odonata	1
Nematomorpha	1	Ephemeroptera	18
Nematoda	141	Plecoptera	18
Rotatoria	130	Megaloptera	2
Mollusca	12	Planipennia	2
Vertebrata	3	Coleoptera	71
Annelida	56	Hymenoptera	3
Crustacea	24	Trichoptera	57
Hydrachnellea	22	Diptera	468
Total	445		640

*Total: 1085 species of Metazoa.

Table 2. Number of species in selected groups (Ephemeroptera; Plecoptera; Trichoptera; Diptera: Chironomidae, Ceratopogonidae, Limoniidae) of aquatic insects in some Central European epirithral and metarhithral streams. (Data from: Dittmar, 1955; Mende, 1968; Zwick, 1969, 1977; Lehmann, 1971; Ringe, 1974; Erpelding, 1975; Mendl, 1975; Havelka, 1976; Malicky, 1976; Sandrock, 1978; Wagner, 1979, 1980a,b, 1982; Caspers, 1980, 1983; Caspers and Wagner, 1980, 1982; Illies, 1980; Marten, 1983; Pitsch, 1983; Eckstein, 1984; Joost *et al.*, 1985; plus unpublished data for the Breitenbach).

Stream	Ephem	Pleco	Trich	Chiro	Cerat	Limon
Aabach (Sauerland)	23	36	64	16	—	—
upper Fulda river (Rhön Mts)*	22	34	56	173	—	37
Feldbach (Rhön Mts)	13	30	37	—	—	—
Grumbach (Rhön Mts)	8	30	46	—	—	—
Breitenbach (Schlitz)	18	18	58	150	51	48
Rohrwiesenb. (Schlitz)	12	13	18	85	59	38
Spitter (Thüringen)	13	30	30	—	—	—
Annaberger B. (nr Bonn)	3	6	23	59	—	38
Sauer (Eifel)	21	36	48	—	—	—
Teichb. (Lunz, Austria)	12	33	33	114	—	41
Schreierbach (nr Lunz)	7	31	31	89	—	43
for comparison: entire Fulda r.	35	41	84	246	—	—

*Epirithral and metarithral section, from spring to Altenfeld.

Biodiversity, species replacement and ecological groups in the Fulda river

The Fulda river (Hesse, Germany) is about 220 km long, its drainage area is almost 5000 km^2. The river drops from 850 m above sea level in the Rhön Mountains to about 110 m above sea level at Hannoversch-Münden. Maps of water quality (Der Hessische Minister, 1986) show the Fulda as only moderately polluted and of overall standard quality, or better than that in places; it therefore is a suitable study object. Detailed descriptions of the stream and its fauna are available. The following papers are mainly used here: Illies, 1953; Lehmann, 1971 (among Chironomidae, only some 140 out of 246 species were common enough to analyse distribution in the Fulda river and only these are considered here); Marten, 1983; Pitsch, 1983; Zwick, 1969; Zwick, 1974. The most detailed information is on insects to which this paper is largely restricted and of which over 600 species are recorded from the Fulda river. In view of the general importance of insects in stream ecosystems, this restriction does not prevent general conclusions.

Except for some ubiquitous ones, every species occupies some restricted range, there is permanent species replacement along the river. Some groups show strong trends of diversity along the Fulda river. For example, while the number of Heteroptera species strongly increases downstream, only very few of the 40 species of Plecoptera occur below

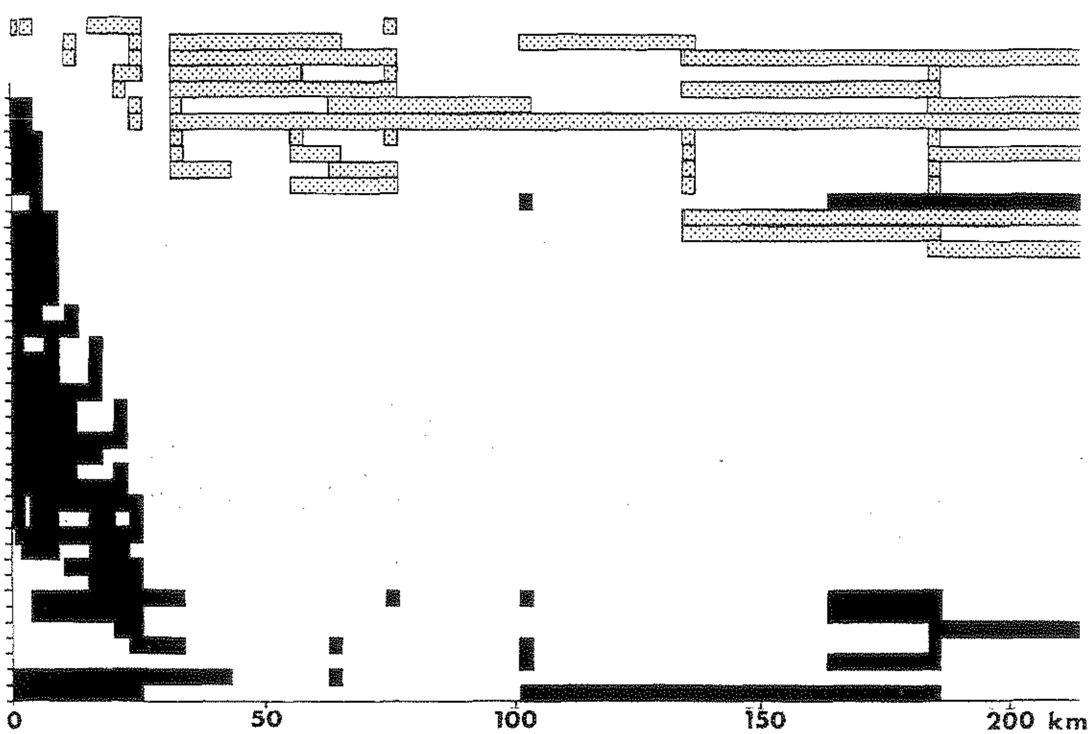

Figure 1. Distribution of Heteroptera (▤) and Plecoptera (■) species (identified only by tick marks) at 20 sampling stations along the Fulda river from spring (km 0) to mouth (km 220). Rheobiontic species black, rheoxenic species stippled. Data after Marten (1983) and Zwick (1969).

Fulda city, most are restricted to the top 20 km of the stream (Fig. 1). The few potamal Plecoptera are endangered, some have even disappeared from the Fulda river since the first collections, in the 1950s. Simuliidae are also much more diverse in the rhithron than in the potamon (see Fig. 5 in Zwick, 1974).

In other orders or families of Diptera the situation is different. The numbers of species of Diptera: Chironomidae (Fig. 2), of Trichoptera (Fig. 3), Coleoptera, less clearly also of the Ephemeroptera present at any given site of the Fulda river do not vary much between different stream sections. As this group of taxa includes the most species-rich ones, total insect species numbers along the stream are fairly uniform, except for a bottleneck below the township of Fulda (Fig. 4).

Using data in the Limnofauna Europaea (Illies, 1978), species from the Fulda river were assigned to three broad ecological groups. The first is restricted to running waters; the second prefers running water but can at least temporarily or occasionally tolerate stagnant waters; the last group is ubiquitous, or even prefers stagnant over running bodies of water. These groups include the rheobiontic, rheophilic or rheoxenic species, respectively. The relatively high downstream diversity in the Fulda river is only maintained because generalist and ubiquitous species appear in polluted, impounded and otherwise modified stretches and compensate for the disappearance of typical stream inhabitants.

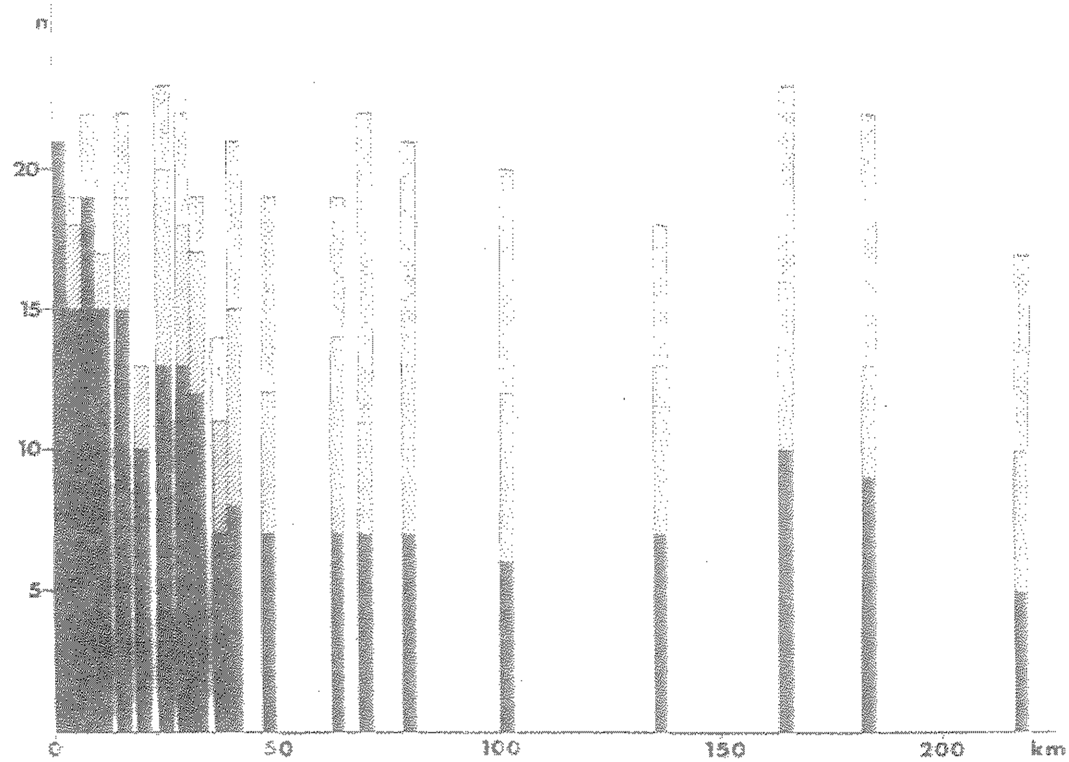

Figure 2. Number (n) of abundant rheobiontic (black), rheophilic (hatched) and rheoxenic (stippling) species of Diptera: Chironomidae at 20 sampling stations along the Fulda river from spring (km 0) to mouth (km 220). Data after Lehmann (1971).

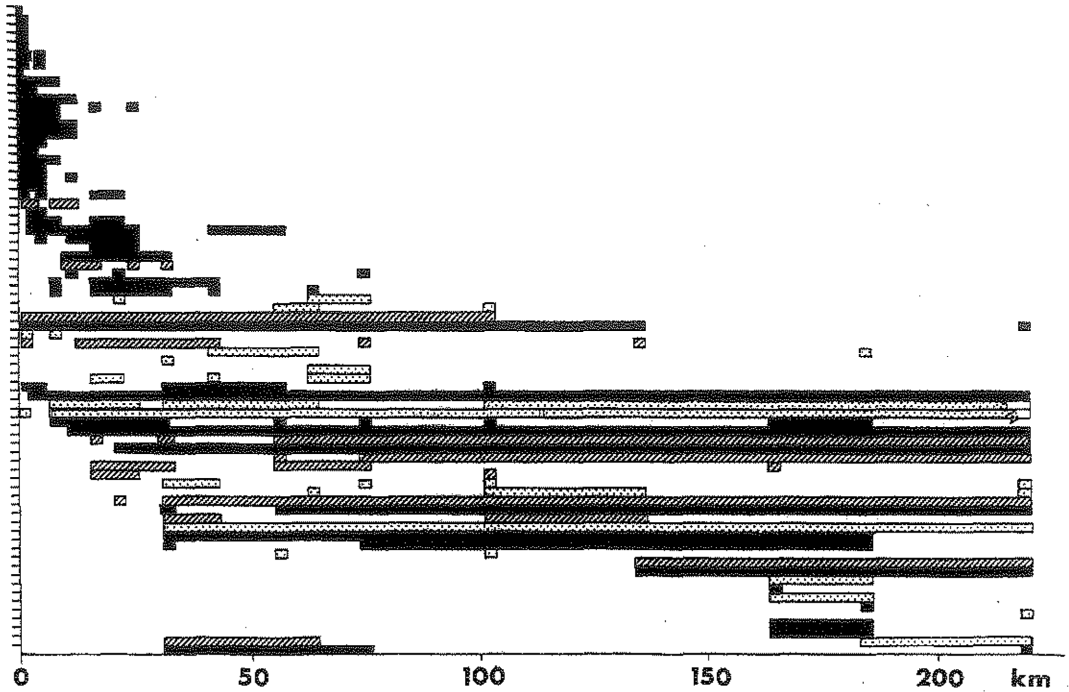

Figure 3. Distribution of Trichoptera species (identified only by tick marks) at 20 sampling stations along the Fulda river from spring (km 0) to mouth (km 220). Rheobiontic species (■), rheophilic species (▨), rheoxenic species (▒). Data after Pitsch (1983).

The short epirhithral section containing almost exclusively rheobiontic species is followed by stream sections with increasing proportions of rheophilic and rheoxenic taxa. Although the potamon also includes rheobiontic species, their proportion is low (Figs 1–4).

Downstream increase of ubiquituous fauna – a natural phenomenon?

Whether the downstream recess of rheobiontic species, and the concomitant increase of rheophilic and rheoxenic taxa described above is a natural phenomenon or reflects human impact is unclear. Present potamon faunas might, at least in part, be secondary surrogate faunas replacing vanished original inhabitants of the potamon.

Thorup (1966) doubted that the distinctness of stream zones in the Fulda river was natural. Indeed, the abrupt drop in the proportion of typical running water species (Fig. 4) coincides with the location of the township of Gersfeld, i.e. some pollution, but also with a step in the slope curve and with a change in valley shape from narrow erosional to relatively wide, with meandering stream course. According to Illies (1953) the same location marks the limit between epirhithron and metarhithron. Similarly, the rhithron–potamon–boundary (after Illies) is at the confluence of the rivers Fulda and Fliede, just upstream from Fulda. At this same site, the slope curve exhibits another major discontinuity (Fig. 3). This agrees well with Huèt's (1946, 1949) concept of the overall importance of stream gradient. However, the low species numbers at this site might as

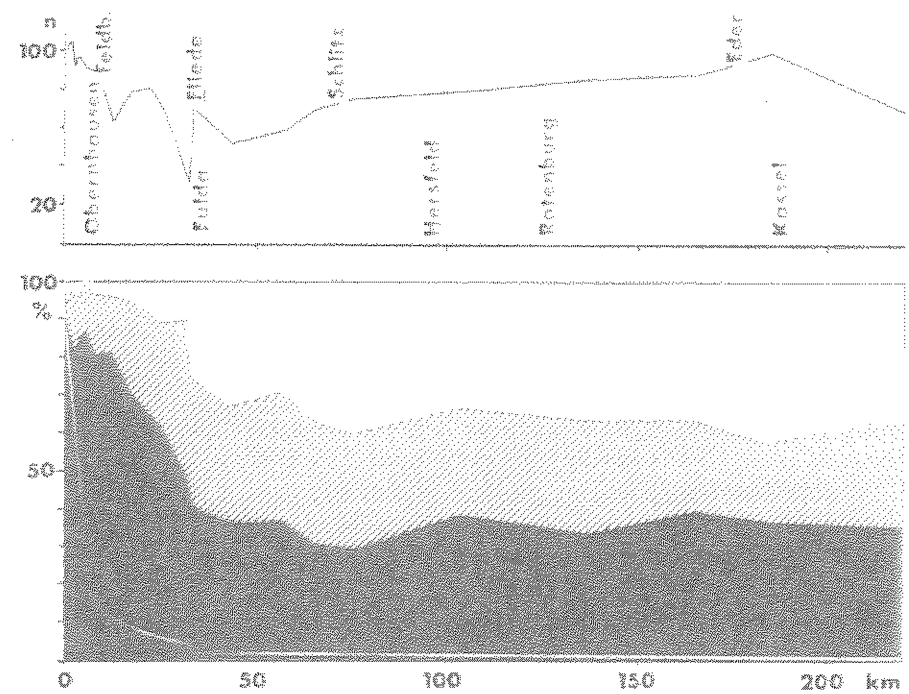

Figure 4. Physical and biological gradients along the Fulda river, at 20 sampling stations from spring (km 0) to mouth (km 220). Top: cumulated species numbers (n) of Ephemeroptera, Plecoptera, Heteroptera, Coleoptera, Trichoptera and Diptera: Chironomidae; approximate location of several townships and tributaries (underlined) also indicated. Bottom: relative importance (%) of rheobiontic (■), rheophilic (▨) and rheoxenic (□) species in the taxa listed above.

White inset, bottom: Mean slope of river bed (‰). Based on data from Zwick (1969), Lehmann (1971), Marten (1983) and Pitsch (1983).

well reflect suburbian impact (effluents from the township of Fulda proper with 60 000 inhabitants enter further downstream, after secondary and recently also tertiary sewage treatment) on the Fulda river, as well as input by the tributary, the Fliede river, which drains a potassium mining area.

Disappearance of potamal species: fishes and stoneflies

Although the extent to which the potamal fauna has been affected by human impact is not precisely known, there is no doubt that major anthropogenic changes did occur. In the historical past, streams became centres of settlements, trade and industry. When humankind started to take scientific interest in stream life, it had already severely interfered with it. A comprehensive reconstruction of the original unaffected biodiversity is impossible (Fittkau and Reiss, 1983). They also recognize that not only interference with the streams themselves but also interference with flood plains reduced the diversity of the faunas of major rivers.

Human impact on riverine fish is well documented. In a list of the fishes of Hesse (Meinel *et al.*, 1987), five species once abundant in the Fulda river but extinct now are named. If one includes the lower course, the Weser river (which is outside Hesse) in the analysis, the list is even longer: sea and river lampreys (*Petromyzon marinus* L., 1758, *Lampetra fluviatilis* L., 1758), sturgeon (*Acipenser sturio* L., 1758), allice shad (*Alosa alosa* L., 1758), salmon (*Salmo salar* L., 1758), sea trout (*Salmo trutta trutta* L., 1758), smelt (*Osmerus eperlanus* L., 1758) and flounder (*Platichthys flesus* L., 1758). The same list applies to other German or Central European rivers.

The list of fish lost from the potamon is longer than that of fish resident in the better preserved rhithron. Fish might be a special case, in that lost species were migratory, anadromous species. Are there similar losses among invertebrates? Subfossil remains of molluscs indicate losses from river faunas, e.g. the early disappearance of the pearl mussel *Margaritifera auricularia* (Spengler, 1793; Jäckel, 1962), but Mollusca constitute only a very small portion of the total fauna. For other invertebrates, especially insects, anthropogenic changes have hardly been documented. Evidence is not readily available, except for stoneflies, where former potamal species still exist in old collections and/or have recognizably been described or depicted (e.g. Hoefnagel, 1592) by early authors. These losses are here documented, as a sample study (references to stonefly literature before 1972 in Illies, 1966; Zwick, 1973).

Newman named the distinctive *Isogenus nubecula* from England and reported it (Newman, 1839) from Hertfordshire, Worcestershire and Nottinghamshire as 'common . . . in most cabinets of British insects'. The same species (as *Perla parisina*; Rambur, 1842) was '. . . exceedingly common in the first days of spring' in Paris. Despax (1951) listed additional French Material. Albarda (1889) saw Rambur's collection and noticed the synonymy; the species was then 'rather common' in the Netherlands, as confirmed by existing collections (Claessens, 1981). Additional reliable literature records and specimens from Ulm (the Danube, Germany) and Dresden (the Elbe, Germany; coll. Klapálek, Prague, The Netherlands), show the species was very widespread in major European rivers. The Fulda and Weser rivers are inside the general range of the species and although *I. nubecula* has not been recorded from them, it was once certainly present (Fig. 5). There are single records from Austria (Theischinger and Humpesch, 1976) and Bulgaria (Russev, 1977) in the early fifties of the present century. By now, the species has disappeared from western and central Europe, but is said to survive in Scandinavia and Poland (Kittel, 1976; Lillehammer, 1988).

Other large and apparently fairly common taxa were the two European species of *Marthamea*, at least *M. vitripennis* (Burmeister, 1839; coll. Klapálek contains many specimens from places in Czechoslovakia from where it has now disappeared) and probably also *Agnetina elegantula* (Klapálek, 1905; Zwick, 1984a, b). All three are extinct in Central Europe today, except at single localities in Poland where the last two have still been found about 15 years ago (Kittel, 1976).

Some species were found only very few times, apparently just before their extinction, around the turn of the century. Records from different river systems suggest these species were once widespread. Examples are the wingless, spider-like *Taeniopteryx araneoides* (Klapálek, 1902; type examined) in the Elbe and the Danube, and *Oemopteryx loewii* (Albarda, 1889; types seen), a species with peculiar short wings with upbent tips from the Rhine between Bonn and Arnhem, and from the Danube between Budapest and Regensburg. Schäffer (1755) observed its mass emergence at Regensburg, mentioning

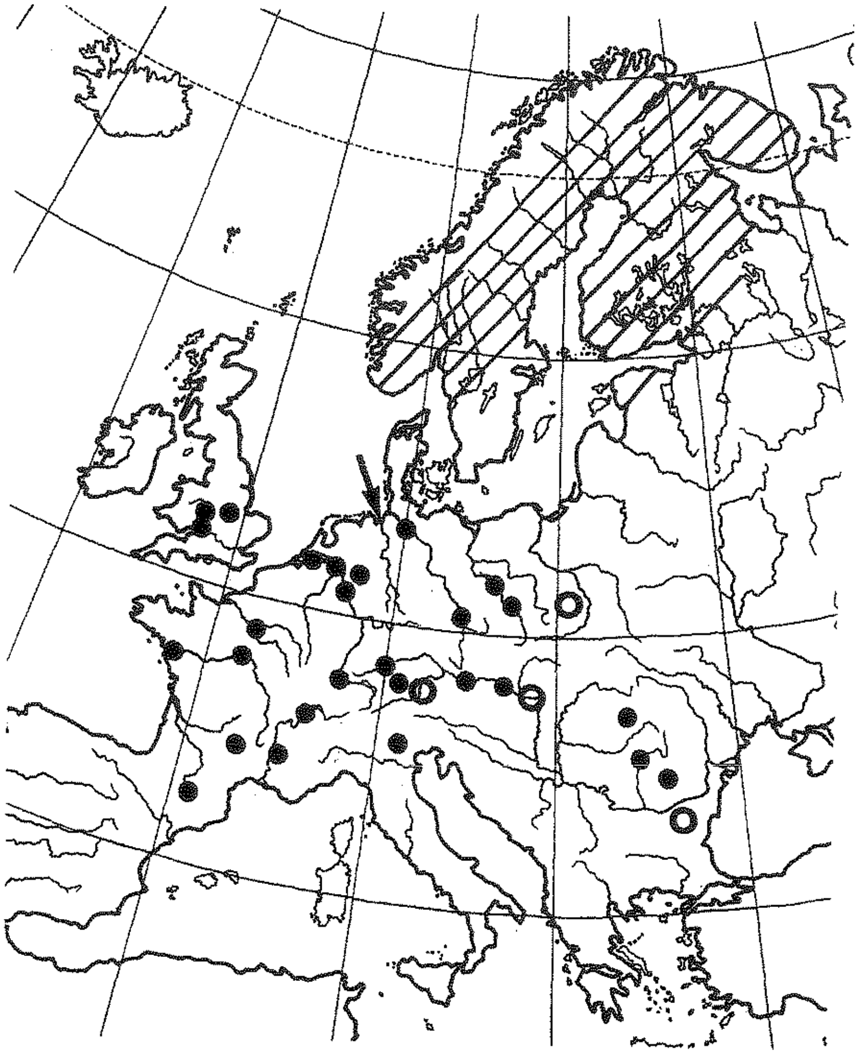

Figure 5. Distribution of the stonefly *Isogenus nubecula* in Europe (after data in Illies (1966) and Zwick (1973)). ●: former confirmed records, now extinct; ○: collections after 1950; Extant Skandinavian and Baltic localities (▨) not individually shown. Arrow marks Weser river, its western headwater branch is the Fulda river.

and illustrating the visible cerci, thereby excluding confusion with *Brachyptera trifasciata* (Pictet, 1832), the second European species with similar wings. *B. trifasciata* was first described from Geneva; large numbers were then observed. In Varallo, at the foot of the Italian Alps northwest of Milano, it was so numerous in 1868 that bushes broke under its weight (Ravizza and Zwick, 1981), but the species is unrecorded from Italy today. In Klapálek's collection, there are numerous males from Vienna, 1899, but there are no recent Austrian records. The last specimen of this species was collected in Geneva, in 1950 (Aubert, 1989). *Dictyogenus imhoffi* (Pictet, 1841) is another species formerly found in large European rivers, but now apparently extinct. The formerly widespread *Isoperla obscura* (Zetterstedt, 1840), *Xanthoperla apicalis* (Newman, 1836) and *Brachyptera braueri* (Klapálek, 1900) have become rarities of scattered distribution in Central Europe. Except *B. trifasciata* and *D. imhoffi*, the fauna of Fulda and Weser rivers once almost certainly included all these riverine species, possibly others still.

Losses of fauna apparently still occur. In the Fulda river, several stonefly species that were abundant at the time of the first collections (Illies, 1953) have since disappeared (*Taeniopteryx schoenemundi* (Mertens, 1923) survived in tributaries for some time, but is now no longer found in these) or became very restricted and rare, e.g. *Brachyptera monilicornis* (Pictet, 1841), *Perla burmeisteriana* (Claassen, 1936) and *Isoperla difformis* (Klapálek, 1909). The mayfly *Oligoneuriella rhenana* (Imhof, 1852) provides a similar example, but unlike the stoneflies, several specimens have recently been observed. At least for Plecoptera, now a group almost restricted to rhithral streams, the low diversity in the potamon is demonstrably unnatural and due to human impact. Must undocumented similar losses in other groups not be suspected?

It is instructive to compare the affinities and probable routes of dispersal of the endangered or extinct potamal Plecoptera with those of the abundant and seemingly not endangered rhithral members of the order. On the whole, the potamal stoneflies belonged to holarctic taxa, their closest relatives often live in Asia and North America.

Oemopteryx loewii was the sole European representative of an otherwise North American genus. *Taeniopteryx* falls into two species groups, one in North America, the other in Europe, with one species ranging into Siberia. One would have to know the larva of the extinct *T. araneoides* to be completely sure of its affinities but by its genitalia, it is very isolated within the European fauna.

Although the very large genus *Isoperla* is holarctic, only the few potamal species in Europe have close relations to species outside the continent. *I. pawlowskii* (Wojtas, 1961), has its only close relative in Armenia; the closest relatives of *I. difformis* and *I. obscura* are East Asian and North American. Note that the many other European species belong to a monophyletic assemblage endemic to Europe and are practically all rhithral species, except *I. grammatica* (Poda, 1761) which advances into the potamal.

Taxonomic splitting has turned the genera *Isogenus* and *Dictyogenus* into European endemics; however, their closest relatives are North American. The perlid genus *Marthamea* is a European endemic, with two extinct or nearly extinct European species, and a third in the Lebanon; its closest relatives are genera in East Asia and North America. *Agnetina elegantula* was the westernmost member of an Asian and North American genus.

This suggests, the potamal Plecoptera may either be very early postglacial Siberian immigrants to Europe, or elements of an ancient indiginous fauna with strong relations to taxa in other parts of the Holarctic Region. It is not known which ecological requirements tied these species to large rivers. However, their known past distributions resemble the distribution of potamal fish. Good examples of endemic fish species restricted to individual river networks are known, especially for the Danube where some remain largely restricted to the main channel, inhabiting narrow band shaped ranges (e.g. Banarescu, 1989).

In contrast, the rhithral Plecoptera, although of restricted distribution within a given river, are, geographically, usually very widespread. Many species inhabit enormous areas, most including some part of the Mediterranean Region. Their affinities are almost entirely with other European species. Several of the genera are endemic to Europe or the European representatives form distinct subgroups in widespread genera, like in *Isoperla*. There are usually only distant relations with non-European taxa. Evidently, the rhithral Plecoptera are mainly recent postglacial immigrants to central Europe from Mediterranean refugia, and this applies to other taxa with which they share the habitat (Zwick, 1982a, b).

Different effects of human impact on potamal and rhithral stream sections: the role of biogeography

Extant Central European potamal faunas are disturbed and consist of a heterogenous mixture of some hardy potamal species, some tolerant rhithral species that may have extended their ranges downstream, and mainly of large numbers of ubiquituous freshwater species. The example of the Fulda river further suggests that in Central Europe only rhithral streams maintain their natural diversity. Although it would be possible to list many individual rhithral streams very negatively affected by people and severe local losses of the fauna, no single species seems threatened now. However, is the rhithral fauna really safe?

The different degree of survival of the original fauna in rhithral and potamal streams might be ascribed to different levels of human impact. Densely populated lowland areas and big river valleys with heavy traffic, intense agriculture or industry, or sometimes both, strikingly contrast with sparsely populated, more or less pristine montane areas where most rhithral streams flow. Also, tolerable levels of contaminants, etc. in small streams may accumulate in lower stream sections and may further develop synergistic effects causing damage. Yet, this is only a partial explanation.

Biogeography plays an important role, but is not normally considered. Generally speaking, local (or occasional) damage to individual stream animal populations may turn into large-scale extermination in cases where distances between populations are greater than average dispersal capacity, i.e. as soon as suitable habitats become islands in an unsuitable surrounding. Disturbances occurring more frequently than normal exchange between local populations have similar effects.

The danger of fragmentation of species' ranges indeed lies in the creation of island habitats: reduced biotic diversity on islands, its dependence on island size (because immigration and recolonization rates depend on distances from other suitable habitats) is well known (MacArthur and Wilson, 1967).

Potamal faunas

By the very nature of stream networks, the risk of being turned into an ecological island is much greater for potamal habitats, major rivers being normally far apart. They are usually more distant from each other than the animals' dispersal capacities allow these to travel regularly. The few good fliers among stream insects, or small forms that are easily passively dispersed are exceptions. For the rest, there is also no great difference between hololimnic and amphibious taxa, unless they can also live in the sea and spread into different rivers from there. On the whole, the ranges of strictly potamal species are naturally subdivided, individual populations are disjunct. In the case of damage to some particular population, recolonization can only occur from within the affected river. Although individual potamon reaches may be very large, their isolation from other similar habitats makes them very vulnerable and species extinctions through human interference occured early.

There are efforts to improve water quality and to restore ecologically sound conditions in rivers. However, in evaluating stream quality, short lists of indicator species instead of full biodiversity are considered. Water quality recorded in maps issued by German State agencies has generally been improving in big rivers, also in the Fulda river (Marten, 1983). Still, this does not guarantee return of the presently missing potamon species. At least for the Plecoptera discussed before, relic populations from where recolonization could occur are unknown and this is probably no exception. However, in the Ephemeroptera, the rediscovery of several seemingly lost species has indeed recently been reported; of one species, large numbers were observed (Bathon, 1983; Marten, 1986).

Rhithral faunas

In counterdistinction, rhithral streams are often in great proximity of each other. Hololimnic and amphibious species, which include most insects, are in different positions requiring separate discussion.

Risks of isolation and accidental extinction are very great for hololimnic rhithral species which can only disperse within the watercourses inhabited. Faunal exchange can only take place by drift into lower stream sections and subsequent upstream migration into different headwater branches. Chances for success are drastically reduced today, many upstream reaches have become island habitats whose hololimnic inhabitants are strongly threatened by accidental local exterminations. Several molluscs, e.g. *Margaritifera margaritifera* (Linnaeus, 1758) (Nesemann, 1983), but also *Bythinella* and some Crustacea, e.g. *Astacus astacus* (Linnaeus, 1758) (Jungbluth, 1978) come to mind, but also little fish like the miller's thumb (*Cottus gobio*, Linnaeus, 1758), which is 'potentially endangered' in Hesse (Meinel *et al.*, 1987) and has already almost disappeared from streams in the west and south of the state.

Ranges of amphibious rhithral insects often coincide with or follow mountain ranges where rhithral streams are abundant habitats. Upper runs of separate catchment areas are often close together. Travel across land or through air from one streamlet to the other is a regular phenomenon for these amphibious species, adults of every generation engage in it. This explains their enormous success in quickly colonizing glacially devastated areas in Europe. The short travel of the adults easily crosses divides and species ranges are normally independent of catchment areas. The quasi-continuity of populations across stream boundaries, formation of metapopulations, is a kind of geographical risk-spreading and ecologically important. Accidents or local human impact damaging some individual stream and its amphibious fauna have usually no long-lasting effect. Recolonization from some other near-by stream, in the same catchment or from beyond the divide, will normally repair damage in a few insect generations' time.

Regular dispersal of aquatic adult insects, perhaps even directed upstream displacement in a characteristic colonization cycle has long been suggested (Müller, 1973). Supporting evidence is rare, but some is available, e.g. Zwick (1990). Enormous numbers of adults leaving streams for reproduction are routinely lost; there is one estimate of a 3% return rate. (Jackson and Fisher, 1986). Oviposition of these relatively few specimens easily assures population survival. Similarly, adults accidentally arriving at another stream must relatively easily be able to found new populations. In the Breitenbach, for example, which has been surveyed for 20 years, *Epeorus sylvicola* (Pictet, 1845) has now suddenly become established in large numbers (personal unpublished observations).

Is there risk for rhithral faunas? Lessons to be learned from the case of the potamon

Rhithral faunas, at least amphibious insects, may appear to be safe from extinction through human impact. However, people should learn from the case of the potamon and provide protection for rhithral streams.

The habitat continuity originally available to amphibious rhithral fauna is in fact no longer existing in Central Europe. Water quality maps (e.g. Der Hessische Minister, 1986) show mountain ranges with clean little streams as islands within areas of poorer water quality. For example, in Hesse, the adjacent Vogelsberg and Rhön Mountains are now ecologically separate for clean water rhithral fauna. Both mountain ranges are naturally disjunct from the Thüringer Wald in the east, and stream acidification in the northern hills of Kaufunger Wald and Habichtswald (Matthias, 1983; Meinel and Matthias, 1982) has severed possible former migration pathways towards the Harz Mountains. In the latter, stream acidification and damage from old mine deposits are widely known problems reducing the internal coherence of stream faunas: fragmentation of rhithral faunas has already occurred on a large scale.

Each of these mountain areas has become an ecological island, and is exposed to risks for biodiversity. The value of the seemingly abundant little mountain streams is not always fully appreciated. Permissions to use (and ecologically damage or destroy) such water courses are too permissively granted. Individual illegal activities are often not prosecuted. As a consequence, at a scale not shown on maps, ecological integrity of mountain stream networks no longer exists. In the past, pristine conditions often ended below the first polluting settlement; because of sewage treatment etc., water quality may now again be improving there. However, with the shift from agricultural to mainly recreational use of the landscape, damage has moved upstream. Recreational settlements, recreational ponds, fish ponds and 'ornamental' ponds (which are sometimes vigorously requested by communities for increased attractiveness to tourists) destroy individual streams, or sections of them. Removal of water for industrial and domestic supply has greatly increased (in the case of the Vogelsberg, to the distant city of Frankfurt, to an extent which is now alarming even the communities and the general public) and has reduced stream discharge, with all related negative ecological effects. Former menaces from road building, tunneling of streams, eutrophication from crop fields, draining wetlands to transform them into pastures, etc. continue and are today pursued with modern, i.e. more powerful, means than before.

Of particular significance is the widespread use of modern insecticides in agriculture, and partly also in forestry. These chemicals are relatively safe to use for man, which makes one forget their exceeding toxicity to arthropods. This has been experienced at the Breitenbach.

It was poisened with an insecticide based on cypermethrin; 8 g (or more) of the agent were unsuspectingly introduced by forest workers washing their hands and gloves. The poison destroyed the arthropod fauna in the lower 3 km of the stream within 36 h, killing more than half of the species or about 95% of animal biomass. Stream flow removed the victims quickly and proof of this accident would have been impossible already after half a

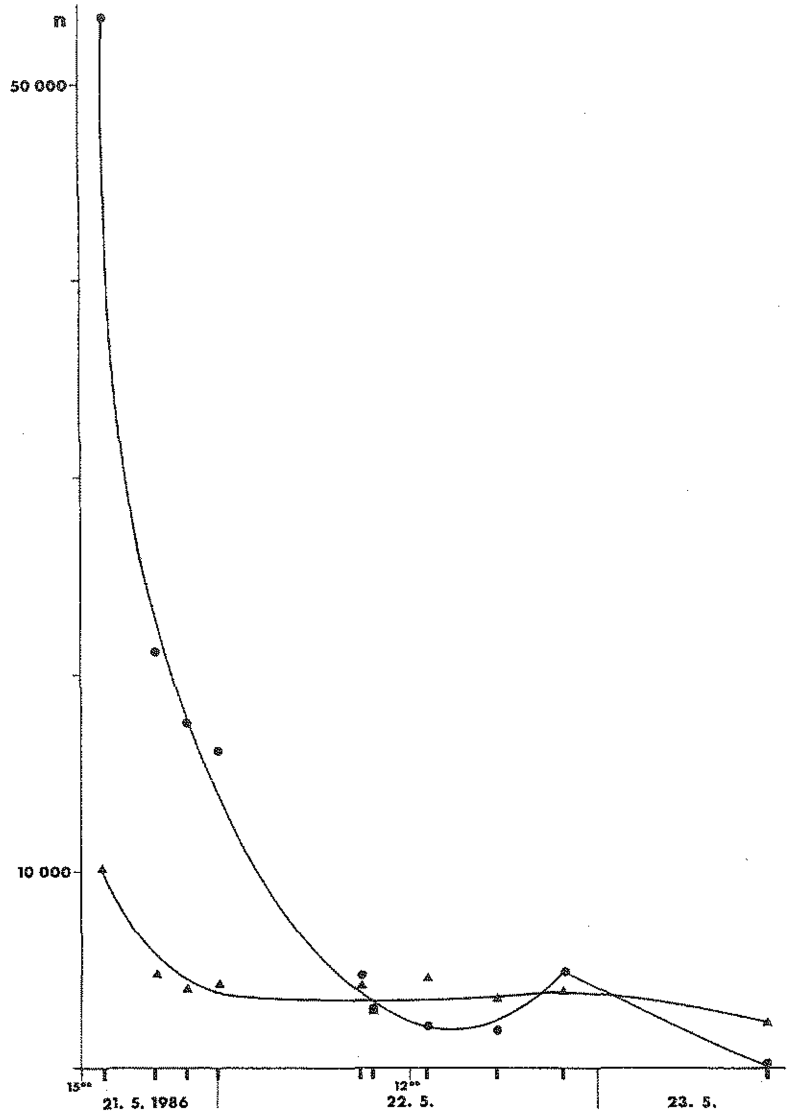

Figure 6. Numbers (n) of poisoned *Gammarus* spp. (upper curve, ●) and of larvae of aquatic insects (lower curve, ▲) in ten drift samples (bold tick marks along abscissa, which is time between 15 h May 21, to 15 h May 23, 1986) in the Breitenbach after accidental insecticide application at 15 h, May 21. Curves hand-fitted to counts of specimens in subsamples or total samples.

day or less. However, the onset of catastrophic drift was noticed and sampling began as soon as possible, only 45 min later, but the greater part of the animals killed was obviously missed. Numbers of those that were collected are still impressive (Fig. 6).

Accordingly, there is no literature record of such damage to streams, at least in Germany, and use of these chemicals is erroneously claimed to present no risk to aquatic fauna (Schollmeyer and Wilhelm, 1984). However, there is also other evidence to the contrary (e.g. Baier *et al.*, 1985; Kulzer *et al.*, 1986; Muirhead-Thompson, 1987). There is circumstantial evidence for similar accidents at other streams near the Breitenbach and of others elsewhere in Hesse. Of course, insecticide treatments on land are also dangerous to rhithral insects, because the adult water insects often live far from water.

Many different factors cause local and temporal damage to rhithral stream coenoses. Together, they all contribute to increasing fragmentation of clean stream habitats and their isolation from each other; resulting faunal discontinuity may turn local damage into regional, then large scale and finally complete extinction. In the case of the potamal faunas the same process was quick, because suitable large river habitats were far apart and were naturally ecological islands. Except for vertebrates, the damage to their fauna went unnoticed for long, its extent will always remain incompletely known for invertebrates.

Presently, there seems to be little danger to rhithral stream fauna but the situation is probably much less safe than it appears. However, lack of monitoring programs considering biodiversity by establishing detailed species lists precludes precise analysis of the situation and even proof of damage already done. We may actually be close to the disappearance of significant portions of rhithral stream fauna, of reduced rhithral biodiversity, without having noticed the damage yet. From the example of potamal streams it is known how the process operates and immediate action should be taken to protect rhithral biodiversity.

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

ATTACHMENT 2

Retzer, Michael E. Changes in the Diversity of Native Fishes in Seven Basins in Illinois, USA. *The American Midland Naturalist,* 153(1):121-134. 2005.

Am. Midl. Nat. 153:121–134

Changes in the Diversity of Native Fishes in Seven Basins in Illinois, USA

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ABSTRACT.—A study of the fish faunas in all or parts of seven Illinois river basins revealed an average loss of 8.4 species per basin over approximately the last 100 y. In contrast, between the 1980s and 1990s, five basins showed an increase in the species richness (number of species) and two showed a statistically significant increase (paired *t*-test) in the species richness per sample site. Only the Kaskaskia River basin had a significant decline (paired *t*-test) in the species richness per sample site between the 1980s and 1990s. Minnows (Cyprinidae) had the largest number of species showing declines over the last 100 y and was followed in decreasing order by darters and perches (Percidae), catfishes (Ictaluridae), suckers (Catostomidae), topminnows (Fundulidae) and sunfishes (Centrarchidae). Changes in the overall fauna since the 1980s show an increase in species occurrence, but minnows and catfishes showed little net change and suckers, sunfishes and darters showed a positive increase in occurrence.

INTRODUCTION

Across North America, fish faunas have been highly altered over the past 100–200 y. Many changes have been noted and summarized in various books that address regional or state faunas (*see* Forbes and Richardson, 1909; Minckley, 1973; Wydoski and Whitney, 1979; Trautman, 1981). Such texts generally discuss declines across much of the native fauna and list a number of factors considered to be responsible for the decline. Much of the information is based on general observations and often on data that are not quantitative or comparative in nature. However, long-term studies that are comparative and well quantified will provide a greater knowledge of large-scale faunal changes over long time periods. Comparative studies of fishes of this type are fairly rare (Anderson *et al.*, 1995).

A number of studies have been published on the stability of fish populations in small streams over 3 to 12 y periods (*see* Grossman *et al.*, 1990 and Matthews, 1998 for reviews of these works). These studies concentrate on short-term fluctuations and not long-term trends over larger areas.

Three recent studies have examined changes in species distributions over large areas and over longer time periods (approximately 30 or 100 y). Patton *et al.* (1997) resampled sites first visited in the 1960s. These sites covered a large portion of Wyoming. In 1986 Anderson *et al.* (1995) resampled 129 sites located throughout most of Texas. Their sites were first sampled in 1953. Both studies calibrated their methods to account for differences in methods and amount of sampling effort. The third study by Koel and Peterka (1998) encompassed the Red River of the North in the Minnesota, North Dakota and South Dakota. This study relied on published and unpublished records including museum specimen records and on personal communications. Although some of the records are unpublished or unsupported by vouchered specimens, they were able to extend the time period to 100 y.

In Illinois, the results of two statewide surveys of fishes have been published by Forbes and Richardson (1909) and Smith (1979). The former study was based on 1500 collections from 600 localities. The latter was based on 3000 collections from 2400 localities. Since the study of Smith (1979), efforts have been made to resurvey the state by biologists of the Illinois Department of Natural Resources (IDNR) and Illinois Natural History Survey (INHS; INHS is now an autonomous entity of IDNR). The early records and recent sampling efforts provide an excellent opportunity to study changes in fish distributions over a large geographic area. Hence, the goal of this study is to determine if there have been any changes in the species richness (the number of species) of native fishes within all or parts of seven river basins in Illinois between 1876–1905 and 1960–1998 (long time period) and between 1982–1986 and 1997–1998 (short time period). Individual species and overall pattern changes in the fauna also is discussed.

METHODS

This study used fish collection data from surveys in all or parts of seven river basins in Illinois: Des Plaines River, upper Kaskaskia River, Kishwaukee River, Pecatonica River, upper Rock River, Salt Creek (of the Sangamon River system) and Vermilion River (of the Wabash River system) (Fig. 1).

The data used were collected during four time periods: 1876–1905, 1960–1970, 1982–1986 and 1997–1998. The 1876–1905 data primarily are based on the study of Forbes and Richardson (1909) and a few additional samples obtained by other collectors (Smith, 1979). The locations of these samples were published in Smith (1979) and were used herein to develop a list of species for each of the basins studied for this time period. These early collections were made using seines and other kinds of nets and were not standardized (*i.e.*, no attempt to quantify the catch per unit effort). Generally, collections were made on the larger tributaries of the drainage basins.

Data from 1960–1970 are from Smith's (1979) survey of Illinois. Although Smith himself sampled most locations, his data also included samples made by IDNR stream crews and other field biologists. Most of Smith's material was not gathered using standardized methods (usually by seine but no record of catch per unit effort). Generally, collections were made throughout the drainage basins.

Data from 1982–1986 mostly were from unpublished reports on basin surveys written by IDNR fisheries personnel. Data for the Pecatonica drainage basin was from Staff Report (1988). During 1982–1986 IDNR stream crews generally used rotenone over a measured distance to quantitatively sample fish populations at shallow sites. At deeper sample sites a boat mounted electroshocker was used for 30 to 60 min. Shocking from boat was effective in collecting large nonbenthic species, but less so in collecting small benthic species. Supplemental seining along the shore was done to capture species that shocking from boat may have missed. Shocking from boat underestimates numbers of minnows, darters and catfishes (Bailey and Dowling, 1990). One exception was that all shallow sites ($N = 4$) in the Des Plaines basin were sampled with a combination of backpack electroshocker and seine instead of rotenone.

Data from 1997–1998 were obtained directly from the field notes and specimens deposited in the INHS fish collection. During 1997–1998 IDNR stream crews used two basic techniques to collect specimens. As in the earlier time period, a boatmounted electroshocker was used for 30 to 60 min in areas too deep to wade and was supplemented by seining. The second method was the use of an electric seine, which was pulled upstream over a measured distance (typically 100 m or more). Electric seining is considered to be highly effective when used in shallow wadable depths (Bayley and Dowling, 1990).

During 1982–1986 and 1997–1998 the samples were taken as part of an effort to monitor fish populations and water quality of each basin. An effort was made to sample both large and small streams. Typically, 20–30% of samples were made on the main-stem of a drainage basin and the balance on smaller tributaries.

While deep water sites were sampled by shocking from boat during both time periods, most of the 1982–1986 IDNR shallow sites in all basins except in the Des Plaines were based

FIG 1.—Map showing the locations of seven study basins in Illinois

on rotenone collections, and 1997–1998 data collections were based on electric seine methods. Because of the differences in efficiency of rotenone and electric seine, an effort was made to equilibrate these methods. Comparisons of these methods or others have been done in Illinois streams and permit equal or near equal comparisons of samples (Larimore, 1961; Bayley *et al.*, 1989; Bayley and Dowling, 1990). Bayley and Dowling (1990) found the electric seine to be about 85% of the efficiency of rotenone in the capture of species. While rotenone was used in early studies, later studies generally used the electric seine over a larger area. The distance sampled using rotenone typically was 91.5 m, whereas most electric seine sites were 91.5 to 183 m. Because a greater sample area will compensate for the less efficiency of the electric seine, both methods were considered to be equivalent if electric seine sites were greater than 91.5. It is possible that very long electric seine sites (>150 m) may have yielded more species than a rotenone sample. However, at these sample lengths, few additional species would be added, based on the results of Lyons (1992) in southern Wisconsin streams. At these lengths, the number of species captured will approach or reach an asymptote. This situation only applied to the Kaskaskia River basin where electric seine sites sometimes exceeded 200 m in length. This possible bias is further discussed in results. Finally, four sites in older Des Plaines study were sampled using an electric backpack shocker or seine. These methods are less efficient than the electric seine (Bayley *et al.*, 1989) and this bias is further discussed in results.

To examine changes in species richness for the long time period (1876–1905 to 1960–1998), I estimated the extirpation of native species in each of the river basins. Species were considered native if they were indigenous to Illinois at the time of Forbes and Richardson (1909). A few of these species have had their distributions altered by stocking and at least one species (*Cyprinella lutrensis*) has expanded naturally its range within Illinois, and these special cases are discussed. Although I would have preferred to test if there had been a net gain or loss in species richness, differences in sampling methods and the larger number of sample sites visited during the later time period would over estimate the number of species appearing in a basin for the first time in that time period. However, the greater effort and number of samples from later period insured that an extirpation of a species likely did occur. For most basins, the early number of sampled sites varied from 8 to 14 although the Kaskaskia and Vermilion drainage basins had 32 and 40 sample sites, respectively. The number of sites sampled 1960–1998 ranged approximately from 50 to 100 per drainage basin. The loss of species was determined by differences in species lists for each of the periods. The 1960–1998 list included all of the species collected during the 1960–1970, 1982–1986 and 1997–1998 periods.

Dividing the long time period along these lines is rather awkward in that even within the 1960–1998 time period, many changes to the fauna may have occurred. Ideally, the 1876–1905 data would be compared with the 1997–1998 data. Unfortunately, the quality and quantity of data makes this comparison difficult at best. Not enough samples were made during 1876–1905 and 1997–1998 to reveal the overall faunal changes in drainage basins that may have occurred. This low number of samples would greatly under estimate the species richness in each the basins at each time period. Indeed, pooling the 1960–1998 data insures a much more robust list of species that existed in the basins and reduces the likelihood of overestimating the number of species lost since the early time period. Also same site comparisons between the two time periods would not be possible as the early collection methods are unknown, and it is likely that few collections were made at the same geographic locations. These two factors would introduce unacceptable bias into the analysis.

For the short time period (1982–1986 to 1997–1998), I examined changes in species richness using two statistics: (1) changes in the species richness per sample site for each drainage basin and (2) net change in the total species richness of each drainage basin. The first statistic, changes in species richness per sample site, was tested using a paired *t*-test. The *t*-test was used to compare means of species richness obtained from sites resampled in two different years. These resampled sites had equivalent collecting methods and sampling effort to limit bias in the analysis. Differences in means were considered to be significant at the 0.05 level.

The second statistic, the net change in species richness of each drainage basin, was based on the sum of the number of species gained and lost between the two time periods across each drainage basin. The gain or loss of species was determined from the lists of species developed for each basin from the IDNR collections. The Vermilion, Salt and Kaskaskia drainage basins used the data from the same-paired sites used for the first statistic. The other basins also used the paired site data but also used data from additional non-paired sample sites. Samples sizes for the earlier and later time periods, respectively, are for the Des Plaines N = 15, 19 sample sites, Kishwaukee N = 15, 19, Pecatonica N = 19, 10 and Rock N = 21, 15. Using this additional data increased the number of species to better represent the total fauna of each basin. However, sample sizes were not equal for these basins, possibly creating bias in the analysis. To estimate sampling bias, species accumulation curves were created based on the addition of new species with the addition of sample sites. Curves for these basins reached asymptotes before the additional site data was added, meaning that extra sites did not add additional species to the list. The unequal number of sites did not introduce sampling bias.

To examine changes in the fauna for the long time period, lists of species for 1876–1905 and 1960–1998 were created for each basin. Species that showed at least one extirpation from one of the basins between 1876–1905 and 1960–1998 were summarized for further discussion of faunal changes (Table 1).

To assess the change in status of species over the short time period, a tabulation of species showing at least one change in occurrence was constructed (Table 2). (Herein I define change of status as the gain or loss of a species in a basin). A species not recorded in a basin during the 1980s, but recorded in the 1990s, was assigned a +1, an occurrence gain. A species recorded in a basin during the 1980s, but not recorded in the 1990s, was assigned a −1, an occurrence loss. A score of net occurrences for each species was summed across all seven basins. This score then reflects the total number of occurrence gains and losses for a species over all seven basins. In turn, all species scores were summed to produce an overall index that reflects net number of new gains or losses. A positive score indicated a positive trend, negative score a negative trend and 0 no net trend in species occurrences across all basins. Significance of overall species occurrence gains and losses between the two time periods was tested using a Wilcoxon signed ranks test of matched pairs (*i.e.*, a pair being the number of occurrence gains and losses for a species between the two time periods). A probability of 0.05 or less was considered significant.

RESULTS

Species richness changes.—All of the drainage basins lost species during the long time period (Table 1). The Vermilion River had the lowest number of extirpated species (4) and the Des Plaines River had the highest loss (16). As a percent of the original native fauna, the Des Plaines and Kishwaukee lost substantial portions of their faunas (28% and 20%, respectively), and the Vermilion had the lowest percent loss (8%). Basins lost a mean of 8.4 species.

During the short time period, there was a general trend of increased species richness within most basins, but only the Des Plaines and Pecatonica drainage basins had significant increases in species richness per sample site (Table 3). The Kaskaskia River had a significant decrease in species richness per sample site. Indeed, this number is likely to be conservative since the higher sample distances of the electric seine method may have yielded a slightly higher number of species than the previous rotenone samples. Although that yield would only be slightly higher because of asymptotic limits on the number of new species that can be discovered (Lyons, 1992).

TABLE 1.—List of species extirpated from all or parts of one or more of seven Illinois basins since 1876–1905

Species	Des Plaines R.	Kaskaskia R.	Kishwaukee R.	Pecatonica R.	Rock R.	Salt Cr.	Vermillon R.	Total number of extirpations.
Lepisosteus osseus	—	k	u	u	k	k	k	1
Amia calva	k	k	u	—	u	k	u	1
Umbra limi	k	u	k	k	—	u	u	1
Campostoma oligolepis	—	—	k	k	k	k	u	2
Erimystax x-punctatus	u	u	k	k	k	—	k	1
Hybopsis amblops SE	u	—	u	u	u	u	k	1
Hybognathus nuchalis	—	k	k	k	—	k	u	2
Notropis anogenus SE	—	u	u	u	u	u	u	1
Notropis chalybeus ST	—	u	u	u	u	u	u	1
Notropis heterolepis SE	—	u	k	—	—	u	—	4
Notropis hudsonius	k	u	—	k	u	—	u	2
Notropis nubilis	u	u	—	k	k	u	u	1
Notropis texanus SE	u	u	—	k	—	u	u	2
Opsopoeodus emiliae	u	—	u	u	u	u	u	1
Erimyzon oblongus	k	k	—	—	u	k	k	2
Erimyzon sucetta	u	u	k	—	u	u	k	1
Moxostoma carinatum ST	u	—	u	u	—	u	k	2
Moxostoma valenciennesi SE	—	u	u	u	u	u	u	1
Ameiurus nebulosus	u	k	u	u	u	—	k	1
Noturus flavus	k	—	k	k	k	k	k	1
Noturus gyrinus	k	k	k	—	k	k	k	1
Noturus miurus	u	—	u	u	u	u	k	1
Noturus nocturnus	—	k	u	u	u	k	u	1
Fundulus diaphanus ST	—	u	—	u	u	—	u	3
Fundulus dispar	—	u	—	k	u	u	u	2
Aphredoderus sayanus	k	k	u	u	u	—	u	1
Labidesthes sicculus	k	k	—	k	k	u	—	2
Percopsis omiscomaycus	—	u	u	u	u	—	u	2
Morone chrysops	—	k	k	u	k	k	k	1
Lepomis humilis	k	k	k	k	k	k	—	1
Lepomis megalotis	k	k	—	u	u	k	k	1
Ammocrypta clara SE	u	k	—	k	—	k	u	2
Etheostoma asprigene	k	k	u	—	u	—	—	3
Etheostoma chlorosomum	u	k	u	u	u	—	u	1
Etheostoma exile SE	—	u	k	k	u	u	k	1
Etheostoma flabellare	k	—	k	k	k	k	k	1
Etheostoma microperca	—	u	k	u	k	u	u	1
Etheostoma zonale	—	u	k	k	k	k	u	1
Percina shumardi	u	—	u	u	u	u	u	1
Stizostedion canadense	u	—	k	k	k	k	k	1
Stizostedion vitreum	k	—	k	k	k	k	k	1
Cottus bairdi	—	u	u	k	k	u	u	1
Total[1] (% loss of native species)	16 (28)	10 (17)	9 (20)	6 (16)	6 (11)	8 (15)	4 (8)	

[1] Total refers to the total number of species extirpated from a drainage since pre-1908

% extirpated is the percent of the species that is extirpated from a basin

SE = state endangered; ST = state threatened u = never known from basin; k = presently known from basin; – = extirpated from basin

TABLE 2.—Changes in native fish species presence/absence for seven Illinois basins between the 1980s and 1990s[1]

Species	Rock R.	Kishwaukee R.	Vermillion R.	Salt Cr.	Des Plaines R.	Pecatonica R.	Upper Kaskaskia R.	Totals[2]
Lepisosteus osseus							+	+1
Lepisosteus platostomus	+						−	0
Amia calva				−	+			0
Anguilla rostrata	+							+1
Dorosoma cepedianum	+					+		+2
Esox americanus					−			−1
Esox lucius					+			+1
Esox masquinongy	+					+		+2
Umbra limi					−			−1
Cyprinella lutrensis	−				−			−2
Cyprinella spiloptera							−	−1
Cyprinella whipplei							−	−1
Erimystax x-punctatus	+					+		+2
Hybopsis amblops			+					+1
Hybognathus hankinsoni	+					−		0
Hybognathus nuchalis		+	+			+		+3
Lythurus fumeus							−	−1
Macrhybopsis aestivalis		−	−					−2
Notemigonus crysoleucas	+		+	−				+1
Notropis atherinoides		−			+			0
Notropis blennius	−							−1
Notropis boops			+					+1
Notropis dorsalis						−		−1
Notropis hudsonius					−	−		−2
Notropis rubellus					+	+		+2
Notropis shumardi							−	−1
Phenacobius mirabilis					+			+1
Phoxinus erythrogaster							+	+1
Pimephales promelas			−					−1
Pimephales vigilax				+				+1
Carpiodes carpio						+		+1
Carpiodes velifer						+		+1
Erimyzon oblongus				+	+			+2
Ictiobus bubalus					+			+1
Ictiobus cyprinellus		+	+					+2
Hypentilium nigricans							−	−1
Ictiobus niger			+					+1
Minytrema melanops				+	+			+2
Moxostoma anisurum					+			+1
Moxostoma carinatum			+					+1
Moxostoma duquesnei	+		+	+				+3
Ameiurus melas	+		−				−	−1
Ameiurus natalis	−					−		−2
Ictalurus punctatus					+			+1
Noturus exilis	+	−				−		−1
Noturus flavus					+			+1
Noturus gyrinus	−	−		−	+			−2

TABLE 2.—Continued

Species	Rock R.	Kishwaukee R.	Vermillion R.	Salt Cr.	Des Plaines R.	Pecatonica R.	Upper Kaskaskia R.	Totals[2]
Noturus miurus			+					+1
Fundulus dispar						+		+1
Fundulus notatus				+	+			+2
Labidesthes sicculus	−				+	−		−1
Culaea inconstans		−				−		−2
Morone chrysops		−	−					−2
Morone mississippiensis	+			+	+		+	+4
Ambloplites rupestris					+			+1
Lepomis gibbosus	+	−				+		+1
Lepomis gulosus			+					+1
Lepomis humilis					+			+1
Lepomis megalotis				+	+			+2
Micropterus punctulatus							+	+1
Pomoxis annularis		+		−	−			−1
Pomoxis nigromaculatus			−	+				0
Ammocrypta clara				−				−1
Etheostoma chlorosomum							+	+1
Etheostoma gracile							−	−1
Etheostoma exile						−		−1
Etheostoma flabellare					+			+1
Etheostoma nigrum					+			+1
Etheostoma spectabile	−				+			0
Etheostoma zonale	+					−		0
Percina caprodes	+					+		+2
Percina maculata	−		+		+			+1
Percina phoxocephala	+		−		+	+		+2
Perca flavescens					−			−1
Sander canadense	+	+				+		+3
Sander vitreum		+	+	+	+			+4
Aplodinotus grunniens			+		+	+		+3
Net change in species richness	+9	−2	+7	+4	+19	+4	−3	Total +38

[1] Based on IDNR samples from early to mid 1980s and 1997–98

[2] A single "–" is equal to a minus one, "+" is equal to a positive one; total is the sum of the row of positive and negative integers

Species richness in the Des Plaines drainage basin could be artificially high due to the use of the more efficient electric seine at four sites in the later time period rather than the backpack shocker and seine used earlier. Bayley *et al.* (1989) showed the relative efficiencies of the electric seine, backpack shocker and seine. However, the difference in efficiencies are unlikely to account for the entire difference in species richness between the time periods, especially when these sites only comprised a minor portion of the entire sample (4 of 15 sites). Also, at just boat electroshock sites, the average number of species collected per site in the earlier study was 12.81 vs. 18.81 in the later samples. This difference suggests that the increase in species richness found at a site has significantly increased.

The largest net increases in the species richness found across a basin were in the Des Plaines and Rock drainage basins, 19 and 9, species, respectively. The Kaskaskia drainage basin had the highest net loss of three species (Table 2).

TABLE 3.—Mean species richness of sample sites for seven drainage basins. Probability of significant differences (P) between means of the 1980s and 1990s calculated from paired *t*-tests. N = number of sample sites

Drainage basin	1982–86	1997–98	N	P
Des Plaines River	21.64	30.69	15	0.001
Kaskaskia River	25.64	22.29	14	0.02
Kishwaukee River	23.50	23.50	12	—
Pecatonica River	16.20	20.20	10	0.05
Rock River	19.44	21.22	9	0.28
Salt Creek	22.42	23.33	12	0.58
Vermilion River	23.22	22.78	9	0.87

Faunal changes.—For the long time period, a total of 42 species showed at least one extirpation from one or more of the basins (Table 1). This total amounts to 31% of the original number of species found among the seven basins. Of the 42 species, most showed extirpations from one or two basins. Three species, *Notropis heterolepis, Fundulus diaphanus* and *Etheostoma asprigene,* showed extirpations from three or four basins. No species had extirpations from more than four basins.

For the short time period, 77 species showed a change in status in at least one basin (Table 2). Of these, 45 showed net occurrence gains, 25 showed net occurrence losses and 7 showed no net changes. An overall index for all species across all basins is +38, a highly positive score. A Wilcoxon signed ranks test of matched pairs test of significance of the net occurrence gains and losses of each species was highly significant, ($Z = 2.621$, $P = 0.009$). Six species showed new occurrences in three or four of the seven basins: *Hybognathus nuchalis, Moxostoma duquesnei, Morone mississippiensis, Sander canadense, S. vitreum* and *Aplodinotus grunniens.* No species had net new occurrence gains in more than four basins. Four species had net occurrence losses from two basins: *Macrhybopsis aestivalis, Notropis hudsonius, N. gyrinus, Culaea inconstans* and *Morone chrysops.* No species had net occurrence losses from three or more basins during the short time period.

DISCUSSION

Species richness.—During the long time period, all seven drainage basins lost four or more species of fishes (Table 1). While it is difficult to estimate the loss of species in an unaltered system over this period, the results provide a relative measure of losses induced by human activities. The Vermilion River had the lowest number of extirpated species, four, and is the least altered of the seven basins (Page *et al.*, 1992). At the other end of the spectrum, is the highly disturbed Des Plaines River, which flows through the Chicago region of Illinois, that has lost the highest number of species, 16 (Table 1). Because of efforts to improve water quality in the Chicago in the last 30 y, the loss of the native fauna probably was higher; recently, the fauna partially has recovered (*see* below). The other drainages are primarily agricultural, and their loss of native fauna, while less than that of the Des Plaines River, still ranged from 8 to 20%.

Koel and Peterka (1998) found that in the Red River (in North and South Dakota and Minnesota) over a similar time period (1892–1994), only one species was extirpated and eight species showed moderate declines out of a total of 84 native and non-native species. This modest decline in species relative to Illinois populations likely is due to two reasons. First, the larger geographic scale of the Red River will mask a greater number of extirpations at smaller scales, an observation also noted by Anderson *et al.* (1995). Second, land-use pressures likely are less in the Red River drainage. This area has a lower population density (U.S. Census Bureau, 2000) and less row-crop methods of agriculture than in Illinois (Schwab and Schleusener, 2003).

During the short time period, all seven drainage basins showed evidence of changing species richness (Tables 2, 3). Except for the upper Kaskaskia and Kishwaukee drainage basins, all of the basins showed an increase in the total number of species found within a basin. However, only the Des Plaines, upper Kaskaskia and Pecatonica rivers showed significant changes in mean number of species per site and a change in total number of native species per basin, suggesting that they have had the greatest changes in species richness.

The basin showing the most significant positive change was the Des Plaines River (Tables 2, 3). Widely perceived to be severely degraded by urban influences (Smith, 1971), this area has benefited greatly from the treatment of sewage and other wastes. Improvements in the fish community were noted as early as the early 1990s (Lerczak *et al.*, 1992). However, as recently as 1995, the basin has been rated a stream of limited resource (The Biological Streams Characterization Work Group, 1996), which indicates that considerable improvement remains to be seen.

The upper Kaskaskia River showed evidence of decreased species richness (Tables 2, 3). The basin was significantly less rich in 1997 and the gain of five native species was little more than half that of the loss of eight native species. Like the other basins (except the Des Plaines River) the Kaskaskia River is located in an area intensively used for agriculture and has a number of small towns and cities on the landscape. Unlike the other basins, two large reservoirs (Lakes Carlyle and Shelbyville) have been created on the mainstem since 1960 (Larimore and Fritz, 1993). Isolation of the sub-basins and actual destruction of much of the mainstem riverine habitats have probably negatively impacted the fauna (Larimore and Fritz, 1993). In fact, Smith (1971) predicted this decline. As extirpation of species from tributaries occurs, re-colonization from extant populations will be inhibited by the reservoirs. Examining individual tributaries to the reservoirs could further test this hypothesis. Direct tributaries to the reservoirs should be less diverse than indirect tributaries of similar size. Larimore and Fritz (1993) thought that the fish community currently is stable in the entire basin. However, this new information suggests otherwise for the upper Kaskaskia River.

The Rock, Salt and Vermilion drainage basins showed net gains in species richness (Table 2). However, none of these drainage basins showed significant increases in species richness per sample site.

The Pecatonica River, a tributary of the Rock River, also increased in species richness since 1984 (Tables 2, 3). Past reports rated the river as fair for diversity (Smith, 1971) and as a moderate aquatic resource (Staff Report, 1988), but the information herein suggests an improvement in the aquatic community.

In Champaign County, Illinois, four fish surveys have been completed with the first being made by Forbes and Richardson (1909). A recent study of Champaign County based on these surveys by Larimore and Bayley (1996) showed trends similar to most of the basins in this study. Their study also included small portions of the upper Kaskaskia and Vermilion rivers. They found a significant decline in species richness after the second survey in 1928. However, species richness has increased since the 1959–1960 survey. They concluded that improved water quality since that time period was largely responsible for the higher species richness.

In contrast, two other studies have indicated recent declines in distributions at time and spatial scales similar to this study. In Wyoming between the 1960s and 1990s, fish assemblages showed mostly declines. Patton *et al.* (1997) attributed the declines to decreased silt loads in the large rivers and increased silt loads and water temperatures in smaller streams. The large river traditionally had fish guilds adapted to high silt loads, whereas smaller streams had guilds adapted to cool temperatures and clear water. Anderson *et al.* (1995) found declines between 1953 and 1986 at resampled sites in Texas. They associated the declines with the introduction of non-native species, eutrophication of water and changes in instream flow. Direct comparisons of these two studies and the study herein are not simple. First, this study begins after the start of the effort to control point source pollution. The other studies begin before pollution control, and they still show overall declines although one would expect some improvements since the 1970s, when point source pollution began to be addressed (Critical Trends Assessment Project, 1994). However, it could be that in the case of Wyoming, a low population state, point source pollution would not have been a major problem anyway, and indeed, the silt loads and temperature changes that Patton *et al.* (1997) cite likely are due to non-point sources. Unless these problems also have been dealt with, it is likely that the assemblages are still in decline in Wyoming.

The problems in Texas are likely to be more similar to those in Illinois given its large population size. Why Anderson *et al.* (1995) failed to show any improvement after the effort to improve water began is unknown. One possibility is that not enough time had passed for water quality improvements to take effect. If so, Texas likely will have improvements in species richness in the 1990s.

Will the positive trends continue for these basins and possibly others in Illinois? If the movement to increase water treatment and reduce soil erosion continues, then stream assemblages should continue to recover. However, many species that require high water and habitat quality have been isolated into small areas and it is not known if these restricted populations are sustainable or if they will be able to recolonize other areas. Restoration and conservation of the species in decline is one of the most important issues to be considered in the recovery of midwestern streams.

Faunal changes.—The number of species showing extirpation from at least one basin over the long term period is a substantial proportion of the original fauna of the seven basins. Beyond just considering the number of species, an examination of the list (Table 1) of species gives insight into the taxonomic and ecological groups most affected over the last 100 y. Not surprisingly, 10 of the 42 species that showed declines are on the Illinois list of endangered and threatened species.

Although most fish families are represented by at least one species, the family of minnows (Cyprinidae) has the largest number of species (11) on the list followed in decreasing order by darters and perches (Percidae), catfishes (Ictaluridae), suckers (Catostomidae), topminnows (Fundulidae) and sunfishes (Centrarchidae) (Table 1). These numbers do not mean necessarily that minnows or darters are more vulnerable to extirpation. However, the numbers simply may reflect the proportion of those families in fish assemblages. Species of minnows and darters dominate fish assemblages of midwestern streams (Pfleiger, 1975; Smith, 1979).

An examination of the fish species in Table 1 indicates that two groups can be distinguished on the basis of their ecologies and life histories. One group of species typically is found in streams of very high water quality, clear water and clean riffles. *Campostoma oligolepis*, *Hybopsis amblops*, *Moxostoma carinatum* and *Ammocrypta clara* are representatives of this group. Water pollution, sedimentation and turbidity are the primary reasons for their decline (Smith, 1979). The second group typically is found in glacial lakes, floodplain lakes and slow moving streams, often with clear water and aquatic vegetation. In Illinois, many of these habitats have been destroyed by drainage and channelization. *Umbra limi*, *Notropis chalybeus*, *Erimyzon sucetta*, *Ameiurus nebulosus*, *Fundulus dispar* and *Etheostoma exile* are examples of this group.

The future of these two groups is likely to be different. While water treatment and erosion abatement is likely to help maintain or increase species adapted to clear and clean streams, the group typically found in lakes, back water lakes and slow moving streams, is likely to decline further as drainage and destruction of habitats continue. Only a significant creation or restoration of these habitats will have a positive impact on these species.

In the Red River basin, the declining groups are similar to those in Illinois and the species generally are the same (Koel and Peterman, 1998). The families with the largest declines in distributions are (in decreasing number of species) minnows, darters and perches, sunfishes, suckers and catfishes. These families also have the largest number of species in the Red River and Illinois. Again, cyprinids, percids, etc., might not necessarily be more vulnerable to decline because of their biology but simply because there are more species of them. Of five minnows species showing declines, three species are also in decline in Illinois: *Hybognathus hankinsoni*, *Notropis anogenous* and *N. heterolepis*. This observation suggests that these species are declining at a larger scale, perhaps across their entire ranges.

Short-term changes show a less grim picture for fishes of the basins in Illinois. Overall, the results indicate more positive species occurrences. A wide variety of taxa show positive changes (Table 2), but within families, the changes are mixed. The minnows showed a strongly negative trend over the long time period, and one would expect the family to have a positive short-term trend. However, nine species had a positive trend vs. ten species that had negative trends. Four of the declining species (*Notropis blennius*, *N. hudsonius*, *N. shumardi* and *Macrhybopsis aestivalis*) generally occur in large rivers and their occurrence in these basins would be considered to be not typical (Smith, 1979). No clear explanation exists for their declines although perhaps changes in flow could account for changes in their distributions. Greater periods of low water might induce them to leave these basins for larger streams. Examination of flow records could be examined to test this hypothesis. Conversely, three species (*Hybognathus nuchalis*, *Erimystax x-punctatus* and *Pimephales vigilax*) are medium-sized stream inhabitants that have increased in occurrence. This observation would be consistent with lower water flows and improved water and habitat quality.

Cyprinella lutrensis has been a species noted for increasing its abundance in the state at the expense of its congeners *C. spiloptera* and *C. whipplei* (Page and Smith, 1970). *Cyprinella lutrensis* prefers habitats that are turbid; the congeners prefer clear water. With increased turbidity in midwestern streams, *C. lutrensis* had increased in abundance. Its decline in occurrence in two basins (Table 2) does suggest that efforts to control erosion may be reversing this trend. The continued decline by *C. spiloptera* and *C. whipplei* does not support this possibility although recovery of these species may be more complex than what we would expect.

All of the species of suckers showed increased occurrences except *Hypentilium nigicans*. In general, these relatively large-bodied species are large stream inhabitants. They probably have benefited from improved water quality in the larger streams since the construction of water treatment facilities around urban areas. *Moxostoma duquesnei* appears to have increased in occurrence more than the other suckers. Forbes and Richardson (1909) found the species to be rare in the state, but Smith's (1979) and more recent records in the collection of fishes at INHS indicate that the species is increasing in abundance across the state.

Most of the species of sunfishes show a positive increase in occurrence. *Lepomis megalotis* probably has benefited from the continued creation of ditches, an environment in which they commonly occur (pers. obs.). However, several of the other species are thought to be fairly sensitive to environmental changes: *Ambloplites rupestris*, *Lepomis gibbosus*, *L. gulosus* and *L. humilis* (Smith, 1979). Their increased occurrences suggest better environmental conditions.

The darters showed a positive trend overall. *Ammocrypta clara* and *Etheostoma exile* showed declines while the species of *Percina* showed increased occurrences. The large perches, *Sander canadense* and *S. vitreum*, showed strong positive trends although these species are likely to be stocked in local reservoirs and large rivers, thereby skewing these results (D. Carney, Illinois Department of Natural Resources, pers. comm.). Interestingly, another large-bodied nonpercid species, *Aplodinotus grunniens*, showed new occurrences in three basins. Presumably, this species is continuing to respond to the increased water quality in the basins.

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SUBMITTED 16 MARCH 2004 ACCEPTED 21 MAY 2004

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

ATTACHMENT 3

The Long-Term Illinois River Fish Population Monitoring Program, Project F-101-R-19, Annual Report to the Illinois Department of Natural Resources by Michael A. McClelland and Greg G. Sass, INHS Technical Report 2008 (10).

ILLINOIS NATURAL HISTORY SURVEY

TECHNICAL REPORT

THE LONG-TERM ILLINOIS RIVER FISH POPULATION MONITORING PROGRAM

Project F-101-R-19

Annual Report to the Illinois Department of Natural Resources

Michael A. McClelland and Greg G. Sass

Illinois River Biological Station
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Illinois Natural History Survey
Division of Ecology and Conservation Sciences
Section for Field Stations and Ecosystems Science

INHS Technical Report 2008 (10)
Date of issue: March 31, 2008

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DISCLAIMER

The findings, conclusions, and views expressed herein are those of the researchers and should not be considered as the official position of the United States Fish and Wildlife Service or the Illinois Department of Natural Resources.

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The Long-term Illinois River Fish Population Monitoring Program (F-101-R) is supported by the Federal Aid in Sport Fish Restoration Act (P.L. 81-6814, Dingell-Johnson/Wallop-Breaux).

EXECUTIVE SUMMARY

Between 4 September and 1 October 2007, 27 sites on the Illinois River waterway and one site in Reach 26 of the Mississippi River were electrofished to monitor fish communities. A total of 8,768 fishes representing 60 species (plus three hybrids) from 14 families were collected during 26.34 hours of sampling. Collections made in 2007 indicated continued high catches of gizzard shad, emerald shiner, and bluegill throughout most of the Illinois River waterway. Common carp and goldfish, which were once dominant, continue to exhibit relatively low in catch rates throughout the Illinois River waterway, contributing only 2.8% of the total catch and 2.9% of the Illinois River Waterway catch. Southern redbelly dace were collected for the first time during project F-101-R sampling along the waterway in 2007. A single specimen was collected from Henry Island (RM 193.8) in Peoria Reach. Silver carp were again collected during project F-101-R sampling at most lower and middle river sites. Silver carp were the most abundantly collected species throughout the waterway in 2007 with 2,921 fish collected comprising 33.3% of the total catch. Silver carp collections in La Grange and Peoria reaches were the highest observed for this species since it was first recorded in 2002. Silver carp collections in La Grange and Peoria reaches were also the highest catches ever recorded for a single species in both reaches in F-101-R sampling. Bighead carp and round goby were collected at new sites in 2007 illustrating further expansion of these invasive species. Bighead carp were collected at Bull's Island (RM 240.8) in Starved Rock Reach marking the furthest upstream collection of this species in F-101-R sampling. Round goby were collected at two sites, Clark Island (RM 215.3) and Hennepin Island (RM 207.7) in Peoria Reach, marking the furthest downstream collection of this species in F-101-R sampling. The sample from Lambie's Boat Harbor (RM 170.3, Peoria Reach) yielded the highest collection of total fish (2,293, 26.2% of the total collected from all 28 sites), while the sample from Moore's Towhead produced the lowest total fish (43, 0.5% of the total collected from all 28 sites). Fish species richness at sites ranged from 27 at Hennepin Island to 10 species at Moore's Towhead. Fish species richness of the lower, middle, and upper waterway was 32, 49, and 38, respectively. Cyprinid catches continued to remain relatively high in the upper waterway, with emerald shiner being the most abundant, making up 19.6% of the total upper waterway catch. Emerald shiner catch percentages for Dresden, Marseilles, and Starved Rock reaches were 0.9%, 30.6%, and 29.9%, respectively. Important sport fish species such as bluegill, largemouth bass, and channel catfish were collected in all six waterway reaches in 2007. Bluegill catch per unit effort in number of fish collected per hour ($CPUE_N$) ranged from 116.5 in Dresden Reach to 4.36 in La Grange Reach. Largemouth bass $CPUE_N$ ranged from 35.0 in Dresden Reach to 0.2 in La Grange reach. Channel catfish $CPUE_N$ ranged from 13.1 in La Grange Reach to 3.6 in Marseilles Reach. In terms of pounds of fish collected per hour ($CPUE_W$), the collection from Peoria Reach yielded the highest biomass at 196.4 pounds per hour while the collection from Marseilles Reach yielded the lowest biomass at 32.6 pounds per hour. Silver carp biomass ranked first over all reaches at 24.1 pounds per hour, comprising 23.5% of the total biomass. Silver carp also ranked first in $CPUE_W$ for Alton, La Grange, and Peoria reaches. Catch in weight for silver carp in each reach was 15.2 (40.9% of the total), 32.8 (33.8% of the total), and 46.3 (23.6% of the total), respectively. Bighead carp ranked first and comprised 43.1 % of the total catch in weight for Starved Rock reach with two individuals captured. Channel catfish ranked first in Marseilles and comprised 36.8% of the total catch in weight with a $CPUE_W$ of 12.0. Common carp ranked first in and comprised 34.0% of the total catch in weight with a $CPUE_W$ of 32.1 for Dresden Reach. Sixteen fishes were observed to have externally visible abnormalities in 2007. Abnormalities were found in fishes of all reaches except La Grange.

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INDEX TO JOB ACCOMPLISHMENTS

[a]Job numbers and titles refer to the F-101-R-19 annual work plan dated January 2007

ACKNOWLEDGMENTS

Project F-101-R is supported by the Federal Aid to Sportfish Restoration Act (P.L. 81-681, Dingell-Johnson/Wallop-Breaux), with funds administered by the U.S.

Fish and Wildlife Service and the Illinois Department of Natural Resources (IDNR). Mr. Larry Dunham (IDNR), Dr. David Thomas, former Chief of the Illinois Natural History Survey (INHS), and Dr. Michael Douglas, Director of the Division of Ecology and Conservation Sciences (INHS) provided administrative support. Mrs. Cammy Smith, Ms. Nerissa Michaels and Mr. Matt Stroub of the Illinois River Biological Station at Havana provided clerical, data entry and data verification support. Mr. Thad Cook, Mr. Matt O' Hara, Ms. Nerissa Michaels, Mr. Maurice Sisson III, Mr. Jared Woodcock, and Mr. Denim Perry assisted with the field work. This survey was originally conceived and initiated in 1957 by the late Dr. William C. Starrett.

INTRODUCTION

This report presents a summary of data collected in 2007 during segment 19 of federal aid project F-101-R, The Long-term Illinois River Fish Population Monitoring

Program. Previous summaries of the long-term data set, begun in 1957, were given by Sparks and Starrett (1975), Sparks (1977), Sparks and Lerczak (1993), Lerczak and Sparks (1994), Lerczak et al. (1994), Koel and Sparks (1999), and McClelland and Pegg (2004). The annual reports for project F-101-R will continue to build upon previously collected data with major analyses of the long-term data set scheduled at five-year intervals. The next summary is due at the end of segment 20. The format used in this report is patterned after previous annual reports of this project (Lerczak et al. 1993, 1994, 1995, and 1996; Koel et al. 1997 and 1998; Koel and Sparks 1999; Arnold et al. 2000; McClelland and Pegg 2001, 2002, 2003, 2004, 2005; McClelland and Cook 2006; McClelland and Sass 2007) to allow for easy comparisons of data among years.

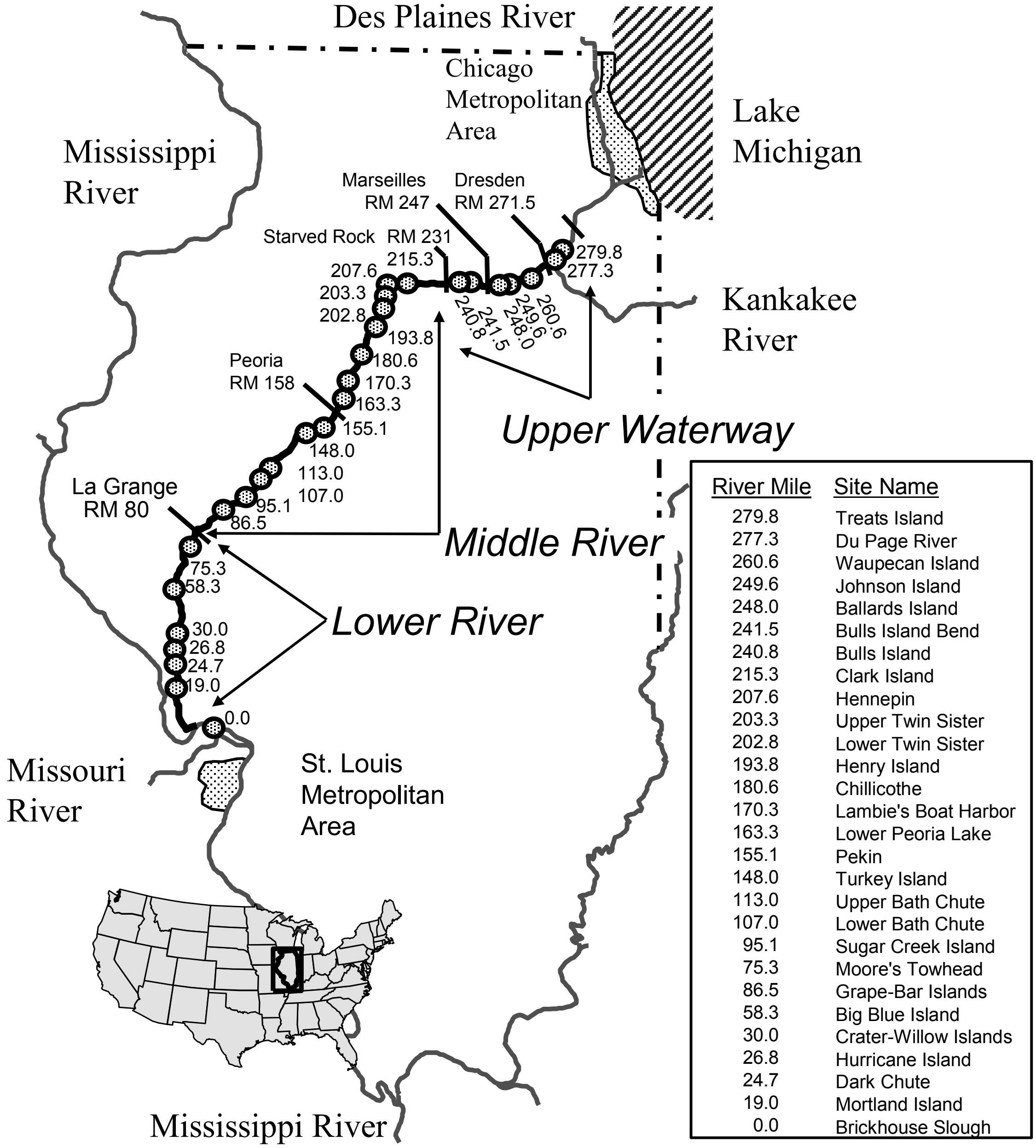
STUDY AREA AND METHODS

Twenty-seven sites were sampled for fish at fixed locations along the Illinois Waterway. Twenty-six of the site locations were defined by Sparks and Starrett (1975) and Lerczak et al. (1994). In 1999, a twenty-seventh site was added at Moore's Towhead in Alton Reach, Illinois River mile 75.3, to more closely monitor fish communities near The Nature Conservancy's (TNC) floodplain restoration project (Spunky Bottoms Merwin Preserve). Twenty-five of the sites were located on the Illinois River, with two additional sites on the lower Des Plaines River. The Des Plaines River, along with the Illinois River forms part of the Illinois Waterway. One additional site was located on the Mississippi River (Figure 1). Seventeen of the sites were in side channels; the remaining sites were in other habitats, including the main channel border, or in a combination of habitat types (see Lerczak et al., 1994).

Following water quality measurements (e.g., dissolved oxygen) at each site, fish populations were sampled by electrofishing from a 16-ft (5-m) aluminum boat using a 3000-watt, three-phase AC generator. Sampling at each site typically lasted one hour. Stunned fish were gathered with a dip net (1/4-in [0.64-cm] mesh) and stored in an oxygenated livewell until sampling was completed. Fish were then identified to species, measured (total length and weight), inspected for externally visible abnormalities, and returned to the water. Additional details on the electrofishing method and equipment were given by Lerczak et al. (1994).

DATA ANALYSIS (Job 4)

For each site, the number of individual fish and total weight (pounds) were tallied for each species. Fish catch rates were quantified as the number of individuals collected per hour of electrofishing ($CPUE_N$) and as weight in pounds collected per hour of electrofishing ($CPUE_W$). Catch data, both the number of individuals and pounds collected per sample and hour, were summarized and reported by collection site. Data from sites was also grouped into reaches defined by navigation dams (Figure 1) as follows: Alton Reach, river mile (RM) 0-80; La Grange Reach, RM 80-158; Peoria Reach, RM 158-231; Starved Rock Reach, RM 231-247; Marseilles Reach, RM 247-271.5; and Dresden Reach, RM 271.5-286 on the Des Plaines River. Data from



River Mile	Site Name
279.8	Treats Island
277.3	Du Page River
260.6	Waupecan Island
249.6	Johnson Island
248.0	Ballards Island
241.5	Bulls Island Bend
240.8	Bulls Island
215.3	Clark Island
207.6	Hennepin
203.3	Upper Twin Sister
202.8	Lower Twin Sister
193.8	Henry Island
180.6	Chillicothe
170.3	Lambie's Boat Harbor
163.3	Lower Peoria Lake
155.1	Pekin
148.0	Turkey Island
113.0	Upper Bath Chute
107.0	Lower Bath Chute
95.1	Sugar Creek Island
75.3	Moore's Towhead
86.5	Grape-Bar Islands
58.3	Big Blue Island
30.0	Crater-Willow Islands
26.8	Hurricane Island
24.7	Dark Chute
19.0	Mortland Island
0.0	Brickhouse Slough

Figure 1. Map of the Illinois River waterway illustrating the three segments of the Illinois River Waterway sampled by electrofishing to monitor fish communities in 2007.

reaches was also combined into three groups; lower (Alton Reach), middle (La Grange and Peoria reaches), and upper (Starved Rock, Marseilles, and Dresden reaches) Illinois Waterway segments defined by their location along the river (waterway) and by the amount of off-channel habitat accessible to fish per unit length of river (Figure 1; Lerczak et al. 1994). Lerczak et al. (1994, 1995, and 1996) found that river fish communities of the three segments differed substantially enough to give segment designations biological meaning.

RESULTS AND DISCUSSION (Job 5)

All equipment was tested and repaired as necessary before the fish sampling season began and staff were given a review in safety procedures and electrofishing methods **(Job 1).**

All 28 sites were sampled between 4 September and 1 October 2007 **(Job 2)**; total electrofishing time was 26.34 h (Table 1). Collected data were entered into Microsoft ACCESS 2000 and verified against original field data sheets until no errors were detected **(Job 3)**. The original data sheets from 2007 sampling and all of the other original data sheets of this project (1957-2007) are stored in flame-resistant cabinets at the Illinois River Biological Station at 704 N. Schrader Avenue, Havana **(Job 3)**.

A. CONDITIONS DURING ELECTROFISHING RUNS

Sampling was conducted in full daylight between 8:25 AM and 5:00 PM central standard time (Table 1). The ranges for physical measurements collected during the 2007 sampling season were as follows: air temperature, 60.8-91.1^{o} F; water

Table 1. Station information and characteristics during sampling in 2007. All stations, except where noted, are on the Illinois River and are listed in downstream-to-upstream order. Site miles are the average river mile and refer to Figure 1.

Sampling		Site		Sample river mile			End time	Duration	Temp (°F)		DO		Secchi	Cond.	Volts	Vel.	Depth[b] (ft)		Stage[c]
Order	Date	Mile[a]	Name	lower	upper	mean	(CST)	(h)	air	water	(ppm)	(% Sat.)	(cm)	(umhos)		(ft/s)	min	max	(ft)
Reach 26, Mississippi River																			
8	13-Sep	0.0	Brickhouse Slough[d]	204.9	205.3	205.1	10:48	1.00	77.7	73.6	10.43	132.82%	19.0	435	225	0.02	0.5	7.0	
Alton Reach																			
23	26-Sep	19.0	Mortland Island	18.1	19.5	18.8	15:35	1.00	70.9	76.6	7.21	86.00%	35.0	736	220	0.20	1.0	8.0	2.35
22	26-Sep	24.7	Dark Chute	24.5	25.5	25.0	13:30	1.00	67.9	75.7	7.10	82.16%	19.0	743	225	0.21	0.5	11.0	2.35
21	26-Sep	26.8	Hurricane Island	27.0	27.9	27.5	11:40	1.00	63.9	75.7	6.75	74.90%	19.0	750	225	0.17	1.0	8.0	2.35
20	26-Sep	30.0	Crater-Willow Island	29.2	30.8	30.0	9:55	1.00	61.9	75.7	6.75	73.30%	28.0	750	225	0.19	1.0	7.5	2.35
24	27-Sep	58.3	Big Blue Island	58.0	59.0	58.5	9:55	1.00	67.0	75.6	7.12	81.63%	33.0	765	220	0.20	1.0	6.5	2.30
25	27-Sep	75.3	Moore's Towhead	74.8	75.8	75.3	12:20	0.42	78.6	76.8	7.70	98.88%	29.0	772	225	0.30	0.5	5.0	2.30
La Grange Reach																			
16	22-Sep	86.5	Grape-Bar Islands	85.7	87.0	86.4	10:48	1.00	71.6	74.7	6.62	79.51%	20.0	766	225	0.20	0.5	6.0	9.96
15	22-Sep	95.1	Sugar Creek Island	94.5	95.0	94.8	8:40	1.00	67.1	74.8	6.47	74.25%	24.0	736	225	0.25	1.0	6.0	9.96
18	24-Sep	107.1	Lower Bath Chute	106.9	107.3	107.1	11:48	1.00	87.0	76.6	6.25	86.49%	23.0	737	225	0.33	1.0	6.5	6.10
17	24-Sep	113.0	Upper Bath Chute	112.8	113.2	113.0	9:24	1.00	79.1	76.8	6.43	82.95%	22.0	765	225	0.33	1.0	7.0	6.10
26	28-Sep	148.0	Turkey Island	148.0	148.3	148.2	9:13	0.50	61.9	74.3	7.45	80.90%	18.0	792	225	0.25	1.0	7.5	3.26
28	1-Oct	155.1	Pekin	154.5	155.3	154.9	9:30	1.00	66.1	70.0	8.33	94.61%	26.0	798	225	0.31	0.5	7.0	431.50
Peoria Reach																			
9	14-Sep	163.4	Lower Peoria Lake	163.5	163.6	163.6	9:25	1.00	60.8	68.1	9.27	99.46%	13.0	664	225	0.01	2.0	4.0	12.87
27	28-Sep	170.3	Lambie's Boat Harbor	170.6	170.8	170.4	12:00	0.92	78.8	69.8	12.97	166.86%	12.0	754	225	0.02	0.5	3.0	12.01
10	17-Sep	180.6	Chillicothe	180.6	181.1	180.9	11:00	1.00	78.6	69.6	10.41	133.68%	21.0	745	225	0.31	0.5	7.0	14.84
11	18-Sep	193.8	Henry Island	193.3	194.5	193.9	10:40	1.00	79.0	71.1	11.06	142.55%	30.0	726	230	0.32	1.0	6.0	14.69
14	19-Sep	202.8	Lower Twin Sister	202.4	203.2	202.8	15:35	1.00	79.1	74.7	13.78	177.78%	31.0	754	230	0.21	1.0	7.0	14.76
13	19-Sep	203.3	Upper Twin Sister	203.3	203.5	203.4	12:55	1.00	79.9	74.1	13.22	171.81%	27.0	765	225	0.27	1.0	7.0	14.76
12	19-Sep	207.7	Hennepin	207.6	208.1	207.9	10:26	1.00	78.6	73.4	12.39	159.11%	34.0	766	225	0.21	0.5	7.0	14.76
19	25-Sep	215.3	Clark Island	214.9	215.6	215.3	10:40	1.00	79.0	76.5	9.03	116.39%	44.0	798	225	0.21	1.0	6.0	11.52
Starved Rock Reach																			
2	4-Sep	240.8	Bulls Island	240.3	241.0	240.7	13:10	1.00	88.9	80.2	8.82	124.05%	53.0	708	230	0.28	1.0	6.5	460.40
1	4-Sep	241.5	Bulls Island Bend	241.1	241.6	241.4	11:25	1.00	86.3	79.3	8.54	117.47%	38.0	706	230	0.41	1.0	6.0	460.40
Marseilles Reach													32.0						
3	5-Sep	248.0	Ballards Island	247.7	248.2	248.0	12:00	1.00	91.1	80.6	9.00	128.93%	62.0	712	230	0.51	0.5	6.0	6.93
4	5-Sep	249.7	Johnson Island	249.7	249.8	249.8	13:25	0.50	89.0	80.8	8.80	123.87%	59.0	713	230	0.43	0.5	4.0	6.93
5	5-Sep	260.6	Waupecan Island	260.2	261.1	260.7	17:00	1.00	88.1	81.5	9.17	128.10%	59.0	713	230	0.40	1.0	6.5	6.93
Dresden Reach																			
6	6-Sep	277.4	Du Page River[e]	276.8	277.8	277.3	8:25	1.00	76.9	82.0	7.40	93.54%	81.0	786	225	0.04	1.0	6.5	505.40
7	6-Sep	279.9	Treats Island[e]	279.6	280.1	279.9	10:53	1.00	79.0	82.6	7.00	90.22%	65.0	774	225	0.26	1.0	6.0	505.40
Minimum								0.42	60.8	68.1	6.3	61.11%	12.0	435	220	0.01	0.5	3.0	
Maximum								1.00	91.1	82.6	13.8	128.77%	81.0	798	230	0.51	1	11.0	
Mean								0.94	76.2	75.8	8.8	110.8%	34.9	737	226	0.24	0.9	6.5	
Total time electrofished								26.34											

[a] Refers to approximate average river mile electrofished at each site, 1957-2007.

[b] Estimated during sampling.

[c] Feet above sea level or river stage (ft) at the U.S. Army Corps of Engineers river gage nearest to the sampling site.

[d] Mississippi River.

[e] Des Plaines River.

temperature, 68.1-82.6^{o} F; dissolved oxygen concentration, 6.3-13.8 ppm; secchi disk transparency, 12.0-81.0 cm; conductivity, 435-798 μhos/cm; surface velocity, 0.01-0.51 ft/s; water depth, 0.5-11.0 ft. All physical values were within the ranges expected based upon previous sampling (Lerczak et al. 1994; Koel and Sparks 1999). All sites were sampled within established water temperature and river level criteria (Table 1; Lerczak et al. 1994).

B. ELECTROFISHING RESULTS

The following data summaries proceed through several levels of detail. First, data on the number of individual fish (by species) collected at each of the 28 sites are presented. Second, catch rates of the number of individuals collected per hour of electrofishing are calculated for each of the seven navigation reaches. Similar summaries are presented for fish weights. Results conclude with fish health as determined by external visual inspection. Fish common names used throughout this report follow Robins et al. (1991). Fish common and scientific names are listed in APPENDIX A.

Numbers of Fish Collected

We collected a total of 8,768 fishes representing 60 species (plus three hybrids) from 14 families during 26.34h of electrofishing at 27 sites on the Illinois River waterway and a single site on the Mississippi River in 2007. Silver carp were the most abundantly collected species, representing 33.3% of the total catch. Silver carp were followed by bluegill (10.5%), emerald shiner (9.0%), gizzard shad (8.3%), bluntnose minnow (4.1%), and orange spotted sunfish (3.7%). Channel catfish and freshwater drum were collected at all 28 sites; emerald shiner and gizzard shad were collected at 27 sites; bullhead minnow were collected at 26 sites; bluegill and common carp were collected at 25 sites; black crappie, green sunfish, orange spotted sunfish, and white bass were collected at 21 sites. The collection from Lambie's Boat Harbor (RM 170.3, Peoria Reach) yielded the most fish (2,293, 26.2% of the total collected from all 28 sites), while the collection from Moore's Towhead (RM 75.3, Alton Reach) yielded the least fish (43, 0.5% of the total collected from all 28 sites). The most fish species collected at one site was 27 obtained at Hennepin Island (RM 207.6) in Peoria Reach. The fewest species collected at a single site was 10 from Moore's Towhead.

Of the 60 fish species and three hybrid crosses, 15 species and two hybrids (bighead carp, bowfin, brown bullhead, common shiner, goldeye, highfin carpsucker, logperch, mud darter, northern hogsucker, redear sunfish, southern redbelly dace, silver redhorse, tadpole madtom, quillback, white perch, common carp x goldfish, and yellow bass x white perch) were collected at only one site. Six fish species (blackstripe topminnow, longear sunfish, river shiner, sauger, threadfin shad, and yellow bullhead) were collected at only two sites. Eight fish species and two hybrids (bowfin, goldeye, highfin carpsucker, mud darter, southern redbelly dace, silver redhorse, tadpole madtom, quillback, common carp x goldfish, and yellow bass x white perch) were represented by single individuals at sites. A maximum of two individuals were collected at sites for each of seven fish species (bighead carp, blackstripe topminnow, brown bullhead, redear sunfish, threadfin shad, white perch, and yellow bullhead).

On the 27 Illinois River waterway sites, we collected 8,503 fishes representing 60 species (plus three hybrids) from 14 families during 25.34 h of sampling. At Brickhouse

Slough on the Mississippi River (RM 204.9), we collected 265 fishes representing 17 species from six families (Table 2). Total catch from Brickhouse Slough in 2007 was the second highest collection ever recorded in F-101-R sampling at this site. Previous high catches occurred in 2006 when 2,267 fishes were collected (McClelland and Sass 2007).

On the lower Illinois River waterway we collected 837 fishes representing 32 species and two hybrids (Table 2). In 2007, fish species richness ranged from 10 at Moore's Towhead (RM 75.3) to 19 at Crater-Willow Islands (RM 30.0). Our 2007 observation at Crater-Willow Islands matches the highest species richness recorded for this site in F-101-R sampling; a previous high species collection of 18 was recorded in 1999 (Arnold et. al 2000). Crater-Willow Islands also exhibited the highest total catch in the lower waterway with 126 total fishes.

We collected 5,881 fishes representing 49 species and two hybrids on the middle Illinois River waterway (Tables 3 and 4). The total catch for the middle river in 2007 was the highest recorded for this region in F-101-R sampling. The six sites on La Grange Reach (RM 80-158) produced 1,773 fishes representing 33 species and two hybrids. Both the total number and total fish species collections for La Grange Reach are the highest ever recorded for this reach in F-101-R sampling. The eight sites on Peoria Reach (RM 158-231) produced 4,103 fishes representing 39 species and one hybrid. The total fish numbers for Peoria Reach also represent the highest recorded for this reach in F-101-R sampling. Fish species richness in the middle river ranged

Table 2. Number of individuals of each fish species collected on the Mississippi River (Brickhouse Slough) and the lower Illinois Waterway (Alton Reach, RM 0-80) in 2007.

		River Mile and Hours Fished							
		Miss. River	Lower Illinois River						
	Mile	0.0	19.0	24.7	26.8	30.0	58.3	75.3	Total
Species	Effort	1.00	1.00	1.00	1.00	1.00	1.00	0.42	5.42
Amiidae									
bowfin						1			1
Catostomidae									
bigmouth buffalo			1	2		2			5
black buffalo							1		1
golden redhorse								1	1
river carpsucker		1				1		1	3
shorthead redhorse					1	1			2
smallmouth buffalo		1							1
Centrarchidae									
black crappie		4	4	2	4	8			22
bluegill		50	7	18	9	13	9		106
bluegill x green sunfish			1						1
green sunfish		9			1	1			11
largemouth bass		1	2	2	2		1		8
orange spotted sunfish		7	3	1		2	5		18
smallmouth bass		1	1			1			3
warmouth		1							1
Clupeidae									
gizzard shad		146	4	8	10	5	12	9	194
Cyprinidae									
bullhead minnow		7	9	9	12	15	14	2	68
common carp			2	1		1	2		6
common carp x goldfish				1					1
emerald shiner		23	34	23	22	20	33	6	161
river shiner					2				2
silver carp		3	2	4	7	6	6		28
silver chub					2				2
silverband shiner						3	3	3	9
spotfin shiner		3	3		3				9
spottail shiner				1					1
Hiodontidae									
goldeye							1		1
Ictaluridae									
channel catfish		4	11	3	4	10	5	5	42
flathead catfish		2		2		1	2		7
Lepisosteidae									
shortnose gar				2	1				3
Moronidae									
white bass			10	6	9	11	1	1	38
Percidae									
mud darter							1		1
sauger								1	1
Sciaenidae									
freshwater drum		2	9	9	10	24	11	14	79
Total individuals		265	103	94	99	126	107	43	837
Total species/hybrids		17/0	15/1	16/1	16/0	19/0	16/0	10/0	32/2

Table 3. Number of individuals of each fish species collected on La Grange Reach (RM 80-158) of the middle Illinois Waterway (RM 80-231) in 2007.

		River Mile and Hours Fished							
								La Grange Reach	Middle River
	Mile	86.5	95.1	107.1	113	148	155.1	Total	Total
Species	Effort	1.00	1.00	1.00	1.00	0.50	1.00	5.50	13.04
Catostomidae									
bigmouth buffalo					1	2		3	68
black buffalo			1			2		3	3
river carpsucker		1			2		1	4	13
shorthead redhorse					1	1	3	5	6
smallmouth buffalo			2	3	4	4	12	25	158
Centrarchidae									
black crappie		1	1	1	1	2		6	27
bluegill		3	6	5	10			24	502
bluegill x green sunfish				1				1	7
green sunfish			3	3	2		1	9	205
largemouth bass						1		1	72
orange spotted sunfish		3	13	35	20			71	300
white crappie					1			1	3
Clupeidae									
gizzard shad		64	29	42	7	2	9	153	401
skipjack herring					1			1	7
threadfin shad						1	1	2	2
Cyprinidae									
bluntnose minnow					1			1	1
bullhead minnow		7	4	3	2	7	3	26	180
common carp		3	17	6	3	3	23	55	185
emerald shiner		38	18	9	16	1		82	228
grass carp		4						4	8
red shiner		9	3	1	5			18	21
river shiner						1		1	1
silver carp		15	25	523	473	3	1	1040	2893
silver chub						1		1	3
silverband shiner		1						1	1
Ictaluridae									
channel catfish		7	8	14	19	6	18	72	133
flathead catfish			3		1			4	9
Lepisosteidae									
shortnose gar							1	1	1
Moronidae									
white bass		2	2	1	2	7	40	54	93
white perch							2	2	2
yellow bass					1	3	3	7	7
yellow bass x white perch							1	1	1
Percidae									
sauger							3	3	3
Poeciliidae									
western mosquitofish		1	2	45				48	52
Sciaenidae									
freshwater drum		2	7	9	8	3	14	43	171
Total Individuals		161	144	701	581	50	136	1773	5881
Total species/hybrids		16/0	17/0	15/1	22/0	18/0	16/1	33/2	49/2

Table 4. Number of individuals of each fish species collected on Peoria Reach (RM 158-231) of the middle Illinois Waterway (RM 80-231) in 2007.

		River Mile and Hours Fished									
										Peoria Reach	Middle River
	Mile	163.3	170.3	180.6	193.8	202.8	203.3	207.6	215.3	Total	Total
Species	Effort	1.00	0.92	1.00	1.00	1.00	1.00	1.00	1.00	7.92	13.42
Catostomidae											
bigmouth buffalo				3	8	9	31	4	10	65	68
golden redhorse				1		1			3	5	5
northern hogsucker			5							5	5
river carpsucker		3		3		1	1		1	9	13
shorthead redhorse									1	1	6
smallmouth buffalo				14	9	13	58	11	28	133	158
Centrarchidae											
black crappie		1	1	3	1		10	4	1	21	27
bluegill		100	146	44	35	13	36	81	23	478	502
bluegill x green sunfish		1	4					1		6	7
green sunfish		53	57	15	1	4	1	45	20	196	205
largemouth bass		7	39	2	2	2	10	9		71	72
orange spotted sunfish		21	14	70	14	1	2	53	54	229	300
pumpkinseed		1	1	2				5		9	9
redear sunfish								2		2	2
rock bass						1				1	1
smallmouth bass						1	1	9	1	12	12
warmouth				1	1					2	2
white crappie			1						1	2	3
Clupeidae											
gizzard shad		7	165	13	6	1	4	12	40	248	401
skipjack herring					1	1	1	1	2	6	7
Cyprinidae											
bullhead minnow		3	3	22	11	20	6	59	30	154	180
common carp		23	13	48	12	11	14	3	6	130	185
emerald shiner		2	10	9	43	14	2	41	25	146	228
golden shiner			6	1						7	7
goldfish			7			2	2			11	11
grass carp					3			1		4	8
red shiner		1							2	3	21
silver carp			1813	3	10	2	18	6	1	1853	2893
silver chub				1				1		2	3
southern redbelly dace					1					1	1
spotfin shiner					1			12	10	23	23
spottail shiner		4			1	9		13		27	27
Gobiidae											
round goby								1	1	2	2
Ictaluridae											
brown bullhead			2							2	2
channel catfish		14	3	14	5	2	5	10	8	61	133
flathead catfish						1	2	1	1	5	9
yellow bullhead							1			1	1
Moronidae											
white bass				12	5	5	5	5	7	39	93
Percidae											
logperch								4		4	4
Poeciliidae											
western mosquitofish								4		4	52
Sciaenidae											
freshwater drum		13	3	50	8	26	12	5	11	128	171
Total individuals		254	2293	331	178	140	222	403	287	4108	5881
Total species/hybrids		15/1	18/1	21/0	21/0	22/0	21/0	27/1	24/0	39/1	49/2

from 15 species collected at Lower Bath Chute (RM 107.1, La Grange Reach) and Lower Peoria Lake (RM 163.3, Peoria Reach) to 27 species at Hennepin Island in 2007. Our 2007 observation is the highest fish species richness ever recorded at Hennepin Island in F-101-R sampling. A previous high fish species collection of 26 was recorded in 2005 (McClelland and Cook 2006). Fish species collections at Clark Island (24 species; RM 215.3) and Lower Twin Sisters Island (22 species; RM 202.8) in Peoria Reach and Turkey Island (18 species; RM 148.0) and Upper Bath Chute (22 species; RM 113.0) in La Grange Reach were also the highest ever recorded for these locations in F-101-R sampling. Lambie's Boat Harbor was the site of the highest total catch on the middle Illinois River waterway with 2,293 fishes. Our collection represents the highest number of fishes ever collected in F-101-R sampling for any collection site throughout the river. The previous high total catch of 1,142 fishes was recorded at Lambie's Boat Harbor in 2002 (McClelland and Pegg 2003). In addition to the high numbers observed at Lambie's Boat Harbor, the collections at Upper Twin Sisters Island (222 fishes; RM 203.3, Peoria Reach), Chillicothe Island (331 fishes; RM 180.6, Peoria Reach), Upper Bath Chute (581 fishes), and Lower Bath Chute (701 fishes) each recorded their highest total catches in F-101-R sampling.

We collected 2,050 fishes representing 38 species and one hybrid cross (Table 5) on the upper Illinois River waterway in 2007. This is the highest fish species collection for the upper river in F-101-R sampling. In addition, fish species collections were the highest ever recorded for each reach in the upper river. A total of 29 fish species were collected in Starved Rock Reach, 27 fish species in Marseilles Reach,

Table 5. Number of individuals of each fish species collected on Starved Rock, Marseilles, and Dresden Reaches of the upper Illinois Waterway (RM 231-280) in 2007.

		River Mle and Hours Fished							
		Starved Rock		Marseilles			Dresden		Upper Waterway Total
	Mile	240.8	241.5	248	249.6	260.6	277.4	279.8	
Species	Effort	1.00	1.00	1.00	0.50	1.00	1.00	1.00	6.50
Catostomidae									
black buffalo			1						1
golden redhorse			7			5	1	3	16
highfin carpsucker		1							1
quillback					1				1
river carpsucker		1	2	2		1			6
shorthead redhorse		12		1		1		1	15
silver redhorse							1		1
smallmouth buffalo		3	1			4		3	11
Centrarchidae									
black crappie			1	1	1		1		4
bluegill		18	14	36	5	10	127	106	316
bluegill x green sunfish		1					12	19	32
green sunfish		1	6	3		16	35	44	105
largemouth bass		9	8	14	2	6	52	18	109
longear sunfish		1	2						3
orange spotted sunfish				2		2	4	1	9
pumpkinseed		1	2	3		7		5	18
rock bass			1	1		1	16		19
smallmouth bass		6	3	2		3	9	6	29
Clupeidae									
gizzard shad			10	10	1	2	42	72	137
Cyprinidae									
bighead carp		2							2
bluntnose minnow		134	36	38	40	15	28	66	357
bullhead minnow		22	8	11	2	1			44
central stoneroller						4			4
common carp		5	1	4	1	2	5	12	30
emerald shiner		173	38	16	101	66	4	3	401
golden shiner							11		11
goldfish				1			12	4	17
silver chub			1						1
silverband shiner								4	4
spotfin shiner		107	35	34	63	14			253
spottail shiner		5	1	5	1			1	13
Fundulidae									
blackstripe topminnow			1	1					2
Gobiidae									
round goby			1	1	2	1			5
Ictaluridae									
channel catfish		3	12	4	2	3	8	6	38
tadpole madtom								1	1
yellow bullhead								1	1
Moronidae									
white bass		1	2			2			5
yellow bass		3							3
Sciaenidae									
freshwater drum		1	2	1	2	17	1	1	25
Total individuals		510	196	191	224	183	369	377	2050
Total species/hybrids		21/1	25/0	22/0	14/0	22/0	17/1	20/1	38/1

and 24 fish species in Dresden Reach. Fish species richness at a single site ranged from 14 at Johnson Island (RM 249.6, Marseilles Reach) to 25 at Bull's Island Bend (RM 241.5, Starved Rock Reach). Fish species collections at Bull's Island (21 fish species; RM 240.8, Starved Rock Reach), Bull's Island Bend, Ballard's Island (22 fish species; RM 248.0, Marseilles Reach), Waupecan Island (22 fish species; RM 260.6, Marseilles Reach) and Treat's Island (20 fish species; RM 279.8, Dresden Reach) were the highest fish species catches observed for these sites in F-101-R sampling. The collection of 510 fishes at Bull's Island also represented the highest total catch in the upper Illinois River waterway in 2007. The collection from Johnson Island of 224 total fishes was the highest total catch at this site in F-101-R sampling. A previous high total catch of 203 fishes was recorded in 1995 (Lerczak et al. 1996).

Catch Rates in Numbers of Individuals Collected per Hour by Reach.

In the following data summary, most of the discussion was restricted either to species that each separately accounted for over 10% of the total catch or to species that were of special significance.

Alton (lower waterway, Illinois River). The 95% lists (fish species were added to the list until 95% of the total catch in numbers was obtained) for Alton, La Grange, and Peoria reaches remained similar to each other, as in past years, although total catch in numbers per hour ($CPUE_N$) varied among reaches. Sixteen fish species accounted for 95.8% of the total catch in Alton Reach (Tables 6 and 7) and overall $CPUE_N$ was 105.54 in 2007. The highest $CPUE_N$ for an individual fish species was 25.48 for emerald shiner. Emerald shiner comprised 24.1% of the total fish collected in

Table 6. Number of individuals of each fish species collected per hour of electrofishing ($CPUE_N$) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2007.

	Reach and Hours Fished							
					Starved			Overall
	Reach 26	Alton	La Grange	Peoria	Rock	Marseilles	Dresden	$CPUE_N$
Species	1.00	5.42	5.50	7.92	2.00	2.50	2.00	26.34
Amiidae								
bowfin		0.18						0.04
Catastomidae								
bigmouth buffalo		0.92	0.55	8.21				2.77
black buffalo		0.18	0.55		0.50			0.19
golden redhorse		0.18		0.63	3.50	2.00	2.00	0.84
highfin carpsucker					0.50			0.04
northern hogsucker				0.63				0.19
quillback						0.40		0.04
river carpsucker	1.00	0.37	0.73	1.14	1.50	1.20		0.84
shorthead redhorse		0.37	0.91	0.13	6.00	0.80	0.50	0.87
silver redhorse							0.50	0.04
smallmouth buffalo	1.00		4.55	16.80	2.00	1.60	1.50	6.45
Centrarchidae								
black crappie	4.00	3.32	1.09	2.65	0.50	0.80	0.50	2.01
bluegill	50.00	10.34	4.36	60.38	16.00	20.40	116.50	35.08
bluegill x green sunfish		0.18	0.18	0.76	0.50		15.50	1.52
green sunfish	9.00	0.37	1.64	24.76	3.50	7.60	39.50	12.19
largemouth bass	1.00	1.29	0.18	8.97	8.50	8.80	35.00	7.18
longear sunfish					1.50			0.11
orange spotted sunfish	7.00	2.03	12.91	28.93		1.60	2.50	12.41
pumpkinseed				1.14	1.50	4.00	2.50	1.03
redear sunfish				0.25				0.08
rock bass				0.13	0.50	0.80	8.00	0.76
smallmouth bass	1.00	0.37		1.52	4.50	2.00	7.50	1.67
warmouth	1.00			0.25				0.11
white crappie			0.18	0.25				0.11
Clupeidae								
gizzard shad	146.00	8.86	27.82	31.33	5.00	5.20	57.00	27.79
skipjack herring			0.18	0.76				0.27
threadfin shad			0.36					0.08
Cyprinidae								
bighead carp					1.00			0.08
bluntnose minnow			0.18		85.00	37.20	47.00	13.59
bullhead minnow	7.00	11.26	4.73	19.45	15.00	5.60		11.09
central stoneroller						1.60		0.15
common carp		1.11	10.00	16.42	3.00	2.80	8.50	8.39
common carp x goldfish		0.18						0.04
emerald shiner	23.00	25.48	14.91	18.44	105.50	73.20	3.50	29.99
golden shiner				0.88			5.50	0.68
goldfish				1.39		0.40	8.00	1.06
grass carp			0.73	0.51				0.30
red shiner			3.27	0.38				0.80
river shiner		0.37	0.18					0.11
silver carp	3.00	4.62	189.09	234.06				110.90
silver chub		0.37	0.18	0.25	0.50			0.23
silverband shiner		1.66	0.18				2.00	0.53
southern redbelly dace				0.13				0.04
spotfin shiner	3.00	1.11		2.91	71.00	44.40		10.82
spottail shiner		0.18		3.41	3.00	2.40	0.50	1.56

Table 6. (continued)
Number of individuals of each fish species collected per hour of electrofishing (CPUEn) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2007.

	Reach and Hours Fished							
Species	Reach 26 1.00	Alton 5.75	La Grange 5.16	Peoria 7.88	Starved Rock 2.00	Marseilles 2.50	Dresden 2.00	Overall $CPUE_N$ 26.29
Fundulidae								
blackstripe topminnow					0.50	0.40		0.08
Gobiidae								
round goby				0.25	0.50	1.60		0.27
Hiodontidae								
goldeye		0.18						0.04
Ictaluridae								
brown bullhead				0.25				0.08
channel catfish	4.00	7.02	13.09	7.71	7.50	3.60	7.00	8.09
flathead catfish	2.00	0.92	0.73	0.63				0.61
tadpole madtom							0.50	0.04
yellow bullhead				0.13			0.50	0.08
Lepisosteidae								
shortnose gar		0.55	0.18					0.15
Moronidae								
white bass		7.02	9.82	4.93	1.50	0.80		5.16
white perch			0.36					0.08
yellow bass			1.27		1.50			0.38
yellow bass x white perch			0.18					0.04
Percidae								
logperch				0.51				0.15
mud darter		0.18						0.04
sauger		0.18	0.55					0.15
Poeciliidae								
western mosquitofish			8.73	0.51				1.97
Sciaenidae								
freshwater drum	2.00	14.22	7.82	16.17	1.50	8.00	1.00	10.44
Total Number per hour	265.00	105.54	322.36	518.69	353.00	239.20	373.00	332.88
Number of species/hybrids	19/0	30/2	33/2	40/1	29/1	27/0	24/1	60/3

Table 7. Fish species ranks by relative abundance (number of fish collected per hour) for 2007 on the 6 reaches of the Illinois Waterway. Species were added to the list in descending order of abundance until 95% of the total catch for that reach was obtained. Percentages are in parentheses.

	Rankings by Reach					
Species	Alton	La Grange	Peoria	Starved Rock	Marseilles	Dresden
Catostomidae						
bigmouth buffalo	15 (0.9)		12 (1.6)			
golden redhorse				11 (1.0)	14 (0.8)	
shorthead redhorse				8 (1.7)		
smallmouth buffalo		11 (1.4)	8 (3.2)			
Centrarchidae						
bluegill	4 (10.3)	12 (1.4)	2 (11.6)	4 (4.5)	4 (8.5)	1 (31.2)
bluegill x green sunfish						6 (4.2)
black crappie	9 (3.3)					
green sunfish			5 (4.8)	11 (1.0)	7 (3.2)	4 (10.6)
largemouth bass	12 (1.3)		11 (1.7)	6 (2.4)	5 (3.7)	5 (9.4)
orange spotted sunfish	10 (2.0)	5 (4.0)	4 (5.6)			
pumpkinseed					10 (1.7)	
rock bass						8 (2.1)
smallmouth bass				10 (1.3)	14 (0.8)	10(2.0)
Clupeidae						
gizzard shad	5 (8.9)	2 (8.6)	3 (6.0)	9 (1.4)	9 (2.2)	2 (15.3)
Cyprinidae						
bluntnose minnow				2 (24.1)	3 (15.6)	3 (12.6)
bullhead minnow	3 (11.3)	10 (1.5)	6 (3.8)	5 (4.2)	8 (2.3)	
common carp	13 (1.1)	6 (3.1)	9 (3.2)	13 (0.8)	12 (1.2)	7 (2.3)
emerald shiner	1 (24.1)	3 (4.6)	7 (3.6)	1 (29.9)	1 (30.6)	
golden shiner						12 (1.5)
goldfish						8 (2.1)
silverband shiner	11 (1.7)					
silver carp	8 (4.6)	1 (58.7)	1 (45.1)			
spotfin shiner	13 (1.1)			3 (20.1)	2 (18.6)	
spottail shiner				13 (0.8)	13 (1.0)	
Ictaluridae						
channel catfish	6 (7.0)	4 (4.1)	13 (1.5)	7 (2.1)	11 (1.5)	11 (1.9)
flathead catfish	15 (0.9)					
Moronidae						
white bass	6 (7.0)	7 (3.1)				
Poeciliidae						
western mosquitofish		8 (2.7)				
Sciaenidae						
freshwater drum	2 (14.2)	9 (2.4)	10 (3.1)		6 (3.3)	
Number of species accounting for 95 % of total catch	16	12	13	14	15	12

this reach. Freshwater drum ranked second with a $CPUE_N$ of 14.22 (14.2% of the total). Bullhead minnow ranked third with a $CPUE_N$ of 11.26 (11.3% of the total) representing the highest $CPUE_N$ for this species in F-101-R sampling. The previous high $CPUE_N$ for bullhead minnow was 3.94 recorded in 2005 (McClelland and Cook 2006).

La Grange (middle waterway, Illinois River). Twelve fish species accounted for 95.5% of the total catch in La Grange Reach (Tables 6 and 7). Overall, $CPUE_N$ was 322.36; the highest catch rate recorded for La Grange Reach in F-101-R sampling. The previous high $CPUE_N$ of 315.09 was observed in 1996 (Koel et al. 1997). In 2007, the highest catch rate for any fish species was 189.09 for silver carp which comprised 58.7% of the total fish collected in this reach. Silver carp were first collected in F-101-R sampling in the La Grange Reach in 2002 and catches increased to a point where the 2007 catch rate for silver carp represented the highest $CPUE_N$ for any single fish species in the La Grange Reach in F-101-R sampling (McClelland and Pegg 2003). Gizzard shad ranked second with a $CPUE_N$ of 27.82 (8.6% of the total). Emerald shiner ranked third with a $CPUE_N$ of 14.91 and accounted for 4.6% of the total. Yellow bass x white perch hybrids were again collected for the second year in F-101-R sampling in La Grange Reach at Pekin (RM155.1).

Peoria (middle waterway, Illinois River). Thirteen fish species accounted for 94.8% of the total catch in Peoria Reach (Tables 6 and 7). Overall, $CPUE_N$ was 518.69 representing the highest catch rate ever recorded for Peoria Reach in F-101-R sampling. A previous high catch rate of 334.97 was observed in 2005 (McClelland and Cook 2006). The highest $CPUE_N$ for any fish species was 234.06 for silver carp comprising 45.1% of the total fishes collected in this reach. The catch rate for silver carp, which were first collected in F-101-R sampling in the Peoria Reach in 2004, represented the highest $CPUE_N$ for any species in this reach in F-101-R sampling (McClelland and Pegg 2005). Bluegill ranked second in Peoria Reach with a $CPUE_N$ of 60.38 (11.6% of the total. Bluegill have ranked among the top two species since 1990 in the Peoria Reach (Lerczak et al. 1993, 1994, 1995, 1996; Koel et al. 1997, 1998, Koel and Sparks 1999; Arnold et al. 2000; McClelland and Pegg 2001, 2002, 2003, 2004, 2005; McClelland and Cook 2006; McClelland and Sass 2007). Gizzard shad ranked third with a $CPUE_N$ of 31.33 (6.0% of the total). Orange spotted sunfish ranked fourth in 2007 with a catch rate of 28.93 (5.6% of the total) representing the highest $CPUE_N$ for this species in the Illinois River waterway in F-101-R sampling. Channel catfish and smallmouth bass were also collected at their highest $CPUE_N$ ever recorded in Peoria Reach in 2007 with catch rates of 7.71 and 1.52, respectively. Four species were collected in Peoria Reach for the first time in F-101-R sampling in 2007; a single rock bass was collected at Lower Twin Sisters Island, a single southern redbelly dace was collected at Henry Island (RM 193.8), northern hogsucker were collected at Lambie's Boat Harbor (RM 170.3), and round goby were collected at Clark Island (RM 215.3) and Hennepin Island (RM 207.6). The collection of round goby at Hennepin Island marked the furthest downstream record of this species for F-101-R sampling since it was first collected in Marseilles and Dresden Reaches in 2004. The collection of southern redbelly dace was the first collection of this species throughout the Illinois River waterway in F-101-R sampling.

Starved Rock (upper waterway, Illinois River). Fourteen fish species accounted for 95.5% of the total catch in Starved Rock Reach (Tables 6 and 7). Overall, $CPUE_N$ was 353.00 in 2007. The highest $CPUE_N$ for any species was 105.50 recorded for emerald shiner, which comprised 29.9% of the total catch. Bluntnose minnow ranked second with a catch rate of 85.00 comprising 24.1% of the total catch representing the highest $CPUE_N$ for this species in Starved Rock Reach in F-101-R sampling. Spotfin shiner ranked third with a catch rate of 71.00 (20.1% of the total) representing the highest $CPUE_N$ for this species in Starved Rock Reach in F-101-R sampling. Similar to Peoria Reach, channel catfish and smallmouth bass were also collected at their highest $CPUE_N$ ever recorded in Starved Rock Reach in 2007 with catch rates of 7.50 and 4.50, respectively. Bighead carp were collected in Starved Rock Reach for the first time in F-101-R sampling at Bull's Island (RM 240.8). The collection of bighead carp in Starved Rock Reach marked the furthest upstream record of this species for F-101-R sampling since they were first collected in La Grange Reach in 2000.

Marseilles (upper waterway, Illinois River). Fifteen fish species accounted for 95.0% of the total catch in Marseilles Reach (Tables 6 and 7) and overall $CPUE_N$ was 239.20 in 2007. The highest $CPUE_N$ for any species was 73.20 for emerald shiner. Emerald shiner comprised of 30.6% of the total fishes collected in this reach. Spotfin shiner ranked second with a $CPUE_N$ of 44.40 (18.6% of total) and bluntnose minnow ranked third with a $CPUE_N$ of 37.20 (15.6% of total), representing the highest catch rate in Marseilles Reach for bluntnose minnow in F-101-R sampling. Largemouth bass again ranked in the top 95% $CPUE_N$ in Marseilles Reach; a catch rate of 8.80 (3.7% of the total catch) was recorded for this species in 2007. The catch rate for channel catfish in 2007 was the highest recorded in Marseilles Reach for this species in F-01-R sampling with a $CPUE_N$ of 3.60 (1.5% of the total catch). Pumpkinseed were collected for the second time in Marseilles Reach in 2007, the $CPUE_N$ of 4.00 observed for this species represented the highest catch rate ever recorded in F-101-R throughout the entire Illinois River waterway.

Dresden (upper waterway, Des Plaines River). Twelve fish species accounted for 95.2% of the total catch in Dresden Reach (Tables 6 and 7). Overall, $CPUE_N$ was 373.00 in 2007. In 2007, the highest $CPUE_N$ for any species was 116.50 for bluegill, which made up 31.2% of the fishes collected. Gizzard shad ranked second with a $CPUE_N$ of 57.00 (15.3% of total). Bluntnose minnow ranked third with a $CPUE_N$ of 47.00, which comprised 12.6% of the total catch. Green sunfish ranked fourth with a $CPUE_N$ of 39.50 (10.6% of total). The catch rate for largemouth bass in 2007 was the highest ever observed for this species in Dresden Reach with a $CPUE_N$ of 35.00 (5^{th} ranked, 9.4% of the total catch). This is the second highest catch rate recorded for largemouth bass throughout the entire Illinois River waterway in F-101-R sampling. The highest $CPUE_N$ of 41.00 was recorded in 2005 in Starved Rock Reach (McClelland and Cook 2006). The catch rate for channel catfish in 2007 was the highest recorded in Dresden Reach for this species in F-01-R sampling with a $CPUE_N$ of 7.00 (1.9% of the total catch). The catch rate for rock bass in 2007 was the highest ever recorded for this species throughout the entire Illinois River waterway with a $CPUE_N$ of 8.00 (2.1% of the total catch). The previous high $CPUE_N$ of 6.50 was recorded in Dresden Reach in 1995 (Lerczak et. al 1996). Silver redhorse and tadpole madtom were collected for the first time in Dresden Reach in 2007. A single silver redhorse was collected at the Mouth of the Du Page River site (RM 277.4) and a single tadpole madtom was collected at Treat's Island.

Catch Rates in Weights (pounds) Collected per Hour by Reach.

The following data summary and discussion was restricted to fish species that individually accounted for over 10% of the total catch and to species that were of special interest. A 95% list was produced for each reach, in which species were ranked by relative biomass (pounds per hour) and added to the list until 95% of the total catch rate in weight for that reach was obtained. Overall, these data indicated that, in terms of biomass, the fish communities of the Illinois River waterway were dominated by silver carp, bighead carp, common carp, smallmouth buffalo, and channel catfish.

Alton (lower waterway, Illinois River). Twelve fish species accounted for 95.2% of the total catch by weight in pounds per hour ($CPUE_W$) in Alton Reach (Tables 8 and 9) in 2007. Overall $CPUE_W$ was 37.09. Silver carp $CPUE_W$ ranked highest at 15.17 (40.9% of total). Channel catfish ranked second with a $CPUE_W$ of 5.63 (15.2% of total). Bigmouth buffalo ranked third with a $CPUE_W$ of 3.34 (9.0% of total). Common carp $CPUE_W$ was 2.62 representing the lowest recorded for this species in Alton Reach in F-101-R sampling.

Table 8. Pounds of each fish species collected per hour of electrofishing ($CPUE_W$) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2007. Pounds per hour less than 0.01, but greater than zero, are indicated by 0.00.

	Reach and Hours Fished							
					Starved			Overall
	Reach 26	Alton	La Grange	Peoria	Rock	Marseilles	Dresden	CPUE
Species	1.00	5.75	5.16	7.88	2.00	2.50	2.00	26.29
Amiidae								
bowfin		0.78						0.16
Catastomidae								
bigmouth buffalo		3.34	1.89	25.86				8.85
black buffalo		0.73	2.05		1.14			0.66
golden redhorse		0.19		0.57	0.47	0.34	0.83	0.34
highfin carpsucker					0.37			0.03
northern hogsucker				0.58				0.18
quillback						0.44		0.04
river carpsucker	0.20	0.08	0.22	1.83	0.45	1.65		0.81
shorthead redhorse		0.06	0.41	0.01	0.05	0.26	0.02	0.13
silver redhorse							0.20	0.02
smallmouth buffalo	0.48		5.81	31.57	2.97	2.94	1.16	11.31
Centrarchidae								
black crappie	2.04	1.76	0.20	0.60	0.24	0.45	0.01	0.72
bluegill	4.00	0.36	0.13	2.97	0.27	1.02	5.34	1.67
bluegill x green sunfish		0.05	0.00	0.05	0.04		2.46	0.22
green sunfish	0.39	0.01	0.03	1.25	0.05	0.14	1.73	0.55
largemouth bass	1.24	0.49	0.03	3.81	3.40	2.79	22.57	3.54
longear sunfish					0.16			0.01
orange spotted sunfish	0.07	0.02	0.08	0.22		0.02	0.01	0.09
pumpkinseed				0.05	0.02	0.07	0.07	0.03
redear sunfish				0.00				0.00
rock bass				0.07	0.01	0.22	1.08	0.12
smallmouth bass	0.73	0.18		0.07	0.61	0.27	1.34	0.26
warmouth	0.06			0.01				0.01
white crappie			0.00	0.12				0.04
Clupeidae								
gizzard shad	7.15	0.43	1.33	2.57	0.12	1.04	3.22	1.76
skipjack herring			0.02	0.06				0.02
threadfin shad			0.01					0.00
Cyprinidae								
bighead carp					25.35			1.93
bluntnose minnow			0.00		0.18	0.11	0.15	0.04
bullhead minnow	0.02	0.02	0.01	0.07	0.04	0.01		0.03
central stoneroller						0.01		0.00
common carp		2.62	18.98	45.27	10.05	4.95	32.10	21.78
common carp x goldfish		0.21						0.04
emerald shiner	0.03	0.08	0.05	0.07	0.31	0.28	0.01	0.10
golden shiner				0.01			0.06	0.01
goldfish				0.08		0.18	0.88	0.11
grass carp			0.00	3.96				1.19
red shiner			0.01	0.00				0.00
river shiner		0.00	0.00					0.00
silver carp	5.41	15.17	32.77	46.30				24.08
silver chub		0.00	0.01	0.00	0.00			0.00
silverband shiner		0.01	0.00				0.01	0.00
southern redbelly dace				0.00				0.00
spotfin shiner	0.00	0.00		0.01	0.14	0.12		0.02
spottail shiner		0.00		0.02	0.02	0.01	0.00	0.01

Table 8. (continued)
Pounds of each fish species collected per hour of electrofishing (CPUEw) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2007. Pounds per hour less than 0.01, but greater than zero, are indicated by 0.00.

	Reach and Hours Fished							
					Starved			Overall
	Reach 26	Alton	La Grange	Peoria	Rock	Marseilles	Dresden	CPUE
Species	1.00	5.75	5.16	7.88	2.00	2.50	2.00	26.29
Fundulidae								
blackstripe topminnow					0.00	0.00		0.00
Gobiidae								
round goby				0.00	0.00	0.01		0.00
Hiodontidae								
goldeye		0.08						0.02
Ictaluridae								
brown bullhead				0.18				0.05
channel catfish	4.88	5.63	14.84	13.72	11.85	11.99	17.82	11.96
flathead catfish	0.71	0.53	12.05	7.23				4.82
tadpole madtom							0.00	0.00
yellow bullhead				0.04			0.39	0.04
Lepisosteidae								
shortnose gar		0.74						0.15
Moronidae								
white bass		1.44	3.12	2.63	0.10	0.69		1.81
white perch			0.04					0.01
yellow bass			0.17		0.04			0.04
yellow bass x white perch			0.01					0.00
Percidae								
logperch				0.01				0.00
mud darter		0.00						0.00
sauger		0.02	0.04					0.01
Poeciliidae								
western mosquitofish			0.01	0.01				0.00
Sciaenidae								
freshwater drum	0.09	2.09	2.48	4.60	0.33	2.60	3.00	2.83
Total pounds per hour	27.49	37.09	96.80	196.38	58.78	32.65	94.44	102.67

Table 9. Fish species ranked by relative biomass in pounds of fish collected per hour for 2007. Species were added to the list in descending order of abundance until 95% of the total catch for that reach was obtained. Percentages are in parentheses.

	Rankings by Reach					
Species	Alton	La Grange	Peoria	Starved Rock	Marseilles	Dresden
Amiidae						
bowfin	8 (2.1)					
Catostomidae						
bigmouth buffalo	3 (9.0)		4 (13.2)			
black buffalo	10 (2.0)	8 (2.1)		6 (1.9)		
golden redhorse				8 (0.8)	12 (1.1)	
quillback					11 (1.4)	
river carpsucker					6 (5.1)	
smallmouth buffalo		5 (6.0)	3 (16.1)	5 (5.1)	3 (9.0)	
Centrarchidae						
black crappie	4 (4.7)				10 (1.4)	
bluegill			10 (1.5)		8 (3.1)	4 (5.6)
bluegill x green sunfish						7 (2.6)
green sunfish						8 (1.8)
largemouth bass	12 (1.3)		9 (1.9)	4 (5.8)	4 (8.6)	2 (23.9)
smallmouth bass				7 (1.0)		9 (1.4)
Clupeidae						
gizzard shad					7 (3.2)	5 (3.4)
Cyprinidae						
bighead carp				1 (43.1)		
common carp	4 (7.1)	2 (19.6)	2 (23.1)	3 (17.1)	2 (15.2)	1 (34.0)
grass carp			8 (2.0)			
silver carp	1 (40.9)	1 (33.9)	1 (23.6)			
Ictaluridae						
channel catfish	2 (15.2)	3 (15.3)	5 (7.0)	2 (20.2)	1 (36.7)	3 (18.9)
flathead catfish	11 (1.4)	4 (12.4)	6 (3.7)			
Lepisosteidae						
shortnose gar	9 (2.0)					
Moronidae						
white bass	7 (3.9)	6 (3.2)			9 (2.1)	
Sciaenidae						
freshwater drum	5 (5.6)	7 (2.6)	7 (2.3)		5 (8.0)	6 (3.2)
Number of species accouting for 95% of total catch	12	8	10	8	12	9

La Grange (middle waterway, Illinois River). Eight fish species accounted for 95.1% of the total catch by weight in La Grange Reach (Tables 8 and 9) in 2007. Overall, $CPUE_W$ was 96.80 in La Grange Reach in 2007. Silver carp again ranked first in La Grange Reach catch by weight with a $CPUE_W$ of 32.77 (33.9% of the total). Common carp ranked second in total catch by weight in La Grange Reach with a $CPUE_W$ of 18.98 (19.6% of total). Channel catfish ranked third with a $CPUE_W$ of 14.84 (15.3% of total) and flathead catfish ranked fourth with a $CPUE_W$ of 12.05 (12.4% of the total). The $CPUE_W$ for channel catfish was the highest ever observed for La Grange Reach and the $CPUE_W$ for flathead catfish was the highest ever observed throughout the entire Illinois River waterway in F-101-R sampling. The catch by weight for largemouth bass on the La Grange Reach prior to 1996 varied, but was typically above two pounds per hour (Lerczak et al. 1993, 1994, 1995, 1996). $CPUE_W$ for largemouth bass has been below two pounds per hour for the last 11 of 12 years (1996, 1997, 1998, 1999, 2001, 2002, 2003, 2004, 2005, 2006, and 2007) and below one pound per hour since 2001 (Koel et al. 1997, 1998; Koel and Sparks, 1999; Arnold et al. 2000; McClelland and Pegg 2002, 2003, 2004, 2005; McClelland and Cook 2006; McClelland and Sass). The catch by weight for largemouth bass (0.03) in 2007 was the second lowest ever recorded in La Grange Reach.

Peoria (middle waterway, Illinois River). Ten fish species accounted for 94.4% of the total catch by weight in Peoria Reach (Tables 8 and 9). Overall, $CPUE_W$ was 196.38. The Peoria Reach collection was the highest catch by weight recorded for all reaches of the Illinois River waterway in 2007. The highest species-specific $CPUE_W$

was 46.30 for silver carp, which made up 23.6% of the total catch by weight for this reach in 2007. The $CPUE_W$ for silver carp represents the highest catch by weight ever recorded for this species in the Peoria Reach in F-101-R sampling. Common carp ranked second with a $CPUE_W$ of 45.27 (23.1% of total) representing the highest catch by weight in Peoria Reach for this species in F-101-R sampling. Smallmouth buffalo ranked third with a $CPUE_W$ of 31.57 (16.1% of total), which also represented the highest catch by weight in Peoria Reach for this species in F-101-R sampling. Channel catfish catch weights were the highest recorded for Peoria Reach for this species in F-101-R sampling. $CPUE_W$ in 2007 for channel catfish was 13.72; the previous high $CPUE_W$ for channel catfish of 9.51 was recorded in 2006 (McClelland and Sass 2007). Flathead catfish catch weights were also the highest recorded for Peoria Reach for this species in F-101-R sampling. $CPUE_W$ in 2007 for flathead catfish was 7.23; the previous high $CPUE_W$ for flathead catfish of 4.80 was recorded in 1998 (Koel and Sparks 1999).

Starved Rock (upper waterway, Illinois River). Eight fish species accounted for 95.0% of the total catch by weight in Starved Rock Reach (Tables 8 and 9). Overall, $CPUE_W$ was 58.78. The catch by weight observed in Starved Rock Reach in 2007 represented the highest $CPUE_W$ for this reach in F-101-R sampling. The highest $CPUE_W$ for any species was 25.35 for bighead carp, which made up 43.1% of the total. The 2007 catch by weight for bighead carp represented the highest ever recorded for this species throughout the Illinois River waterway and it was the first year this species has been collected in Starved Rock Reach in F-101-R sampling. Two bighead carp collected in Starved Rock Reach accounted for the total biomass. Channel catfish ranked second with a $CPUE_W$ of 11.85 (20.2% of total) representing the highest catch by weight in Starved Rock Reach for this species in F-101-R sampling. Common carp ranked third with a $CPUE_W$ of 10.05 (17.1% of total). Largemouth bass catch by weight was the highest ever recorded for this species in Starved Rock Reach in F-101-R sampling. $CPUE_W$ for largemouth bass in 2007 was 3.40; previous high catch by weight was 1.61 recorded in 1998 (Koel and Sparks 1999).

Marseilles (upper waterway, Illinois River). Twelve fish species accounted for 94.7% of the total catch by weight in Marseilles Reach (Tables 8 and 9). Overall, $CPUE_W$ was 32.65 in 2007. Channel catfish $CPUE_W$ ranked highest at 11.99 (36.7% of total), which represented the highest catch by weight ever recorded in Marseilles Reach for this species in F-101-R sampling. Common carp ranked second with a $CPUE_W$ of 4.95 (15.2% of total). Smallmouth buffalo ranked third with a $CPUE_W$ of 2.94 (9.0% of total).

Dresden (upper waterway, Des Plaines River). Nine fish species accounted for 94.8% of the total catch by weight in Dresden Reach (Tables 8 and 9). Overall, $CPUE_W$ was 94.44, representing the highest catch by weight ever observed for Dresden Reach in F-101-R sampling. The highest $CPUE_W$ for any species in Dresden Reach for 2007 was 32.10 for common carp, which made up 34.0% of the total. The catch by weight for common carp was the highest ever observed in Dresden Reach for this species in F-101-R sampling. Largemouth bass ranked second with a $CPUE_W$ of 22.57 (23.9% of total). The catch by weight observed for largemouth bass represented the highest $CPUE_W$ ever recorded for this species throughout the Illinois River waterway in F-101-R sampling. The previous high catch by weight for largemouth bass was 14.24

recorded in Dresden Reach in 2002 (McClelland and Pegg 2003). Channel catfish ranked third with a $CPUE_W$ of 17.82 (18.9% of total). This is the highest catch by weight ever recorded in Dresden Reach for channel catfish in F-101-R sampling. The catch by weight observed in Dresden Reach for bluegill was 5.34 representing the highest catch by weight ever recorded for bluegill throughout the Illinois River waterway.

Fish Health Determined by External Visual Inspection.

Sixteen fishes were observed to have externally visible abnormalities in 2007. Abnormalities were found on fishes in all reaches except La Grange. Abnormalities recorded ranged from fin and barbel erosion to external injuries. Fin infections were observed on five fishes, one occurring at Brickhouse Slough on the Mississippi River and four in the upper river. A largemouth bass and smallmouth bass were observed with eye and face injuries in Dresden Reach. One largemouth bass was observed to have a side injury in Alton Reach and a smallmouth buffalo exhibited an eroded opercle in Peoria Reach.

CONCLUSIONS

Samples collected by electrofishing on the Illinois Waterway during September through October 2007 provided evidence of continued increases in fish species richness, catch rates, and low incidence of visual abnormalities. One hundred fish species and seven hybrids have been collected since William Starrett began this survey in 1957. Eighty three fish species and six hybrids have been documented by project F-101-R sampling (1989-present); 60 species and two hybrids from 14 families were collected during 26.34 h of sampling in 2007. Southern redbelly dace were collected for the first time in 2007 along the waterway; a single specimen was collected at Henry Island in Peoria Reach (middle waterway). Yellow bass x white perch hybrid was collected for the second time in F-101-R sampling; one specimen was collected at Pekin in La Grange Reach (middle waterway). Rock bass and northern hogsucker were collected for the first time in Peoria Reach in 2007. A single rock bass was collected at Lower Twin Sisters Island and five specimens of northern hogsucker were collected at Lambie's Boat Harbor. Round goby were also collected for the first time at two sites in Peoria Reach (Clark Island and Hennepin Island) and bighead carp were collected for the first time in Starved Rock Reach (upper river) at Bull's Island in 2007. These two invasive species are expanding their ranges in opposite directions along the Illinois River waterway. Round goby expansion is occurring downstream from Lake Michigan and the 2007 collections in Peoria Reach illustrate the furthest downstream collection from previous years (2004-2006). Bighead carp expansion is occurring upstream from the Mississippi River and the 2007 collections of this species in Starved Rock Reach illustrate the furtherest upstream collection from previous years (2000-2006). A single specimen each of two species, silver redhorse and tadpole madtom, were collected for the first time in Dresden Reach (upper river) at the Mouth of the Du Page River and Treat's Island, respectively.

Peoria Reach continued to produce the highest number of fish species (39) along the Illinois River waterway and the highest total catch (4,108). This was likely due, in part, to a greater number of sites in this reach, varied site types (backwater and side channel), and its position along the waterway, which included the Great Bend (above Hennepin) of the Illinois River. Peoria Reach represents a transition from a river which is constricted, has few contiguous backwaters, and is high in gradient (upper river) to a large river floodplain system with low gradient (lower river) (Sparks 1977).

Catch rates in terms of number of fish collected per hour and total catch numbers along the Illinois Waterway were the highest ever recorded for La Grange and Peoria reaches. Catches of several sportfish species in multiple reaches were at their highest in 2007. Channel catfish exhibited high catch rates for Peoria, Starved Rock, Marseilles, and Dresden reaches. Smallmouth bass catches were at their highest for Peoria and Starved Rock reaches. Largemouth bass catches were at their highest for Dresden Reach. Pumpkinseed catches in Marseilles Reach and rock bass catches in Dresden Reach were the highest ever recorded for these species throughout the entire river in F-101-R sampling. Increased catches of individual sportfish species may be a result of numerous factors, many of which may be difficult to identify, but may be indicative of improved water quality conditions, coherent timing of hydrological events (flooding), and habitat improvements.

The catch in weight of fishes collected was again highest in Peoria Reach, where $CPUE_W$ was 196.38. Fish species accounting for this high catch in weight were silver carp, common carp, smallmouth buffalo, and channel catfish. Several sportfish species catches in terms of relative biomass were at their highest in 2007. Channel catfish catch in weight was the highest ever observed for La Grange, Peoria, Starved Rock, Marseilles, and Dresden reaches. Flathead catfish catch in weight was the highest ever observed for Peoria Reach and the catch in weight recorded for this species in La Grange Reach was the highest ever observed throughout the Illinois River waterway. Largemouth bass catch in weight was the highest ever observed for Starved Rock

Reach and the catch in weight recorded for this species in Dresden Reach was the highest ever observed throughout the Illinois River waterway. Bluegill catch in weight in Dresden Reach was also the highest ever observed throughout the Illinois River waterway. Non-native fish species continued to have a major role in relative biomass catches in the Illinois River waterway. Common carp, silver carp, bighead carp, and grass carp combined to produce 1284.7 pounds of the 2676.8 (48.0%) total pounds collected on the Illinois River waterway. Silver carp relative biomass collections continue to increase in the lower and middle river. The catch in weight of silver carp was the highest recorded for this species in Peoria Reach. Since their first collection in Alton Reach in 2001, silver carp biomass has increased to become the dominant species by weight for the Illinois Waterway (although only collected in the lower and middle waterway reaches, ranking 1st in all three reaches in 2007) with a total of 628.9 pounds collected in 2007.

Of the 2,704.3 total pounds of fish collected during our 2007 survey, 2,087.7 pounds (77.2%) were collected from the middle river. The upper waterway produced 388.1 pounds (14.4%) while the lower waterway produced 201.0 pounds (7.4%). Although these catches may be reflective of higher productivity of the middle Illinois Waterway floodplain ecosystem, a greater number of collections in this section may likely play a role.

Sport fishes were collected throughout the waterway in 2007, although catch rate in number and weight varied among reaches. For channel catfish, we usually collect more individuals per hour in Alton Reach (lower waterway) than in the middle or upper waterway reaches. However, La Grange Reach produced the greatest catch of channel catfish in number over all reaches. In terms of catch in weight for channel catfish, the lower and middle waterway reaches usually produced the highest pounds per hour. In 2007, Dresden Reach exhibited the highest $CPUE_W$ of channel catfish at 17.82 pounds per hour. White bass were most abundant and provided the highest $CPUE_W$ in the middle waterway. Black crappie was most abundant and provided the highest catches by weight in the lower waterway. Bluegill $CPUE_N$ and $CPUE_W$ was greatest in Dresden Reach of the upper waterway. Largemouth bass $CPUE_N$ and $CPUE_W$ was also highest in Dresden Reach in 2007. As in previous years of project F-101-R sampling, we collected low numbers of sauger. Smallmouth bass, which were usually found in low numbers, were again collected in every reach of the upper waterway, in the Peoria Reach of the middle waterway, and Alton Reach of the lower waterway. A total of 16 fishes had externally visible abnormalities. Seven (43.7%) were sediment-contact fishes. The highest incidence occurred in the upper waterway where 0.5% of all fishes exhibited visual abnormalities. In the lower and middle waterway, only 0.2% and 0.03% fishes, respectively, exhibited abnormalities.

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APPENDIX A. Fish species collected during Long-term Monitoring of the Illinois Waterway, 1957-2007. Common names marked by an asterisk indicate species that were collected from 1989 through 2007 during federal aid project F-101-R. Common and scientific names are from Robins et al. (1991) and Cross et al. (1995). Habitat associations are based on behavioral descriptions from Pflieger (1975), Cross et al. (1995) and communications with INHS fisheries biologists.

Family Name	Common Name	Scientific Name	Habitat Association (B=benthic)
Lepisosteidae	longnose gar*	*Lepisosteus osseus*	
	shortnose gar*	*Lepisosteus platostomus*	
	spotted gar*	*Lepisosteus oculatus*	
Amiidae	bowfin*	*Amia calva*	
Hiodontidae	goldeye*	*Hiodon alosoides*	
	mooneye*	*Hiodon tergisus*	
Anguillidae	American eel	*Anguilla rostrata*	
Clupeidae	gizzard shad*	*Dorosoma cepedianum*	
	skipjack herring*	*Alosa chrysochloris*	
	threadfin shad*	*Dorosoma petenense*	
Cyprinidae	bighead carp*	*Hypophthalmichthys nobilis*	
	bigmouth shiner*	*Notropis dorsalis*	B
	blacknose dace*	*Rhinichthys atratulus*	B
	bluntnose minnow*	*Pimephales notatus*	
	bullhead minnow*	*Pimephales vigilax*	
	central stoneroller*	*Campostoma anomalum*	B
	common carp*	*Cyprinus carpio*	B
	common carp x goldfish*	*Cyprinus carpio x Carassius aurtatus*	B
	common shiner*	*Luxilus cornutus*	
	creek chub*	*Semotilus atromaculatus*	
	emerald shiner*	*Notropis atherinoides*	
	fathead minnow*	*Pimephales promelas*	
	ghost shiner	*Notropis buchanani*	
	golden shiner*	*Notemigonus crysolucas*	
	goldfish*	*Carassius auratus*	B
	grass carp*	*Ctenopharyngodon idella*	
	hornyhead chub	*Nocomis biguttatus*	
	Mississippi silvery minnow	*Hybognathus nuchalis*	B
	pugnose minnow	*Opsopoeodus emiliae*	
	redfin shiner	*Lythrurus umbratilis*	
	red shiner*	*Cyprinella lutrensis*	
	ribbon shiner*	*Lythrurus fumeus*	
	river shiner*	*Notropis blennius*	
	sand shiner*	*Notropis stramineus*	
	silverband shiner*	*Notropis shumardi*	
	silver carp*	*Hypophthalmichthys molitrix*	
	silver chub*	*Hybopsis storeriana*	B
	silverjaw minnow	*Notropis buccatus*	B
	southern redbelly dace*	*Phoxinus erythrogaster*	
	spotfin shiner*	*Cyprinella spiloptera*	
	spottail shiner*	*Notropis hudsonius*	
	steelcolor shiner	*Cyprinella whipplei*	
	striped shiner*	*Luxilus chrysocephalus*	
	suckermouth minnow*	*Phenacobius mirabilis*	B
Catostomidae	bigmouth buffalo*	*Ictiobus cyprinellus*	B
	black buffalo*	*Ictiobus niger*	B
	black redhorse	*Moxostoma duzuesnei*	B
	golden redhorse*	*Moxostoma erythrurum*	B
	highfin carpsucker*	*Carpoides velifer*	B
	northern hogsucker*	*Hypentelium nigricans*	B
	quillback*	*Carpoides cyprinus*	B
	river carpsucker*	*Carpoides carpio*	B
	river redhorse	*Moxostoma carinatum*	B
	shorthead redhorse*	*Moxostoma macrolepidotum*	B
	silver redhorse*	*Moxostoma anisurum*	B
	smallmouth buffalo*	*Ictiobus bubalus*	B
	white sucker*	*Catostomus commersoni*	B

Appenidix A Continued.

Family Name	Common Name	Scientific Name	Habitat Association (B=benthic)
Ictaluridae	black bullhead*	*Ameiurus melas*	B
	blue catfish	*Ictalurus furcatus*	B
	brown bullhead*	*Ameiurus nebulosus*	B
	channel catfish*	*Ictalurus punctatus*	B
	flathead catfish*	*Pylodictis olivaris*	B
	freckled madtom*	*Noturus nocturnus*	B
	tadpole madtom*	*Noturus gyrinus*	B
	white catfish	*Ameiurus catus*	B
	yellow bullhead*	*Ameiurus natalis*	B
Esocidae	grass pickerel*	*Esox americanus vermiculatus*	
	nothern pike	*Esox lucius*	
Salmonidae	rainbow trout	*Oncoryhnchus mykiss*	
Percopsidae	trout-perch	*Percopsis omiscomaycus*	B
Fundulidae	banded killifish*	*Fundulus diaphanus*	
	blackstripe topminnow*	*Fundulus notatus*	
Poeciliidae	western mosquitofish*	*Gambusia affinis*	
Atherinidae	brook silverside*	*Labidesthes sicculus*	
Moronidae	striped bass	*Morone saxatilis*	
	striped bass x white bass*	*Morone saxatilis x M. chrysops*	
	white bass*	*Morone chrysops*	
	white perch*	*Morone americana*	
	yellow bass*	*Morone mississippiensis*	
	yellow bass x white perch*	*Morone mississippiensis x M. americana*	
Centrarchidae	black crappie*	*Pomoxis nigromaculatus*	
	bluegill*	*Lepomis macrochirus*	
	bluegill x green sunfish*	*Lepomis macrochirus x L. cyanellus*	
	green sunfish*	*Lepomis cyanellus*	
	largemouth bass*	*Micropterus salmoides*	
	longear sunfish*	*Lepomis megalotis*	
	orangespotted sunfish*	*Lepomis humilis*	
	orangespotted sunfish x bluegill*	*Lepomis humilis x L. macrochirus*	
	orangespotted sunfish x green sunfish*	*Lepomis humilis x L. cyanellus*	
	pumpkinseed*	*Lepomis gibbosus*	
	pumpkinseed x green sunfish*	*Lepomis gibbosus x L. cyanellus*	
	redear sunfish*	*Lepomis microlophus*	
	rock bass*	*Ambloplites rupestris*	
	smallmouth bass*	*Micropterus dolomieu*	
	spotted sunfish*	*Lepomis punctatus*	
	warmouth*	*Lepomis gulosus*	
	white crappie*	*Pomoxis annularis*	
Percidae	bluntnose darter	*Etheostoma chlorosomum*	B
	johnny darter*	*Etheostoma nigrum*	B
	logperch*	*Percina caprodes*	B
	mud darter*	*Etheostoma asprigene*	B
	sauger*	*Stizostedion canadense*	
	slenderhead darter*	*Percina phoxocephala*	B
	walleye*	*Stizostedion vitreum*	
	yellow perch*	*Perca flavescens*	
Sciaenidae	freshwater drum*	*Aplodinotus grunniens*	B
Gobiidae	round goby*	*Neogobius melanostomus*	B

APPENDIX B. Species richness (S) at Long-term Illinois River Fish Population Monitoring (F-101-R) sites.

Description	Site #	Reach	Low S	(year)	High S	(year)
Treats Island	279.8	3	10	(2003)	20	(2007)
Du Page River	277.4	3	11	(1999, 2000)	20	(2006)
Waupecan Island	260.6	4	11	(1996)	22	(2007)
Johnson Island	249.6	4	6	(1993)	16	(1995)
Ballards Island	248.0	4	10	(1991)	22	(2007)
Bulls Island Bend	241.5	5	8	(1990)	25	(2007)
Bulls Island	240.8	5	8	(1990, 96, 99)	21	(2007)
Clark Island	215.3	6	11	(1990)	24	(2007)
Hennepin	207.6	6	2	(1990)	27	(2007)
Upper Twin Sister	203.3	6	8	(1990)	22	(2001)
Lower Twin Sister	202.8	6	7	(1992)	22	(2007)
Henry Island	193.8	6	12	(1991)	24	(2005)
Chillicothe	180.6	6	14	(1989,91,92,96)	26	(2006)
Lambie's Boat Harbor	170.3	6	9	(1989)	22	(2006)
Lower Peoria Lake	163.3	6	10	(1989)	20	(2005)
Pekin	155.1	7	6	(1992)	19	(2005)
Turkey Island	148.0	7	8	(2004)	18	(2007)
Upper Bath Chute	113.0	7	12	(1994)	22	(2001, 2007)
Lower Bath Chute	107.1	7	9	(1992)	19	(2001)
Sugar Creek Island	95.1	7	10	(1989, 1999, 2003)	20	(2005)
Grape-Bar Islands	86.5	7	7	(1989)	23	(1994)
Moore's Towhead	75.3	8	6	(2002)	17	(2004, 2005)
Big Blue Island	58.3	8	9	(1990)	20	(2005, 2006)
Crater-Willow Islands	30.0	8	11	(2003)	19	(2007)
Hurricane Island	26.8	8	11	(1990, 1999, 2004)	20	(1997)
Dark Chute	24.7	8	11	(1994, 2004)	18	(2006)
Mortland Island	19.0	8	10	(2003)	19	(2006)
Brickhouse Slough	0.0	26	10	(1990)	20	(2005)

[1]Sites 0.0-215.3 were not sampled during 1993 (n=18 years) (sites 240.8-279.8 n=19 years).

APPENDIX C. Total catch (C) at Long-term Illinois River Fish Population Monitoring (F-101-R) sites.

Description	Site #	Reach	Low C	(year)	High C	(year)
Treats Island	279.8	3	55	(1996)	586	(1995)
Du Page River	277.4	3	88	(1991)	614	(1995)
Waupecan Island	260.6	4	35	(1996)	266	(2006)
Johnson Island	249.6	4	15	(2003)	224	(2007)
Ballards Island	248.0	4	34	(1991)	492	(2005)
Bulls Island Bend	241.5	5	36	(1990)	897	(1995)
Bulls Island	240.8	5	32	(1990)	919	(2006)
Clark Island	215.3	6	45	(1991)	396	(1997)
Hennepin	207.6	6	2	(1990)	523	(2005)
Upper Twin Sister	203.3	6	33	(1990)	222	(2007)
Lower Twin Sister	202.8	6	33	(1990)	218	(2001)
Henry Island	193.8	6	54	(1990)	474	(1996)
Chillicothe	180.6	6	80	(1992)	331	(2007)
Lambie's Boat Harbor	170.3	6	47	(2003)	2293	(2007)
Lower Peoria Lake	163.3	6	83	(1991)	507	(2005)
Pekin	155.1	7	22	(1992)	524	(1996)
Turkey Island	148.0	7	30	(1992)	165	(1995)
Upper Bath Chute	113.0	7	80	(2002, '03)	581	(2007)
Lower Bath Chute	107.1	7	57	(1992)	701	(2007)
Sugar Creek Island	95.1	7	37	(2003)	238	(1996)
Grape-Bar Islands	86.5	7	42	(1990)	524	(1994)
Moore's Towhead	75.3	8	31	(2003)	263	(2005)
Big Blue Island	58.3	8	25	(1990)	240	(2005)
Crater-Willow Islands	30.0	8	57	(2003)	207	(1994)
Hurricane Island	26.8	8	50	(1999)	304	(2005)
Dark Chute	24.7	8	47	(2004)	237	(1991)
Mortland Island	19.0	8	28	(2004)	195	(1991)
Brickhouse Slough	0.0	26	53	(1996)	267	(2006)

[1]Sites 0.0-215.3 were not sampled during 1993 (n=18 years) (sites 240.8-279.8 n=19 years).

Appendix D (Job 5). Publications, reports, and presentations that resulted from research conducted during segments 6-15 of project F-101-R, the Long-term Illinois River Fish Population Monitoring Program (funded under Federal Aid in Sportfish Restoration Act, P.L. 81-681, Dingell-Johnson, Wallup-Breaux).

I. Publications

Irons, K.S., G.G. Sass, M.A. McClelland, and J.D. Stafford. 2007. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carps in the Illinois River, USA: Evidence for Competition and Reduced Fitness? Journal of Fish Biology 71 (Supplement D), 258-273.

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<u>II. Essays</u>

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Kevin S. Irons, Greg G. Sass, Thad R. Cook, T. Mathew O'Hara, Michael A. McClelland, Nerissa N. Michaels, and Mathew R. Stroub. An Overview of the Illinois River Biological Station's Asian Carp's Research. Presented at the 46th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, IL, February 26-28, 2008.

Michael A. McClelland, Greg G. Sass, Thad R. Cook, Kevin S. Irons, T. Matt O'Hara, Camilla S. Smith, Nerissa N. Michaels, and Mathew R. Stroub. Fifty Years of the Long-Term Illinois River Fish Population Monitoring Program, 1957-2007. Presented at the 46th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, IL, February 26-28, 2008.

Kevin S. Irons, Greg G. Sass, Michael A. McClelland, and Joshua D. Stafford. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carps in the Illinois River, USA: Evidence for Competition and Reduced Fitness? Fisheries Society of the British Isles International Symposium: Non-native Fishes: Integrated Biology of Establishment Success and Dispersal. University of Exeter, Exeter, U.K., July 23-27.

Kevin S. Irons, Greg G. Sass, Michael A. McClelland, and Joshua D. Stafford. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carp in the Illinois River: Evidence for Competition and Reduced Fitness? Presented at the 39th Annual Meeting of the Mississippi River Research Consortium, La Crosse, WI, April 12-13, 2007.

Michael A. McClelland and Greg G. Sass. Trends in Largemouth Bass and Bluegill Populations Among the Upper and Lower Illinois River, 1957-2006. Presented at the 39th Annual Meeting of the Mississippi River Research Consortium, La Crosse, WI, April 12-13, 2007.

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Koel, T.M., T.R. Cook, and K.S. Irons. Criteria for biota-friendly operations of the Peoria and La Grange locks and dams, Illinois River Waterway. 61st Midwest Fish and Wildlife Conference, Chicago, Illinois December 5-8, 1999.

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Koel, T.M. Changes in fish community structure: effects of hydrological variability in the Upper Mississippi River System. Presented to the Illinois Natural History Survey, Center for Aquatic Ecology, Havana Field Station Director Search Committee and Senior Staff, March 24, 1999.

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Sparks, R.E. Large river-floodplain ecosystems of the Midwest: status, trends, and management needs. Presented at the U.S. Environmental Protection Agency's "Ecological Seminar Series" held in Chicago, Illinois, 14 March.

IV. Poster Presentations (presenter in bold)

Koel, T.M. and R.E. Sparks. The Long-term Illinois River Fish Population Monitoring Program. National Meeting of the Ecological Society of America, Spokane, Washington, August 10-14, 1998.

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Lerczak, T.V., R.E. Sparks, and K.D. Blodgett. Long-term trends (1959-1994) in fish populations of the Illinois River. Poster presented at the Illinois State Academy of Science Annual Meeting, Charleston, Illinois, 6 October 1995.

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Michael A. McClelland, Greg G. Sass, Thad R. Cook, Kevin S. Irons, T. Matt O'Hara, Camilla S. Smith, Nerissa N. Michaels, and Mathew R. Stroub. Fifty Years of the Long-Term Illinois River Fish Population Monitoring Program, 1957-2007. Presented at the 46th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, IL, February 26-28, 2008.

Pegg, M.A. and M.A. McClelland. Long-term fish population trends along the Illinois River. Poster presented at the 63rd Midwest Fish and Wildlife Conference, Des Moines, Iowa, December, 2001.

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Lerczak, T.V. Seminar on Illinois River environmental issues. Conducted for Biology 140 (Human Ecology) at Spoon River College, 27 June 1994.

Lerczak, T.V. A photo trip up the Illinois River. After dinner talk presented to Havana Rotary Club, Havana, Illinois, 17 April 1995.

Blodgett, K.D. Ecosystem management for the Illinois River: can biological integrity be restored? Invited lecture for Earth Day celebration at Spoon River College, Canton, Illinois, 19 April 1995.

McClelland, M.A. The Long Term Illinois River Fish Population Monitoring Program. After dinner talk presented to Central Christian Men's 10th Annual Fish Fry, August 2003.

VI. Data Requests

1. Sam Cull, City of Peru, Electrical Department, Peru, Illinois
2. Stanley and Associates, Muscatine, Iowa
3. U.S. Army Corps of Engineers, Rock Island, Illinois
4. Shelly Miller, Aquatic Ecologist, The Nature Conservancy, Peoria, Illinois
5. K. Douglas Blodgett, Project Manager, The Nature Conservancy, Havana, Illinois
6. Kevin Irons, Fishery Biologist, LTRMP, Havana, Illinois
7. Matt O'Hara, Fishery Biologist, LTRMP, Havana, Illinois

8. Scott Langloss, Writer for Adventure Sports Outdoors
9. Richard Sparks, Director of Research National Great Rivers Research & Education Center
10. Jim Mick, Illinois Department of Natural Resources
11. James B. McLaren, ASA Analysis & Communication, Inc.
12. Ximing Cai, University of Illinois
13. Rob Maher, Illinois Department of Natural Resources
14. Karen Haggerty, U.S. Army Corps of Engineers
15. Mike Kacinski, EA Engineering

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

ATTACHMENT 4

The Long-Term Illinois River Fish Population Monitoring Program, Project F-101-R-19, Annual Report to the Illinois Department of Natural Resources by Michael A. McClelland and Greg G. Sass, INHS Technical Report 2009 (7).

ILLINOIS NATURAL HISTORY SURVEY

T E C H N I C A L   R E P O R T

THE LONG-TERM ILLINOIS RIVER FISH POPULATION MONITORING PROGRAM

Project F-101-R-20

Annual Report to the Illinois Department of Natural Resources

Michael A. McClelland and Greg G. Sass

Illinois River Biological Station
704 North Schrader Avenue
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Illinois Natural History Survey

INHS Technical Report 2009(7)
Date of issue: March 16, 2009

The Long-Term Illinois River Fish Population Monitoring Program

F-101-R-20

Annual Report

Michael A. McClelland and Greg G. Sass

Illinois River Biological Station
Illinois Natural History Survey
Institute of Natural Resource Sustainability
University of Illinois
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March 16, 2009

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DISCLAIMER

The findings, conclusions, and views expressed herein are those of the researchers and should not be considered as the official position of the United States Fish and Wildlife Service or the Illinois Department of Natural Resources.

ACKNOWLEDGMENT OF SUPPORT

The Long-term Illinois River Fish Population Monitoring Program (F-101-R) is supported by the Federal Aid in Sport Fish Restoration Act (P.L. 81-6814, Dingell-Johnson/Wallop-Breaux).

EXECUTIVE SUMMARY

Between 21 August and 20 October 2008, 25 sites on the Illinois River waterway and one site in Reach 26 of the Mississippi River were electrofished to monitor fish communities. A total of 8,171 fishes representing 62 species (plus one hybrid) from 15 families were collected during 24.68 hours of sampling. Collections made in 2008 indicated continued high catches of gizzard shad, emerald shiner, and bluegill throughout most of the Illinois River waterway. Two new fish species were collected for the first time during project F-101-R. Blackside darter and longnose dace were each collected in the upper river. Single specimens of blackside darter were collected from Bull's Island Bend (RM 241.5) in Starved Rock Reach and Waupecan Island (RM 260.6) in Marseilles Reach. Two specimens of blackside darter were collected from Treat's Island (RM 279.8) in Dresden Reach. Two specimens of longnose dace were also collected at Waupecan Island. Several fish species were collected for the first time within a given river reach in 2008. A single specimen of bighead carp was collected for the first time at Brickhouse Slough on the Mississippi River. A single specimen of redear sunfish was collected at Crater-Willow Islands (RM30.0) in Alton Reach. Two new species were collected in La Grange Reach; a single pumpkinseed was collected at Pekin (RM 155.1) and two specimens of bowfin were collected at Lower Bath Chute (RM 107.1). Two specimens of blackstripe topminnow were collected for the first time in Peoria Reach at Hennepin Island (RM 207.6). Along with blackside darter and longnose dace, two additional fish species were collected in Marseilles Reach. A single specimen of mud darter and two specimens of brook silverside were also collected at Waupecan Island. A single logperch was collected for the first time in Dresden Reach at the Mouth of the DuPage River (RM 277.4). Gizzard shad were the most abundant species collected throughout the waterway in 2008 with 1,802 fish collected comprising 22.1% of the total catch. The sample from Lambie's Boat Harbor (RM 170.3, Peoria Reach) yielded the highest collection of total fish (1,375, 16.8% of the total collection), while the sample from Turkey Island (RM 148.0) produced the lowest total fish (58, 0.07% of the total collection). Fish species richness at sites ranged from 27 at Clark Island (RM 215.3, Peoria Reach) to 12 species at Moore's Towhead (RM 75.3, Alton Reach) and Turkey Island. Fish species richness of the lower, middle, and upper waterway was 24, 49, and 42, respectively. Cyprinid catches continued to remain relatively high in the upper waterway, with bluntnose minnow being the most abundant (429 total fish), making up 17.9% of the total upper waterway catch. Bluntnose minnow, emerald shiner and spotfin shiner together totaled 1,223 fish comprising 51.1% of the upper waterway catch. Important sport fish species such as bluegill, largemouth bass, and channel catfish were collected in all six waterway reaches in 2008. Bluegill catch per unit effort in number of fish collected per hour ($CPUE_N$) ranged from 169.50 in Dresden Reach to 12.76 in Alton Reach. Largemouth bass $CPUE_N$ ranged from 25.50 in Dresden Reach to 4.50 in Starved Rock Reach. Channel catfish $CPUE_N$ ranged from 20.78 in La Grange Reach to 2.07 in Marseilles Reach. In terms of pounds of fish collected per hour ($CPUE_W$), the collection from Peoria Reach yielded the highest biomass at 140.4 pounds per hour while the collection from Marseilles Reach yielded the lowest biomass at 38.3 pounds per hour. Common carp biomass ranked first over all reaches at 27.1 pounds per hour, comprising 28.6% of the total biomass. Common carp also ranked first in $CPUE_W$ for Alton, La Grange, Peoria, Starved Rock, and Marseilles reaches and second in $CPUE_W$ in Dresden Reach. Silver carp were only collected in three reaches of the waterway yet catch in weight for silver carp ranked second over all reaches with a $CPUE_W$ of 16.19. Catch in weight for two sport fish species, channel catfish and bluegill, were the highest ever observed in a given reach. A high $CPUE_W$ of 23.48 was observed for channel catfish in Alton Reach and a high $CPUE_W$ of 8.31 was observed for bluegill in Dresden Reach.

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[a]Job numbers and titles refer to the F-101-R-20 annual work plan dated January 2008

ACKNOWLEDGMENTS

Project F-101-R is supported by the Federal Aid to Sportfish Restoration Act (P.L. 81-681, Dingell-Johnson/Wallop-Breaux), with funds administered by the U.S. Fish and Wildlife Service and the Illinois Department of Natural Resources (IDNR). Mr. Larry Dunham (IDNR), Dr. Brian Anderson, Chief of the Illinois Natural History Survey (INHS), and Dr. Michael Douglas, Director of the Division of Ecology and Conservation Sciences (INHS) provided administrative support. Mrs. Cammy Smith of the Illinois River Biological Station at Havana provided clerical, data entry and data verification support. Mr. Thad Cook, Mr. Matt O' Hara, Ms. Nerissa Michaels, Mr. Brett Feger, and Mr. Matt Stroub assisted with field collections. This survey was originally conceived and initiated in 1957 by the late Dr. William C. Starrett.

INTRODUCTION

This report presents a summary of data collected in 2008 during segment 20 of federal aid project F-101-R, The Long-term Illinois River Fish Population Monitoring Program. Previous summaries of the long-term data set, begun in 1957, were given by Sparks and Starrett (1975), Sparks (1977), Sparks and Lerczak (1993), Lerczak and Sparks (1994), Lerczak et al. (1994), Koel and Sparks (1999), and McClelland and Pegg (2004). The annual reports for project F-101-R will continue to build upon previously collected data with major analyses of the long-term data set scheduled at five-year intervals. The next summary is due at the end of segment 20. The format used in this report is patterned after previous annual reports of this project (Lerczak et al. 1993, 1994, 1995, and 1996; Koel et al. 1997 and 1998; Koel and Sparks 1999; Arnold et al. 2000; McClelland and Pegg 2001, 2002, 2003, 2004, 2005; McClelland and Cook 2006; McClelland and Sass 2007; McClelland and Sass 2008) to allow for easy comparisons of data among years.

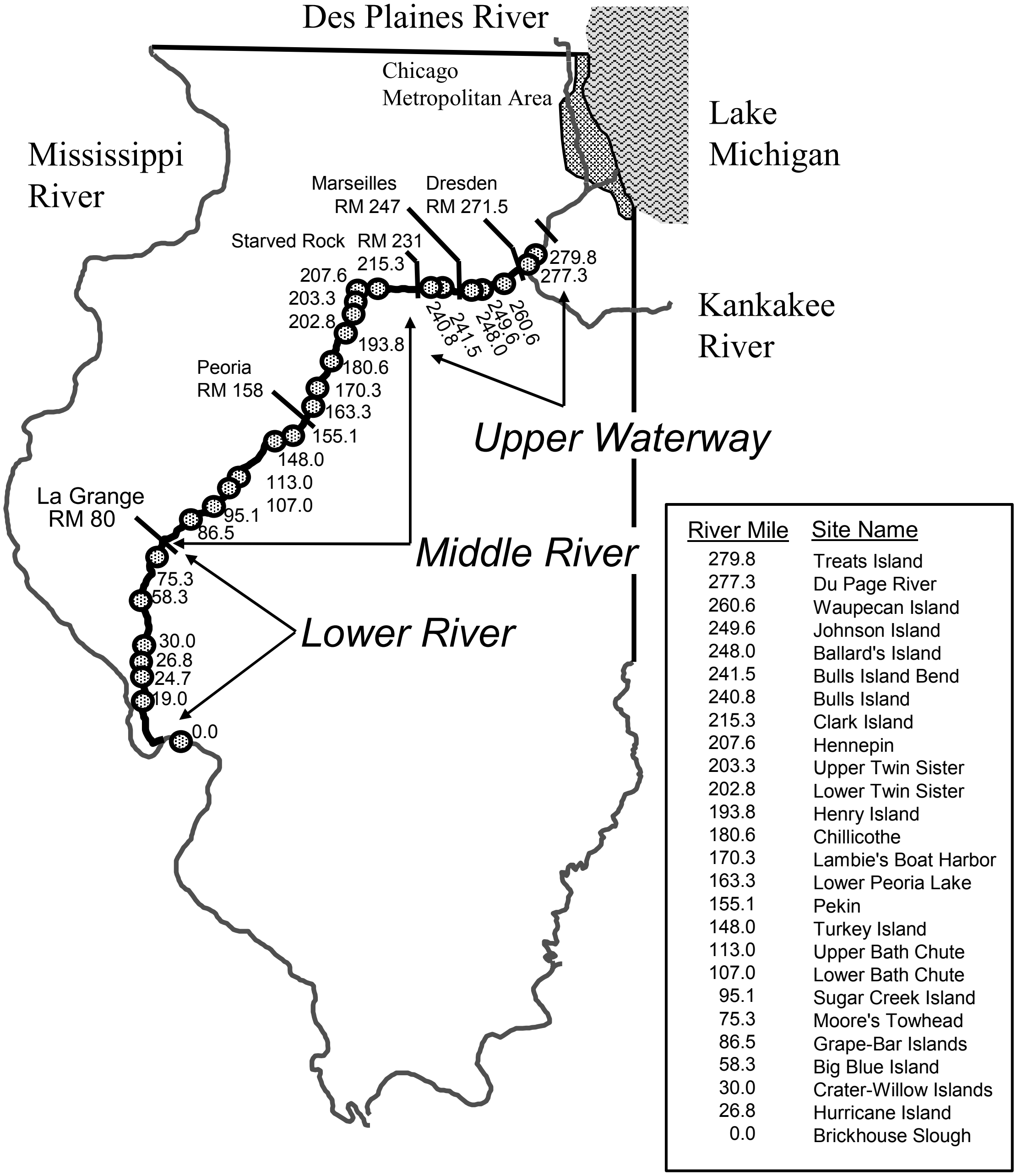
STUDY AREA AND METHODS

Twenty-seven sites have been sampled annually for fish at fixed locations along the Illinois Waterway. Twenty-six of the site locations were defined by Sparks and Starrett (1975) and Lerczak et al. (1994). In 1999, a twenty-seventh site was added at Moore’s Towhead in Alton Reach, Illinois River mile 75.3, to more closely monitor fish communities near The Nature Conservancy’s (TNC) floodplain restoration project (Spunky Bottoms Merwin Preserve). Twenty-five of the sites were located on the Illinois River, with two additional sites on the lower Des Plaines River. The Des Plaines River, along with the Illinois River forms part of the Illinois Waterway. One additional site was located on the Mississippi River (Figure 1). Seventeen of the sites were in side channels; the remaining sites were in other habitats, including the main channel border, or in a combination of habitat types (see Lerczak et al., 1994). In 2008, a total of 25 sites were sampled.

Following water quality measurements (e.g., dissolved oxygen) at each site, fish populations were sampled by electrofishing from a 16-ft (5-m) aluminum boat using a 3000-watt, three-phase AC generator. Sampling at each site typically lasted one hour. Stunned fish were gathered with a dip net (1/4-in [0.64-cm] mesh) and stored in an oxygenated livewell until sampling was completed. Fish were then identified to species, measured (total length and weight), inspected for externally visible abnormalities, and returned to the water. Additional details on the electrofishing method and equipment were given by Lerczak et al. (1994).

DATA ANALYSIS (Job 4)

For each site, the number of individual fish and total weight (pounds) were tallied for each species. Fish catch rates were quantified as the number of individuals collected per hour of electrofishing ($CPUE_N$) and as weight in pounds collected per hour of electrofishing ($CPUE_W$). Catch data, both the number of individuals and pounds collected per sample and hour, were summarized and reported by collection site. Data from sites was also grouped into reaches defined by navigation dams (Figure 1) as follows: Alton Reach, river mile (RM) 0-80; La Grange Reach, RM 80-158; Peoria Reach, RM 158-231; Starved Rock Reach, RM 231-247; Marseilles Reach, RM 247-271.5; and Dresden Reach, RM 271.5-286 on the Des Plaines River. Data from



River Mile	Site Name
279.8	Treats Island
277.3	Du Page River
260.6	Waupecan Island
249.6	Johnson Island
248.0	Ballard's Island
241.5	Bulls Island Bend
240.8	Bulls Island
215.3	Clark Island
207.6	Hennepin
203.3	Upper Twin Sister
202.8	Lower Twin Sister
193.8	Henry Island
180.6	Chillicothe
170.3	Lambie's Boat Harbor
163.3	Lower Peoria Lake
155.1	Pekin
148.0	Turkey Island
113.0	Upper Bath Chute
107.0	Lower Bath Chute
95.1	Sugar Creek Island
75.3	Moore's Towhead
86.5	Grape-Bar Islands
58.3	Big Blue Island
30.0	Crater-Willow Islands
26.8	Hurricane Island
0.0	Brickhouse Slough

Figure 1. Map of the Illinois River waterway illustrating the three segments of the Illinois River Waterway with sites sampled by electrofishing to monitor fish communities in 2008.

reaches was also combined into three groups; lower (Alton Reach), middle (La Grange and Peoria reaches), and upper (Starved Rock, Marseilles, and Dresden reaches) Illinois Waterway segments defined by their location along the river (waterway) and by the amount of off-channel habitat accessible to fish per unit length of river (Figure 1; Lerczak et al. 1994). Lerczak et al. (1994, 1995, and 1996) found that river fish communities of the three segments differed substantially enough to give segment designations biological meaning.

RESULTS AND DISCUSSION (Job 5)

All equipment was tested and repaired as necessary before the fish sampling season began and staff were given a review in safety procedures and electrofishing methods **(Job 1).**

A total of 26 sites were sampled between 21 August and 20 October 2008 **(Job 2)**; two sites were unable to be sampled due to high water conditions. River levels exceeded water level criteria at Dark Chute (RM 24.7) and Mortland Island (RM 19.0) in Alton Reach during the sampling period. Total electrofishing time for sites sampled was 24.68 h (Table 1). Collected data were entered into Microsoft ACCESS 2000 and verified against original field data sheets until no errors were detected **(Job 3)**. The original data sheets from 2008 sampling and all of the other original data sheets of this project (1957-2008) are stored in flame-resistant cabinets at the Illinois River Biological Station at 704 N. Schrader Avenue, Havana **(Job 3)**.

Table 1. Station information and characteristics during sampling in 2008. All stations, except where noted, are on the Illinois River and are listed in downstream-to-upstream order. Site miles are the average river mile and refer to Figure 1.

Sampling		Site		Sample river mile			End time	Duration	Temp (°F)		DO		Secchi	Cond.	Volts	Vel.	Depth[b] (ft)		Stage[c]
Order	Date	Mile[a]	Name	lower	upper	mean	(CST)	(h)	air	water	(ppm)	(% Sat.)	(cm)	(umhos)		(ft/s)	min	max	(ft)
Reach 26, Mississippi River																			
22	8-Oct	0.0	Brickhouse Slough[d]	204.9	205.3	205.1	11:05	1.00	61.9	66.2	8.50	92.30%	21.0	353	225	0.01	0.5	5.5	
Alton Reach																			
10	3-Sep	26.8	Hurricane Island	27.0	27.9	27.5	9:55	0.93	68.9	79.2	3.60	42.08%	22.0	485	220	0.06	1.0	7.0	1.99
8	28-Aug	30.0	Crater-Willow Island	29.2	30.8	30.0	9:30	1.00	79.0	80.4	5.20	67.02%	27.0	648	220	0.13	0.5	7.0	1.92
7	27-Aug	58.3	Big Blue Island	58.0	59.0	58.5	11:30	1.00	78.6	80.1	6.70	86.04%	19.0	655	220	0.15	0.5	6.0	2.14
6	27-Aug	75.3	Moore's Towhead	74.8	75.8	75.3	8:45	0.75	68.9	78.6	6.40	74.82%	26.0	652	220	0.19	0.5	6.0	2.14
La Grange Reach																			
11	8-Sep	86.5	Grape-Bar Islands	85.7	87.0	86.4	12:50	1.00	61.9	70.7	5.50	59.73%	16.0	648	220	0.56	1.0	7.0	10.51
9	2-Sep	95.1	Sugar Creek Island	94.5	95.0	94.8	11:23	1.00	87.1	82.4	5.00	69.25%	18.0	676	220	0.20	0.5	5.5	9.68
4	25-Aug	107.1	Lower Bath Chute	106.9	107.3	107.1	9:30	1.00	68.9	79.9	4.50	52.61%	17.0	655	220	0.20	0.5	7.0	6.27
3	22-Aug	113.0	Upper Bath Chute	112.8	113.2	113.0	9:06	1.00	77.0	80.6	5.00	63.26%	24.0	654	220	0.13	1.0	7.0	5.78
2	21-Aug	148.0	Turkey Island	148.0	148.3	148.2	12:30	0.58	70.3	81.7	5.90	69.95%	23.0	663	220	0.23	0.5	7.5	3.19
1	21-Aug	155.1	Pekin	154.5	155.3	154.9	10:20	1.00	68.0	80.2	7.20	83.40%	22.0	640	220	0.23	0.5	7.0	431.50
Peoria Reach																			
12	9-Sep	163.4	Lower Peoria Lake	163.5	163.6	163.6	9:15	1.00	59.3	64.9	7.20	75.97%	16.0	680	225	0.06	0.5	3.5	12.29
13	9-Sep	170.3	Lambie's Boat Harbor	170.6	170.8	170.4	12:50	1.00	70.8	68.2	9.30	110.82%	18.0	679	220	0.06	0.5	2.5	12.29
18	12-Sep	180.6	Chillicothe	180.6	181.1	180.9	10:15	1.00	70.3	71.1	6.80	80.62%	19.0	607	220	0.23	0.5	7.0	15.63
26	20-Oct	193.8	Henry Island	193.3	194.5	193.9	10:15	1.00	56.9	59.0	9.30	95.47%	42.0	660	220	0.41	0.5	7.0	15.30
25	17-Oct	202.8	Lower Twin Sister	202.4	203.2	202.8	13:40	1.00	55.2	63.0	8.40	84.54%	60.0	681	220	0.32	0.5	7.0	15.54
24	17-Oct	203.3	Upper Twin Sister	203.3	203.5	203.4	11:35	1.00	52.6	62.8	8.80	85.85%	54.0	683	220	0.29	0.5	7.0	15.54
23	17-Oct	207.7	Hennepin	207.6	208.1	207.9	9:50	1.00	49.2	62.6	8.60	80.43%	52.0	681	220	0.24	0.5	8.0	15.54
5	26-Aug	215.3	Clark Island	214.9	215.6	215.3	10:24	1.00	69.2	77.7	8.50	99.67%	33.0	708	220	0.14	0.5	6.5	10.75
Starved Rock Reach																			
15	10-Sep	240.8	Bulls Island	240.3	241.0	240.7	11:25	1.00	77.7	74.1	8.00	101.88%	52.0	621	220	0.29	0.5	7.5	459.60
14	10-Sep	241.5	Bulls Island Bend	241.1	241.6	241.4	9:30	1.00	61.1	72.7	8.00	86.12%	50.0	617	225	0.46	0.5	7.0	459.60
Marseilles Reach													32.0						
16	11-Sep	248.0	Ballards Island	247.7	248.2	248.0	10:08	1.00	70.2	73.2	7.60	90.02%	85.0	677	220	0.23	0.5	4.0	5.60
17	11-Sep	249.7	Johnson Island	249.7	249.8	249.8	11:35	0.42	74.3	73.8	7.60	93.72%	70.0	626	220	0.12	0.5	3.5	5.60
21	2-Oct	260.6	Waupecan Island	260.2	261.1	260.7	9:40	1.00	54.2	64.0	8.90	88.51%	78.0	594	225	0.46	1.0	6.0	6.27
Dresden Reach																			
19	24-Sep	277.4	Du Page River[e]	276.8	277.8	277.3	11:15	1.00	74.2	75.9	7.00	86.24%	67.0	854	215	0.05			504.50
20	24-Sep	279.9	Treats Island[e]	279.6	280.1	279.9	13:00	1.00	79.0	76.3	7.40	95.38%	60.0	852	215	0.17			504.50
Minimum								0.42	49.2	59.0	3.6	42.08%	16.0	353	215	0.01	0.5	2.5	
Maximum								1.00	87.1	82.4	9.3	110.82%	85.0	854	225	0.56	1	8.0	
Mean								0.95	67.9	73.1	7.1	81.4%	39.3	652	220	0.22	0.5	5.7	
Total time electrofished								24.68											

[a]Refers to approximate average river mile electrofished at each site, 1957-2008.

[b]Estimated during sampling.

[c]Feet above sea level or river stage (ft) at the U.S. Army Corps of Engineers river gage nearest to the sampling site.

[d]Mississippi River.

[e]Des Plaines River.

A. CONDITIONS DURING ELECTROFISHING RUNS

Sampling was conducted in full daylight between 8:45 AM and 1:40 PM central standard time (Table 1). The ranges for physical measurements collected during the 2008 sampling season were as follows: air temperature, 49.2-87.1^{o} F; water temperature, 59.0-82.4^{o} F; dissolved oxygen concentration, 3.6-9.3 ppm; secchi disk transparency, 16.0-85.0 cm; conductivity, 353-854 µhos/cm; surface velocity, 0.01-0.56 ft/s; water depth, 0.5-8.0 ft. All physical values were within the ranges expected based upon previous sampling (Lerczak et al. 1994; Koel and Sparks 1999). The 26 sites sampled were within established water temperature and river level criteria (Table 1; Lerczak et al. 1994).

B. ELECTROFISHING RESULTS

The following data summaries proceed through several levels of detail. First, data on the number of individual fish (by species) collected at each of the 26 sites are presented. Second, catch rates of the number of individuals collected per hour of electrofishing are calculated for each of the seven navigation reaches. Similar summaries are presented for fish weights. Fish common names used throughout this report follow Robins et al. (1991). Fish common and scientific names are listed in APPENDIX A.

<u>Numbers of Fish Collected</u>

We collected a total of 8,171 fishes representing 62 species (plus one hybrid) from 15 families during 24.68h of electrofishing at 25 sites on the Illinois River waterway and a single site on the Mississippi River in 2008. Gizzard shad were the most abundant species collected (1,802 total fish), representing 22.0% of the total catch. Gizzard shad were followed by bluegill (1,141, 14.0% of total), freshwater drum (732, 9.0% of total), emerald shiner (730, 8.9% of total), silver carp (478, 5.9% of total), bluntnose minnow (429, 4.1% of total), spotfin shiner (377, 4.6% of total), and largemouth bass (307, 3.8% of total). Bluegill were collected at all 26 sites sampled; common carp were collected at 25 sites; gizzard shad and largemouth bass were collected at 24 sites; channel catfish and freshwater drum were collected at 22 sites; smallmouth buffalo were collected at 21 sites. The collection from Lambie's Boat Harbor (RM 170.3, Peoria Reach) yielded the most fish (1,375, 16.8% of the total collected from 26 sites sampled), while the collection from Turkey Island (RM 148.0, La Grange Reach) yielded the least fish (58, 0.07% of the total collected from 26 sites sampled). The most fish species collected at one site was 27 obtained at Clark Island (RM 215.3) in Peoria Reach. The fewest species collected at a single site was 12 from Moore's Towhead (RM 75.3, Alton Reach) and Turkey Island.

Of the 62 fish species and one hybrid cross, 16 species (bighead carp, brook silverside, brown bullhead, golden shiner, grass pickerel, highfin carpsucker, logperch, longnose dace, mooneye, mud darter, river carpsucker, rock bass, silverband shiner, slenderhead darter, tadpole madtom, and western mosquitofish) were collected at only one site. Six fish species (black buffalo, black bullhead, bowfin, longear sunfish, redear sunfish, and round goby) were collected at only two sites. Ten fish species (bighead carp, golden shiner, grass pickerel, longnose gar, mooneye, mud darter, silverband shiner, slenderhead darter, tadpole madtom, and western mosquitofish) were represented by single individuals at sites. A maximum of two individuals were collected at sites for each of six fish species (black buffalo, brook silverside, brown bullhead, highfin carpsucker, longnose dace, and redear sunfish).

On the 25 Illinois River waterway sites sampled, we collected 8,052 fishes representing 62 species (plus one hybrid) from 15 families during 23.68 h of sampling. At Brickhouse Slough on the Mississippi River (RM 204.9), we collected 119 fishes representing 19 species from nine families (Table 2). The total number of fish species collected from Brickhouse Slough in 2008 was the third highest collection ever recorded in F-101-R sampling at this site. The highest fish species collection occurred in 2005 when 20 fish fish species were collected (McClelland and Cook 2006). A single bighead carp was collected at Brickhouse Slough in 2008 marking the first collection for this species at this site in F-101-R sampling.

On the lower Illinois River waterway, we collected 611 fishes representing 24 species from nine families (Table 2). In 2008, fish species richness ranged from 12 at Moore's Towhead (RM 75.3) to 19 at Big Blue Island (RM 58.3). Hurricane Island (RM 26.8) exhibited the highest total catch in the lower waterway with 178 total fishes.

We collected 5,048 fishes representing 49 species and one hybrid on the middle Illinois River waterway (Tables 3 and 4). The total catch for the middle river in 2008 was the second highest recorded for this region in F-101-R sampling. The six sites on La Grange Reach (RM 80-158) produced 1,603 fishes representing 37 species and one hybrid. Total fish species collections for La Grange Reach are the highest ever recorded for this reach in F-101-R sampling, while total fish numbers were the third highest ever recorded. The eight sites on Peoria Reach (RM 158-231) produced 3,445 fishes representing 42 species and one hybrid. The total fish numbers and total fish

Table 2. Number of individuals of each fish species collected on the Mississippi River (Brickhouse Slough) and the lower Illinois Waterway (Alton Reach, RM 0-80) in 2008.

		River Mile and Hours Fished					
		Miss. River	Lower Illinois River				
	Mile	0.0	26.8	30.0	58.3	75.3	Total
Species	Effort	1.00	1.00	1.00	0.93	0.75	3.68
Amiidae							
bowfin				2			2
Catostomidae							
bigmouth buffalo		2		1			1
river carpsucker			1		1		2
shorthead redhorse			1	1	3		5
smallmouth buffalo		8		3	8	3	14
Centrarchidae							
black crappie		1		2	1		3
bluegill		12	11	18	17	1	47
green sunfish		10					
largemouth bass		4	3	8	7	4	22
orange spotted sunfish		4			1		1
redear sunfish				1			1
smallmouth bass		1					
warmouth					1		1
Clupeidae							
gizzard shad		55	5	23	29	99	156
skipjack herring			1			1	2
threadfin shad		1	4	2	3		9
Cyprinidae							
bighead carp		1					
bullhead minnow		1	4		2		6
common carp		2	11	11	6	10	38
emerald shiner			3	5	1		9
silver carp		4	12	4	18	2	36
Ictaluridae							
channel catfish		6	32	17	8	12	69
flathead catfish		2	5	5	4	4	18
Lepisosteidae							
spotted gar		1	1				1
Moronidae							
white bass		1	13	6	4	6	29
Percidae							
sauger					1	5	6
Sciaenidae							
freshwater drum		3	71	18	28	16	133
Total individuals		119	178	127	143	163	611
Total species/hybrids		19/0	16/0	17/0	19/0	12/0	24/0

Table 3. Number of individuals of each fish species collected on La Grange Reach (RM 80-158) of the middle Illinois Waterway (RM 80-231) in 2008.

		River Mile and Hours Fished							
								La Grange Reach	Middle River
	Mile	86.5	95.1	107.1	113.0	148.0	155.1	Total	Total
Species	Effort	1.00	1.00	1.00	1.00	0.58	1.00	5.58	13.58
Amiidae									
bowfin				2				2	2
Catostomidae									
bigmouth buffalo			1		1		1	3	67
black buffalo		1						1	2
river carpsucker		4	3	1			1	9	22
shorthead redhorse		7	3	4	2	1	1	18	22
smallmouth buffalo		2	11	21	1	6		41	108
Centrarchidae									
black crappie		3	5	26	8			42	79
bluegill		20	21	35	45	12	11	144	647
bluegill x green sunfish				1				1	11
green sunfish		2	5	25	3		1	36	164
largemouth bass		7	7	80	29	3	8	134	195
orange spotted sunfish		30	35	14	8		2	89	237
pumpkinseed							1	1	2
warmouth				2	1			3	4
white crappie			2	2	8			12	14
Clupeidae									
gizzard shad		33	34	20	6		8	101	1376
skipjack herring		3		2				5	7
threadfin shad		29	6	17	24			76	85
Cyprinidae									
bullhead minnow		4						4	22
common carp			21	11	8	5	9	54	151
emerald shiner		13	4	3	1			21	292
goldfish				12				12	20
grass carp			1	1		1	2	5	18
red shiner		1						1	9
silver carp		4	8	10	13	1	11	47	438
silver chub		5	2					7	7
silverband shiner			1					1	1
Hiodontidae									
mooneye			1					1	1
Ictaluridae									
black bullhead				14				14	21
channel catfish		58	5	12	18	10	13	116	136
flathead catfish		5	5	7	3	1		21	27
tadpole madtom		1						1	1
Lepisosteidae									
longnose gar		1						1	1
spotted gar							1	1	1
Moronidae									
white bass		8	5	17	13	10	42	95	134
yellow bass		7	2	2				11	12
Percidae									
sauger		6	1	1		3		11	21
Sciaenidae									
freshwater drum		284	16	42	33	5	81	461	591
Total Individuals		538	205	384	225	58	193	1603	5048
Total species/hybrids		25/0	25/0	26/1	19/0	12/0	16/0	37/1	49/1

Table 4. Number of individuals of each fish species collected on Peoria Reach (RM 158-231) of the middle Illinois Waterway (RM 80-231) in 2008.

		River Mile and Hours Fished									
										Peoria Reach	Middle River
	Mile	163.3	170.3	180.6	193.8	202.8	203.3	207.6	215.3	Total	Total
Species	Effort	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	8.00	13.58
Catostomidae											
bigmouth buffalo		3	4		6	6	34	5	6	64	67
black buffalo									1	1	2
golden redhorse		1	1	1	3					6	6
highfin carpsucker									2	2	2
river carpsucker		10							3	13	22
shorthead redhorse					1			1	2	4	22
smallmouth buffalo		9	4	7	4	15	19		9	67	108
Centrarchidae											
black crappie				2		1	23		11	37	79
bluegill		230	87	85	2	2	38	10	49	503	647
bluegill x green sunfish		4	5						1	10	11
green sunfish		69	36	6	1		3	7	6	128	164
largemouth bass		18	16	20			1	1	5	61	195
orange spotted sunfish		21	26	13	9	2	9	63	5	148	237
pumpkinseed							1			1	2
smallmouth bass			1	2		1			3	7	7
warmouth							1			1	4
white crappie		1					1			2	14
Clupeidae											
gizzard shad		55	554	10	8	7	2	105	534	1275	1376
skipjack herring			1					1		2	7
threadfin shad					4	1	1	1	2	9	85
Cyprinidae											
bullhead minnow		3	3	1					11	18	22
central stoneroller								1		1	1
common carp		19	8	13	21	17	4	3	12	97	151
emerald shiner		2	201	11		10	1	31	15	271	292
golden shiner							1			1	1
goldfish			4			1	1	2		8	20
grass carp		3	4	3	1		1		1	13	18
red shiner		2		5					1	8	9
silver carp		7	342	18	2	1	13	5	3	391	438
spotfin shiner				1				4	7	12	12
spottail shiner		10	40					2	5	57	57
Fundulidae											
blackstripe topminnow								2		2	2
Ictaluridae											
black bullhead			7							7	21
brown bullhead			2							2	2
channel catfish		5		8	4			1	2	20	136
flathead catfish							1		5	6	27
yellow bullhead		1	4							5	5
Moronidae											
white bass		2		11	4	7	2	5	8	39	134
yellow bass			1							1	12
Percidae											
logperch								4		4	4
sauger				1			3	2	4	10	21
Poeciliidae											
western mosquitofish								1		1	1
Sciaenidae											
freshwater drum		19	24	21	7	19	9	9	22	130	591
Total individuals		494	1375	239	77	90	169	266	735	3445	5048
Total species/hybrids		21/1	22/1	20/0	15/0	14/0	22/0	23/0	27/1	42/1	49/1

species collections for Peoria Reach represent the second highest recorded for this reach in F-101-R sampling. Fish species richness in the middle river ranged from 12 species collected at Turkey Island (RM 148.0, La Grange Reach) to 27 species and one hybrid collected at Clark Island (RM 215.3, Peoria Reach) in 2008. Our 2008 collections represent the highest fish species richness observation ever recorded in the middle river with 36 fish species (plus one hybrid) collected in La Grange Reach. Numerous sites in the middle river also recorded highest fish species collections. Observations at Bar-Grape Islands (25; RM 86.5), Sugar Creek Island (25; RM 95.1), and Lower Bath Chute (26; RM 107.1) in La Grange Reach were all the highest ever recorded in F-101-R sampling at these sites. In Peoria Reach high fish species collections were recorded at Lower Peoria Lake (21; RM 163.3), Lambie's Boat Harbor (22; RM 170.3), Upper Twin Sisters Island (22; RM 203.3), and Clark Island (27). Lambie's Boat Harbor was the site of the highest total catch on the middle Illinois River waterway with 1,375 fishes. Our 2008 collection at Lambie's Boat Harbor represents the second highest number of fishes ever collected in F-101-R sampling for a single collection site throughout the river. The highest total catch at any given site was 2,293 fishes recorded at Lambie's Boat Harbor in 2007 (McClelland and Sass 2008). In addition to the high numbers observed at Lambie's Boat Harbor, the collections at Bar-Grape Islands (538 fishes) and Clark Island (735 fishes) each recorded their highest total catches in F-101-R sampling.

We collected 2,393 fishes representing 42 species and one hybrid (Table 5) on the upper Illinois River waterway in 2008. In addition, fish species collections were the highest ever recorded for Marseilles and Dresden reaches. A total of 36 fish species in

Table 5. Number of individuals of each fish species collected on Starved Rock, Marseilles, and Dresden Reaches of the upper Illinois Waterway (RM 231-280) in 2008.

		River Mle and Hours Fished							
		Starved Rock		Marseilles			Dresden		Upper Waterway Total
	Mile	240.8	241.5	248	249.6	260.6	277.4	279.8	
Species	Effort	1.00	1.00	1.00	0.42	1.00	1.00	1.00	6.42
Atherinidae									
brook silverside						2			2
Catostomidae									
golden redhorse			1			2			3
river carpsucker					1	2			3
shorthead redhorse			3			1			4
smallmouth buffalo		6		1	1	4		1	13
Centrarchidae									
black crappie		2	1	1	2			1	7
bluegill		16	23	30	10	17	209	130	435
bluegill x green sunfish							5	9	14
green sunfish		6	3	2	2	3	20	33	69
largemouth bass		3	6	21	4	1	39	12	86
longear sunfish				3				1	4
orange spotted sunfish				2	1	3	4	11	21
pumpkinseed			4	3	1	8	1		17
redear				1					1
rock bass							16		16
smallmouth bass		2	3	1		2	12		20
Clupeidae									
gizzard shad		35	78	43	23		32	4	215
skipjack herring			1		1				2
threadfin shad			2				1		3
Cyprinidae									
bluntnose minnow		41	81	56	32	68	78	73	429
bullhead minnow		21	40	20	5	6		7	99
central stoneroller		3	7	3					13
common carp		3	4	5	2	5	4	7	30
emerald shiner		198	172	20	11	18	10		429
goldfish						1	5	1	7
grasscarp			1						1
longnose dace						2			2
river shiner			8						8
silver chub				1					1
spotfin shiner		60	99	36	47	102	12	9	365
spottail shiner			12	3		1	1		17
Esocidae									
grass pickerel				1					1
Fundulidae									
blackstripe topminnow				3				3	6
Gobiidae									
round goby			2			3			5
Ictaluridae									
channel catfish		5	4	3		2	7	3	24
flathead catfish		1							1
yellow bullhead								6	6
Moronidae									
white bass						1			1
Percidae									
blackside darter			1			1		2	4
logperch				1			1		2
mud darter						1			1
slenderhead darter						1			1
Sciaenidae									
freshwater drum			1		2			2	5
Total individuals		402	557	260	145	257	457	315	2393
Total species/hybrids		15/0	24/0	23/0	16/0	25/0	17/1	18/1	42/1

Marseilles Reach and 25 fish species (plus one hybrid) in Dresden Reach were collected. Fish species richness at a single site ranged from 15 at Bull's Island (RM 249.6, Marseilles Reach) to 25 at Waupecan Island (RM 260.6, Marseilles Reach). Fish species collections in 2008 at Ballard's Island (23 fish species; RM 248.0, Marseilles Reach), Johnson Island (16 fish species; RM 249.6, Marseilles Reach), and Waupecan Island (25 fish species) were the highest fish species catches observed for these sites in F-101-R sampling.

<u>**Catch Rates in Numbers of Individuals Collected per Hour by Reach.**</u>

In the following data summary, most of the discussion was restricted either to species that each separately accounted for over 10% of the total catch or to species that were of special significance. A 95% list was created for fish species ranks by reach. Fish species were added to the list until 95% of the total catch in number was obtained.

Alton (lower waterway, Illinois River). Twelve fish species accounted for 94.8% of the total catch in Alton Reach (Tables 6 and 7) and overall $CPUE_N$ was 166.03 in 2008. The highest $CPUE_N$ for an individual fish species was 42.35 for gizzard shad. Gizzard shad comprised 25.5% of the total fish collected in this reach. Freshwater drum ranked second with a $CPUE_N$ of 36.11 (21.8% of the total). The catch rate observed for freshwater drum is the highest recorded for this species in Alton Reach in F-101-R sampling. The previous high catch rate for freshwater drum in

Table 6. Number of individuals of each fish species collected per hour of electrofishing ($CPUE_N$) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2008.

Species	Reach and Hours Fished							
	Reach 26	Alton	La Grange	Peoria	Starved Rock	Marseilles	Dresden	Overall $CPUE_N$
	1.00	4.68	5.58	8.00	2.00	2.42	2.00	24.68
Amiidae								
bowfin		0.54	0.36					0.16
Atherinidae								
brook silverside						0.83		0.08
Catastomidae								
bigmouth buffalo	2.00	0.27	0.54	8.00				2.84
black buffalo			0.18	0.13				0.08
golden redhorse				0.75	0.50	0.83		0.36
highfin carpsucker				0.25				0.08
river carpsucker		0.54	1.61	1.63		1.24		1.09
shorthead redhorse		1.36	3.22	0.50	1.50	0.41		1.26
smallmouth buffalo	8.00	3.80	7.34	8.38	3.00	2.48	0.50	5.79
Centrarchidae								
black crappie	1.00	0.81	7.52	4.63	1.50	1.24	0.50	3.65
bluegill	12.00	12.76	25.79	62.88	19.50	23.59	169.50	46.23
bluegill x green sunfish			0.18	1.25			7.00	1.01
green sunfish	10.00		6.45	16.00	4.50	2.90	26.50	9.85
largemouth bass	4.00	5.97	24.00	7.63	4.50	10.76	25.50	12.44
longear sunfish						1.24	0.50	0.16
orange spotted sunfish	4.00	0.27	15.94	18.50		2.48	7.50	10.66
pumpkinseed			0.18	0.13	2.00	4.97	0.50	0.77
redear sunfish		0.27				0.41		0.08
rock bass							8.00	0.65
smallmouth bass	1.00			0.88	2.50	1.24	6.00	1.13
warmouth		0.27	0.54	0.13				0.20
white crappie			2.15	0.25				0.57
Clupeidae								
gizzard shad	55.00	42.35	18.09	159.38	56.50	27.31	18.00	73.01
skipjack herring		0.54	0.90	0.25	0.50	0.41		0.45
threadfin shad	1.00	2.44	13.61	1.13	1.00		0.50	3.97
Cyprinidae								
bighead carp	1.00				1.00			0.04
bluntnose minnow					61.00	64.55	75.50	17.38
bullhead minnow	1.00	1.63	0.72	2.25	30.50	12.83	3.50	5.19
central stoneroller				0.13	5.00	1.24		0.57
common carp	2.00	10.32	9.67	12.13	3.50	4.97	5.50	8.95
emerald shiner		2.44	3.76	33.88	185.00	20.28	5.00	29.58
golden shiner				0.13				0.04
goldfish			2.15	1.00		0.41	3.00	1.09
grass carp			0.90	1.63	0.50			0.77
longnose dace						0.83		0.08
red shiner			0.18	1.00				0.36
river shiner					4.00			0.32
silver carp	4.00	9.77	8.42	48.88				19.37
silver chub			1.25					0.32
silverband shiner			0.18					0.04
spotfin shiner				1.50	79.50	76.55	10.50	15.28
spottail shiner				7.13	6.00	1.66	0.50	3.00
Esocidae								
grass pickerel						0.41		0.04

Table 6. (continued)
Number of individuals of each fish species collected per hour of electrofishing (CPUEn) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2008.

	Reach and Hours Fished							
Species	Reach 26 1.00	Alton 3.68	La Grange 5.58	Peoria 8.00	Starved Rock 2.00	Marseilles 2.42	Dresden 2.00	Overall $CPUE_N$ 24.68
Fundulidae								
blackstripe topminnow				0.25		1.24	1.50	0.32
Gobiidae								
round goby					1.00	1.24		0.20
Hiodontidae								
mooneye			0.18					0.04
Ictaluridae								
black bullhead			2.51	0.88				0.85
brown bullhead				0.25				0.08
channel catfish	6.00	18.73	20.78	2.50	4.50	2.07	5.00	9.52
flathead catfish	2.00	4.89	3.76	0.75	0.50			1.94
tadpole madtom			0.18					0.04
yellow bullhead				0.63			3.00	0.45
Lepisosteidae								
longnose gar			0.18					0.04
spotted gar	1.00	0.27	0.18					0.04
Moronidae								
white bass	1.00	7.87	17.01	4.88		0.41		6.69
yellow bass			1.97	0.13				0.49
Percidae								
blackside darter					0.50	0.41	1.00	0.16
logperch				0.50		0.41	0.50	0.24
mud darter						0.41		0.04
sauger		1.63	1.97	1.25				1.09
slenderhead darter						0.41		0.04
Poeciliidae								
western mosquitofish				0.13				0.04
Sciaenidae								
freshwater drum	3.00	36.11	82.57	16.25	0.50	0.83	1.00	29.66
Total Number per hour	119.00	166.03	287.28	430.63	479.50	273.55	386.00	330.92
Number of species/hybrids	19/0	24/0	37/1	42/1	26/0	36/0	25/1	62/1

Table 7. Fish species ranks by relative abundance (number of fish collected per hour) for 2008 on the 6 reaches of the Illinois Waterway. Species were added to the list in descending order of abundance until 95% of the total catch for that reach was obtained. Percentages are in parentheses.

	Rankings by Reach					
Species	Alton	La Grange	Peoria	Starved Rock	Marseilles	Dresden
Catostomidae						
bigmouth buffalo			10 (1.9)			
shorthead redhorse		16 (1.1)				
smallmouth buffalo	10 (2.3)	12 (2.6)	9 (1.9)		11 (0.9)	
Centrarchidae						
black crappie		11 (2.6)	14 (1.1)			
bluegill	4 (7.7)	2 (9.0)	2 (14.6)	6 (4.1)	4 (8.6)	1 (43.9)
bluegill x green sunfish						9 (1.8)
green sunfish		13 (2.2)	7 (3.7)	9 (0.9)	10 (1.1)	3 (6.9)
largemouth bass	8 (3.6)	3 (8.4)	11 (1.8)	9 (0.9)	7 (3.9)	4 (6.6)
orange spotted sunfish		7 (5.5)	5 (4.3)		11 (0.9)	8 (1.9)
pumpkinseed					8 (1.8)	
rock bass						7 (2.1)
smallmouth bass						10 (1.6)
white crappie		18 (0.7)				
Clupeidae						
gizzard shad	1 (25.5)	5 (6.3)	1 (37.0)	4 (11.8)	3 (10.0)	5 (4.7)
threadfin shad	11 (1.5)	8 (4.7)				
Cyprinidae						
bluntnose minnow				3 (12.7)	2 (23.6)	2 (19.6)
bullhead minnow				5 (6.4)	6 (4.7)	
central stoneroller				8 (1.0)		
common carp	5 (6.2)	9 (3.4)	8 (2.8)		8 (1.8)	11 (1.4)
emerald shiner	11 (1.5)	14 (1.3)	4 (7.9)	1 (38.6)	5 (7.4)	12 (1.3)
goldfish		18 (0.7)				
silver carp	6 (5.9)	10 (2.9)	3 (11.3)			
spotfin shiner				2 (16.6)	1 (27.9)	6 (2.7)
spottail shiner			12 (1.7)	7 (1.3)	14 (0.6)	
Ictaluridae						
black bullhead		17 (0.9)				
channel catfish	3 (11.3)	4 (7.2)		9 (0.9)	13 (0.8)	12 (1.3)
flathead catfish	9 (2.9)	14 (1.3)				
Moronidae						
white bass	7 (4.7)	6 (5.9)	13 (1.1)			
Sciaenidae						
freshwater drum	2 (21.8)	1 (28.8)	6 (3.8)			
Number of species accounting for 95 % of total catch	12	19	14	11	14	13

Alton Reach was 34.97 recorded in 2005 (McClelland and Cook 2006). Channel catfish ranked third with a $CPUE_N$ of 18.73 (11.3% of the total) representing the second highest $CPUE_N$ in Alton Reach for this species. Redear sunfish were collected for the first time in Alton Reach in 2008. A single specimen was collected at Crater-Willow Islands (RM 30.0).

La Grange (middle waterway, Illinois River). Nineteen fish species accounted for 95.6% of the total catch in La Grange Reach (Tables 6 and 7). Overall, $CPUE_N$ was 287.10. In 2008, the highest catch rate for any fish species was 82.57 for freshwater drum which comprised 28.8% of the total fish collected in this reach. This is the highest catch rate ever observed for freshwater drum over all reaches in F-101-R sampling. The previous high catch for freshwater drum was 46.06 recorded in Peoria Reach in 2005 (McClelland and Cook 2006). Bluegill ranked second with a $CPUE_N$ of 25.79 (9.0% of the total). Largemouth bass ranked third with a $CPUE_N$ of 24.00 and accounted for 8.4% of the total. The largemouth bass catch observed represents the highest ever recorded for this species in La Grange Reach in F-101-R sampling. A previous high catch rate of 9.19 was recorded in 1991 (Lerczak et al. 1992). Channel catfish also recorded a high catch rate in La Grange reach in 2008. Channel catfish ranked fourth with a $CPUE_N$ of 20.78 (7.2% of the total). This catch rate is the highest ever recorded for channel catfish over all reaches in F-101-R sampling. The previous high catch rate was 19.40 observed in Peoria Reach in 1996 (Koel et al. 1997). Two fish species were collected in La Grange Reach for the first time in 2008. A single pumpkinseed was collected at Pekin (RM 155.1) and two bowfin were collected at Lower Bath Chute (RM 107.1).

Peoria (middle waterway, Illinois River). Fourteen fish species accounted for 94.9% of the total catch in Peoria Reach (Tables 6 and 7). Overall, $CPUE_N$ was 430.62 representing the second highest catch rate recorded for Peoria Reach in F-101-R sampling. The highest $CPUE_N$ for any fish species was 159.38 for gizzard shad comprising 37.0% of the total fishes collected in this reach. Bluegill ranked second in Peoria Reach with a $CPUE_N$ of 62.88 (14.6% of the total). Bluegill have ranked among the top two species since 1990 in the Peoria Reach (Lerczak et al. 1993, 1994, 1995, 1996; Koel et al. 1997, 1998, Koel and Sparks 1999; Arnold et al. 2000; McClelland and Pegg 2001, 2002, 2003, 2004, 2005; McClelland and Cook 2006; McClelland and Sass 2007, McClelland and Sass 2008). Silver carp ranked third with a $CPUE_N$ of 48.88 (11.3% of the total). The catch rate observed for silver carp represents the second highest $CPUE_N$ recorded for this species in F-101-R sampling since they were first collected in this reach in 2004 (McClelland and Pegg 2005). One fish species was collected in for the first time in F-101-R sampling for Peoria Reach in 2008; two specimens of blackstripe topminnow were collected at Hennepin Island (RM 207.6)

Starved Rock (upper waterway, Illinois River). Eleven fish species accounted for 95.2% of the total catch in Starved Rock Reach (Tables 6 and 7). Overall, $CPUE_N$ was 479.50 in 2008. The highest $CPUE_N$ for any species was 185.00 recorded for emerald shiner, which comprised 38.6% of the total catch. Spotfin shiner ranked second with a catch rate of 79.50 comprising 16.6% of the total catch representing the highest $CPUE_N$ for this species over all reaches in F-101-R sampling. Bluntnose minnow ranked third with a catch rate of 61.00 (12.7% of the total) and gizzard shad ranked fourth with a catch rate of 56.50 (11.8% of the total). One fish species was collected for the first time in F-101-R sampling in Starved Rock Reach. A single blackside darter was collected at Bull's Island Bend (RM 241.5) representing the first record of this species at any site for F-101-R sampling.

Marseilles (upper waterway, Illinois River). Fourteen fish species accounted for 94.1% of the total catch in Marseilles Reach (Tables 6 and 7) and overall $CPUE_N$ was 273.55 in 2008. The highest $CPUE_N$ for any species was 76.55 for spotfin shiner comprising 27.9% of the total fishes collected in this reach. The $CPUE_N$ observed for spotfin shiner represents the second highest catch rate recorded for this species over all reaches in F-101-R sampling and tops the previous high catch rate of 71.00 recorded in 2007 (McClelland and Sass 2008). The catch rates recorded for spotfin shiner for both Starved Rock Reach and Marseilles Reach in 2008 were each higher than our 2007 observation. Bluntnose minnow ranked second with a $CPUE_N$ of 64.55 (23.6% of total), representing the highest catch rate in Marseilles Reach for bluntnose minnow in F-101-R sampling. Gizzard shad ranked third with a $CPUE_N$ of 27.31 (10.0% of total). Largemouth bass again ranked in the top 95% $CPUE_N$ in Marseilles Reach; a catch rate of 10.76 (7th ranked, 3.9% of the total) was recorded for this species in 2008 representing the second highest $CPUE_N$ for this species in Marseilles Reach. Pumpkinseed were collected for the second straight year in Marseilles Reach in 2008, the $CPUE_N$ of 4.97 observed for this species represented the highest catch rate ever recorded in F-101-R throughout the entire Illinois River waterway for this species. Four fish species were collected in Marseilles Reach for the first time in F-101-R sampling in 2008. In addition to the first collection of blackside darter in Starved Rock Reach, a single specimen of this species was also collected at Waupecan Island (RM 260.6). Two specimens of longnose dace were also collected for the first time in F-101-R sampling at Waupecan Island. Two specimens each of brook silverside and a single mud darter were also collected at Waupecan Island, marking the first collection of these two fish species in Marseilles Reach.

Dresden (upper waterway, Des Plaines River). Thirteen fish species accounted for 95.7% of the total catch in Dresden Reach (Tables 6 and 7). Overall, $CPUE_N$ was 386.00 in 2008. The highest $CPUE_N$ in Dresden Reach for any species was 169.50 for bluegill, which made up 43.9% of the fishes collected. The catch rate observed for bluegill represents the highest $CPUE_N$ ever recorded for this species over all reaches in F-101-R sampling. The previous high catch rate of 164.00 was also recorded in Dresden Reach in 2005 (McClelland and Cook 2006). Bluntnose minnow ranked second with a $CPUE_N$ of 75.50 (19.6% of total). The catch rate for largemouth bass in 2008 was the second highest ever observed for this species in Dresden Reach with a $CPUE_N$ of 25.50 (4^{th} ranked, 6.6% of the total catch). This is the third highest catch rate recorded for largemouth bass throughout the entire Illinois River waterway in F-101-R sampling. The highest $CPUE_N$ of 41.00 was recorded in 2005 in Starved Rock Reach (McClelland and Cook 2006). The catch rate for rock bass in 2008 tied the current highest $CPUE_N$ recorded for this species throughout the entire Illinois River waterway with a $CPUE_N$ of 8.00 (7^{th} ranked,2.1% of the total catch). The previous high $CPUE_N$ of 6.50 was recorded in Dresden Reach in 1995 (Lerczak et. al 1996). Two fish species were collected for the first time in Dresden Reach in 2008. As in the case of Starved Rock and Marseilles reaches, two specimens of blackside darter were collected for the first time at Treat's Island (RM 279.9). A single logperch was also collected at the Mouth of the Du Page River site (RM 277.4).

Catch Rates in Weights (pounds) Collected per Hour by Reach.

The following data summary and discussion was restricted to fish species that individually accounted for over 10% of the total catch and to species that were of special interest. A 95% list was produced for each reach, in which species were ranked by relative biomass (pounds per hour) and added to the list until 95% of the total catch rate in weight for that reach was obtained. Overall, these data indicated that, in terms of biomass, the fish communities of the Illinois River waterway were dominated by common carp, silver carp, and channel catfish.

Alton (lower waterway, Illinois River). Eight fish species accounted for 95.5% of the total catch by weight in pounds per hour ($CPUE_W$) in Alton Reach (Tables 8 and 9) in 2008. Overall $CPUE_W$ was 94.98. Common carp $CPUE_W$ ranked highest at 28.76 (30.3% of total). Silver carp ranked second with a $CPUE_W$ of 24.65 (26.0% of total). Channel catfish ranked third with a $CPUE_W$ of 23.48 (24.7% of total). The $CPUE_W$ observed for channel catfish represents the highest catch by weight for this species over all reaches for F-101-R sampling. A previous high $CPUE_W$ of 19.07 was recorded for channel catfish in Alton Reach in 1996 (Koel et al. 1997). The catch by weight observed for freshwater drum was the highest recorded for this species in Alton Reach in F-101-R sampling with a $CPUE_W$ of 4.34 (4^{th} ranked, 4.6% of the total).

Table 8. Pounds of each fish species collected per hour of electrofishing ($CPUE_W$) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2008. Pounds per hour less than 0.01, but greater than zero, are indicated by 0.00.

	Reach and Hours Fished							
					Starved			Overall
	Reach 26	Alton	La Grange	Peoria	Rock	Marseilles	Dresden	CPUE
Species	1.00	3.68	5.58	8.00	2.00	2.42	2.00	24.68
Amiidae								
bowfin		3.32	0.11					0.52
Atherinidae								
brook silverside						0.00		0.00
Catastomidae								
bigmouth buffalo	0.17	1.18	1.82	19.58				6.94
black buffalo			0.25	0.31				0.16
golden redhorse				0.26	0.16	0.19		0.12
highfin carpsucker				0.05				0.02
river carpsucker		0.69	2.06	2.16		0.99		1.37
shorthead redhorse		0.49	0.76	0.36	0.02	0.01		0.36
smallmouth buffalo	1.94	0.18	4.04	15.12	3.87	4.32	0.28	6.68
Centrarchidae								
black crappie	0.02	0.31	0.92	1.76	1.07	0.52	0.22	0.98
bluegill	1.15	0.85	2.10	6.31	0.53	1.18	8.31	3.53
bluegill x green sunfish			0.01	0.17	0.04			0.15
green sunfish	0.15		0.37	1.13	0.14	0.06	1.24	0.57
largemouth bass	0.69	1.53	5.66	6.17	1.83	6.64	22.44	6.15
longear sunfish						0.03	0.02	0.00
orange spotted sunfish	0.05	0.00	0.23	0.18		0.04	0.03	0.12
pumpkinseed			0.02	0.00	0.04	0.16	0.03	0.03
redear sunfish		0.01				0.05		0.01
rock bass							1.20	0.10
smallmouth bass	1.01			0.62	0.98	0.08	2.21	0.51
warmouth		0.02	0.09	0.00				0.02
white crappie			0.53	0.10				0.15
Clupeidae								
gizzard shad	1.18	0.36	0.36	1.82	1.57	1.61	1.24	1.16
skipjack herring		0.01	0.01	0.02	0.03	0.05		0.02
threadfin shad	0.01	0.01	0.06	0.01	0.01		0.00	0.02
Cyprinidae								
bighead carp	2.04							0.08
bluntnose minnow					0.17	0.20	0.20	0.05
bullhead minnow	0.00	0.01	0.00	0.01	0.09	0.04	0.01	0.02
central stoneroller				0.00	0.03	0.01		0.00
common carp	1.15	28.76	23.02	40.90	12.73	16.60	20.24	27.10
emerald shiner		0.00	0.01	0.08	0.71	0.06	0.03	0.09
golden shiner				0.00				0.00
goldfish			0.08	0.05		0.03	1.02	0.12
grass carp			2.38	3.56	7.59			2.31
longnose dace						0.01		0.00
red shiner			0.00	0.01				0.00
river shiner					0.01			0.00
silver carp	4.11	24.65	15.27	27.43				16.19
silver chub			0.00					0.00
silverband shiner			0.00					0.00
spotfin shiner				0.01	0.17	0.20	0.03	0.04
spottail shiner				0.04	0.03	0.01	0.01	0.02
Esocidae								
grass pickerel						0.05		0.00

Table 8. (continued)
Pounds of each fish species collected per hour of electrofishing (CPUEw) on Reach 26 of the Mississippi River (Brickhouse Slough) and on six reaches of the Illinois Waterway in 2008. Pounds per hour less than 0.01, but greater than zero, are indicated by 0.00.

	Reach and Hours Fished							
Species	Reach 26 1.00	Alton 3.68	La Grange 5.58	Peoria 8.00	Starved Rock 2.00	Marseilles 2.42	Dresden 2.00	Overall CPUE 24.68
Fundulidae								
blackstripe topminnow				0.00		0.00	0.00	0.00
Gobiidae								
round goby					0.01	0.01		0.00
Hiodontidae								
mooneye			0.01					0.00
Ictaluridae								
black bullhead			0.01	0.16				0.05
brown bullhead				0.06				0.02
channel catfish	3.82	23.48	16.56	4.66	5.09	4.13	17.49	11.15
flathead catfish	0.83	2.97	3.41	0.26	1.20			1.43
tadpole madtom			0.00					0.00
yellow bullhead				0.23				0.21
Lepisosteidae								
longnose gar			0.01					0.00
spotted gar	0.12	0.04	0.02					0.01
Moronidae								
white bass	0.05	1.59	3.35	2.01		0.03		1.65
yellow bass			0.25	0.00				0.06
Percidae								
blackside darter					0.00	0.00	0.00	0.00
logperch				0.01		0.00	0.00	0.00
mud darter						0.00		0.00
sauger		0.10	0.19	0.09				0.09
slenderhead darter						0.00		0.00
Poeciliidae								
western mosquitofish				0.00				0.00
Sciaenidae								
freshwater drum	2.42	4.34	7.75	4.68	0.55	1.02	1.61	4.29
Total pounds per hour	20.91	94.98	91.76	140.37	38.63	38.30	80.70	94.68

Table 9. Fish species ranked by relative biomass in pounds of fish collected per hour for 2008. Species were added to the list in descending order of abundance until 95% of the total catch for that reach was obtained. Percentages are in parentheses.

	Rankings by Reach					
Species	Alton	La Grange	Peoria	Starved Rock	Marseilles	Dresden
Amiidae						
bowfin	5 (3.5)					
Catostomidae						
bigmouth buffalo		12 (2.0)	3 (13.9)			
river carpsucker		11 (2.2)	10 (1.5)		8 (2.6)	
smallmouth buffalo		6 (4.4)	4 (10.8)	4 (10.0)	3 (11.3)	
Centrarchidae						
black crappie				8 (2.8)		
bluegill		10 (2.3)	5 (4.5)		6 (3.1)	4 (10.3)
green sunfish						8 (1.5)
largemouth bass	8 (1.6)	5 (6.2)	6 (4.4)	5 (4.7)	2 (17.3)	1 (27.8)
smallmouth bass				9 (2.5)		5 (2.7)
Clupeidae						
gizzard shad			12 (1.3)	6 (4.1)	5 (4.2)	8 (1.5)
Cyprinidae						
common carp	1 (30.3)	1 (25.1)	1 (29.1)	1 (33.0)	1 (43.3)	2 (25.1)
emerald shiner				10 (1.8)		
grass carp		9 (2.6)	9 (2.5)	2 (19.6)		
silver carp	2 (26.0)	3 (16.6)	2 (19.5)			
Ictaluridae						
channel catfish	3 (24.7)	2 (18.0)	8 (3.3)	3 (13.2)	4 (10.8)	3 (21.7)
flathead catfish	6 (3.1)	7 (3.7)		7 (3.1)		
yellow bullhead						6 (2.1)
Moronidae						
white bass	7 (1.7)	8 (3.6)	11 (1.4)			
Sciaenidae						
freshwater drum	4 (4.6)	4 (8.4)	7 (3.3)		7 (2.7)	7 (2.0)
Number of species accouting for 95% of total catch	8	12	12	10	8	9

La Grange (middle waterway, Illinois River). Twelve fish species accounted for 95.3% of the total catch by weight in La Grange Reach (Tables 8 and 9) in 2008. Overall, $CPUE_W$ was 91.76 in La Grange Reach in 2008. Common carp ranked first in La Grange Reach catch by weight with a $CPUE_W$ of 23.02 (25.1% of the total). Channel catfish ranked second in total catch by weight in La Grange Reach with a $CPUE_W$ of 16.56 (18.0% of total). The catch by weight observed for channel catfish was again the highest recorded for La Grange Reach in F-101-R sampling following a previous high $CPUE_W$ of 14.84 recorded in 2007 (McClelland and Sass 2008). Silver carp ranked third in catch by weight with a $CPUE_W$ of 15.27 (16.6% of the total). The catch by weight for freshwater drum was 7.75 (4^{th} ranked, 8.4% of the total) representing the highest $CPUE_W$ ever recorded for this species over all reaches in F-101-R sampling. A previous high catch by weight of 5.60 was recorded in 2005 (McClelland and Cook 2006). The catch by weight for largemouth bass on the La Grange Reach prior to 1996 varied, but was typically above two pounds per hour (Lerczak et al. 1993, 1994, 1995, 1996). $CPUE_W$ for largemouth bass was previously below two pounds per hour for the last 11 of 12 years (1996, 1997, 1998, 1999, 2001, 2002, 2003, 2004, 2005, 2006, and 2007) and had been below one pound per hour since 2001 (Koel et al. 1997, 1998; Koel and Sparks, 1999; Arnold et al. 2000; McClelland and Pegg 2002, 2003, 2004, 2005; McClelland and Cook 2006; McClelland and Sass 2007 and 2008). The catch by weight for largemouth bass in 2008 increased considerably (5.66; 5^{th} ranked) and was the second highest $CPUE_W$ ever recorded in La Grange Reach in F-101-R sampling.

Peoria (middle waterway, Illinois River). Twelve fish species accounted for 95.7% of the total catch by weight in Peoria Reach (Tables 8 and 9). Overall, $CPUE_W$ was 140.37. The Peoria Reach collection was the highest catch by weight recorded for all reaches of the Illinois River waterway in 2008. The highest species-specific $CPUE_W$ was 40.90 for common carp, which made up 29.1% of the total catch by weight for this reach in 2008. Silver carp ranked second with a $CPUE_W$ of 27.43 (19.5% of total). Bigmouth buffalo ranked third with a $CPUE_W$ of 19.58 (13.9% of total) and smallmouth buffalo ranked fourth with a $CPUE_W$ of 15.12 (10.8% of the total). The catch by weight observed for bluegill was 6.31 and represents the highest $CPUE_W$ recorded in Peoria Reach and the second highest over all reaches (behind the catch by weight observed in Dresden Reach in 2008) in F-101-R sampling. The previous high $CPUE_W$ observed for this species in Peoria Reach was 4.33 recorded in 2005 (McClelland and Cook 2006).

Starved Rock (upper waterway, Illinois River). Ten fish species accounted for 94.8% of the total catch by weight in Starved Rock Reach (Tables 8 and 9). Overall, $CPUE_W$ was 38.63. The highest $CPUE_W$ for any species was 12.73 for common carp, which made up 33.0% of the total catch by weight. Grass carp ranked second with a $CPUE_W$ of 7.59 (19.3% of total) representing the second highest catch by weight in Starved Rock Reach and over all reaches for this species in F-101-R sampling. Channel catfish ranked third with a $CPUE_W$ of 5.09 (13.2% of total). Smallmouth buffalo catch by weight ranked fourth with a $CPUE_W$ of 3.87 (10.0% of the total).

Marseilles (upper waterway, Illinois River). Eight fish species accounted for 95.3% of the total catch by weight in Marseilles Reach (Tables 8 and 9). Overall, $CPUE_W$ was 38.30 in 2008. Common carp $CPUE_W$ ranked highest at 16.60 (43.3% of total). Largemouth bass ranked second with a $CPUE_W$ of 6.64 (17.3% of total). The catch by weight observed for largemouth bass represents the highest $CPUE_W$ recorded for this species in Marseilles Reach in F-101-R sampling. Smallmouth buffalo ranked third with a $CPUE_W$ of 4.32 (11.3% of total) and channel catfish ranked fourth with a $CPUE_W$ of 4.13 (10.8% of total).

Dresden (upper waterway, Des Plaines River). Nine fish species accounted for 94.7% of the total catch by weight in Dresden Reach (Tables 8 and 9). Overall, $CPUE_W$ was 80.70 in 2008 representing the second highest catch by weight observed for Dresden Reach in F-101-R sampling. The highest $CPUE_W$ for any species in Dresden Reach was 22.44 for largemouth bass, which made up 27.8% of the total. The catch by weight for largemouth bass was the second highest ever observed over all reaches and in Dresden Reach for this species in F-101-R sampling. The highest catch by weight for largemouth bass was 22.57 recorded in Dresden Reach in 2007 (McClelland and Sass 2008). Common carp ranked second with a $CPUE_W$ of 20.24 (25.1% of total). Channel catfish ranked third with a $CPUE_W$ of 17.49 (21.7% of total). The catch by weight observed in Dresden Reach for bluegill was 8.31(4^{th} ranked, 10.3% of the total) representing the highest catch by weight ever recorded for bluegill throughout the Illinois River waterway. Smallmouth bass catch by weight in Dresden Reach was also the highest ever recorded throughout the Illinois River waterway with a

$CPUE_W$ of 2.21 (5th ranked, 2.7% of the total). The previous high catch by weight observed for smallmouth bass was 1.64 recorded in 1995 in Dresden Reach (Koel et al. 1996).

CONCLUSIONS

Samples collected by electrofishing on the Illinois Waterway during August through October 2008 provided evidence of continued increases in fish species richness and catch rates. A total of 102 fish species and seven hybrids have been collected since William Starrett began this survey in 1957. Eighty-five fish species and six hybrids have been documented by project F-101-R sampling (1989-present); 62 species and one hybrid from 15 families were collected during 24.68 h of sampling in 2008. Blackside darter and longnose dace were collected for the first time in 2008 along the waterway. A single specimen of blackside darter was collected at two sites; Bull's Island Bend in Starved Rock Reach (upper waterway) and Waupecan Island in Marseilles Reach (upper waterway). Two specimens of blackside darter were collected at Treat's Island in Dresden Reach (upper waterway). Two specimens of longnose dace were collected at Waupecan Island. Redear sunfish was collected for the first time in Alton Reach; one specimen was collected at Crater-Willow Islands. Two fish species were collected for the first time in La Grange Reach (middle waterway) in 2008. Two specimens of bowfin were collected at Lower Bath Chute and one specimen of pumpkinseed was collected at Pekin. Blackstripe topminnow was collected for the first time in Peoria Reach (middle waterway) in 2008. Two specimens were collected at Hennepin Island. Two additional new fish species were collected in Marseilles Reach for the first time in conjunction with blackside darter. Two specimens of brook silverside and a single specimen of mud darter were also collected at Waupecan Island. A single specimen of logperch was collected in Dresden Reach (upper river) for the first time at the Mouth of the Du Page River.

Peoria Reach continued to produce the highest number of fish species (42 plus one hybrid) along the Illinois River waterway and the highest total catch (3,445). This was likely due, in part, to a greater number of sites in this reach, varied site types (backwater and side channel), and its position along the waterway, which included the Great Bend (above Hennepin) of the Illinois River. Peoria Reach represents a transition from a river which is constricted, has few contiguous backwaters, and is high in gradient (upper river) to a large river floodplain system with low gradient (lower river) (Sparks 1977).

Catch rates in terms of number of fish collected per hour and total catch numbers along the Illinois Waterway were again among the highest ever recorded for La Grange and Peoria reaches. Catches of several sportfish species in multiple reaches were at their highest in 2008. Channel catfish and largemouth bass exhibited high catch rates for La Grange Reach. The catch rates for pumpkinseed in Marseilles Reach and bluegill in Dresden Reach were the highest ever recorded for these species throughout the entire river in F-101-R sampling. Continued increase in catches of individual sportfish species may be a result of numerous factors, many of which may be difficult to identify, but may be indicative of improved water quality conditions, coherent timing of hydrological events (flooding), and habitat improvements.

The catch in weight of fishes collected in 2008 was dominated by common carp, silver carp, and channel catfish. These three fish species combined for a total weight of 1343 .65 pounds, comprising 57.5% of the total biomass observed. Catch in weight for a single reach was again highest in Peoria Reach in 2008. Fish species accounting for this high catch in weight were common carp, silver carp, bigmouth buffalo, and smallmouth buffalo. Several sportfish species catches in terms of relative biomass were at their highest in 2008. Channel catfish catch in weight was the highest ever observed for La Grange Reach and the catch in weight recorded for Alton Reach was the highest ever observed for this species in a single reach. Largemouth bass catch in weight was the second highest ever observed for La Grange and Dresden reaches and the highest catch in weight for this species in Marseilles Reach. Bluegill catch in weight was the highest recorded for Peoria Reach and the catch in weight in Dresden Reach was the highest ever observed throughout the Illinois River waterway in a single reach. Non-native fish species continued to have a major role in relative biomass catches in the Illinois River waterway. Common carp, silver carp, bighead carp, and grass carp combined to produce 1,127.5 pounds of the 2,336.5 total pounds collected comprising 48.2% of the total biomass. Common carp relative biomass collections ranked first in Alton, La Grange, Peoria, Starved Rock, and Marseilles reaches and second in Dresden Reach in 2008. The total catch in weight across all reaches for common carp was the highest recorded for this species in F-101-R sampling. Silver carp continued to rank among the top three species of the lower and middle river in terms of relative biomass, while the total relative biomass collection across all reaches for grass carp was the highest recorded for this species in F-101-R sampling.

The middle river comprised 1,634.8 (70.6%) of the 2,315.6 total pounds of fish collected on the Illinois River waterway during our 2008 survey. The lower waterway produced 349.4 pounds (15.1%) while the upper waterway produced 331.4 pounds (14.3%). Although these catches may be reflective of higher productivity of the middle Illinois Waterway floodplain ecosystem, a greater number of collections in this section may continue to play a role.

Sport fishes were collected throughout the waterway in 2008, although catch rate in number and weight varied among reaches. For channel catfish, we usually collected more individuals per hour in Alton Reach (lower waterway) than in the middle or upper waterway reaches. However, La Grange Reach produced the greatest catch of channel catfish in number over all reaches at 20.78 fish per hour. In terms of catch in weight for channel catfish, the lower and middle waterway reaches usually produced the highest pounds per hour and in 2008, Alton Reach exhibited the highest $CPUE_W$ of channel catfish at 23.48 pounds per hour. As in previous years, white bass were most abundant and provided the highest $CPUE_W$ in the middle waterway. Black crappie was most abundant and provided the highest catches by weight in the middle waterway. Bluegill $CPUE_N$ and $CPUE_W$ was greatest in Dresden Reach and the upper waterway as a whole, but total catch numbers were greatest in the middle river. Largemouth bass $CPUE_N$ and $CPUE_W$ was also highest in Dresden Reach in 2008, but catch rates by river segment were highest in the middle river. As in previous years of project F-101-R sampling, we collected low numbers of sauger (27 total fish collected). Smallmouth bass, which were usually found in low numbers, were again collected in every reach of the upper waterway and in the Peoria Reach of the middle waterway (27 total fish collected).

APPENDIX A. Fish species collected during Long-term Monitoring of the Illinois Waterway, 1957-2008. Common names marked by an asterisk indicate species that were collected from 1989 through 2008 during federal aid project F-101-R. Common and scientific names are from Robins et al. (1991) and Cross et al. (1995). Habitat associations are based on behavioral descriptions from Pflieger (1975), Cross et al. (1995) and communications with INHS fisheries biologists.

Family Name	Common Name	Scientific Name	Habitat Association (B=benthic)
Lepisosteidae	longnose gar*	*Lepisosteus osseus*	
	shortnose gar*	*Lepisosteus platostomus*	
	spotted gar*	*Lepisosteus oculatus*	
Amiidae	bowfin*	*Amia calva*	
Hiodontidae	goldeye*	*Hiodon alosoides*	
	mooneye*	*Hiodon tergisus*	
Anguillidae	American eel	*Anguilla rostrata*	
Clupeidae	gizzard shad*	*Dorosoma cepedianum*	
	skipjack herring*	*Alosa chrysochloris*	
	threadfin shad*	*Dorosoma petenense*	
Cyprinidae	bighead carp*	*Hypophthalmichthys nobilis*	
	bigmouth shiner*	*Notropis dorsalis*	B
	blacknose dace*	*Rhinichthys atratulus*	B
	bluntnose minnow*	*Pimephales notatus*	
	bullhead minnow*	*Pimephales vigilax*	
	central stoneroller*	*Campostoma anomalum*	B
	common carp*	*Cyprinus carpio*	B
	common carp x goldfish*	*Cyprinus carpio x Carassius aurtatus*	B
	common shiner*	*Luxilus cornutus*	
	creek chub*	*Semotilus atromaculatus*	
	emerald shiner*	*Notropis atherinoides*	
	fathead minnow*	*Pimephales promelas*	
	ghost shiner	*Notropis buchanani*	
	golden shiner*	*Notemigonus crysolucas*	
	goldfish*	*Carassius auratus*	B
	grass carp*	*Ctenopharyngodon idella*	
	hornyhead chub	*Nocomis biguttatus*	
	longnose dace*	*Rhinichthys cataractae*	B
	Mississippi silvery minnow	*Hybognathus nuchalis*	B
	pugnose minnow	*Opsopoeodus emiliae*	
	redfin shiner	*Lythrurus umbratilis*	
	red shiner*	*Cyprinella lutrensis*	
	ribbon shiner*	*Lythrurus fumeus*	
	river shiner*	*Notropis blennius*	
	sand shiner*	*Notropis stramineus*	
	silverband shiner*	*Notropis shumardi*	
	silver carp*	*Hypophthalmichthys molitrix*	
	silver chub*	*Hybopsis storeriana*	B
	silverjaw minnow	*Notropis buccatus*	B
	southern redbelly dace*	*Phoxinus erythrogaster*	
	spotfin shiner*	*Cyprinella spiloptera*	
	spottail shiner*	*Notropis hudsonius*	
	steelcolor shiner	*Cyprinella whipplei*	
	striped shiner*	*Luxilus chrysocephalus*	
	suckermouth minnow*	*Phenacobius mirabilis*	B
Catostomidae	bigmouth buffalo*	*Ictiobus cyprinellus*	B
	black buffalo*	*Ictiobus niger*	B
	black redhorse	*Moxostoma duzuesnei*	B
	golden redhorse*	*Moxostoma erythrurum*	B
	highfin carpsucker*	*Carpoides velifer*	B
	northern hogsucker*	*Hypentelium nigricans*	B
	quillback*	*Carpoides cyprinus*	B
	river carpsucker*	*Carpoides carpio*	B
	river redhorse	*Moxostoma carinatum*	B
	shorthead redhorse*	*Moxostoma macrolepidotum*	B
	silver redhorse*	*Moxostoma anisurum*	B
	smallmouth buffalo*	*Ictiobus bubalus*	B
	white sucker*	*Catostomus commersoni*	B

Appenidix A Continued.

Family Name	Common Name	Scientific Name	Habitat Association (B=benthic)
Ictaluridae	black bullhead*	*Ameiurus melas*	B
	blue catfish	*Ictalurus furcatus*	B
	brown bullhead*	*Ameiurus nebulosus*	B
	channel catfish*	*Ictalurus punctatus*	B
	flathead catfish*	*Pylodictis olivaris*	B
	freckled madtom*	*Noturus nocturnus*	B
	tadpole madtom*	*Noturus gyrinus*	B
	white catfish	*Ameiurus catus*	B
	yellow bullhead*	*Ameiurus natalis*	B
Esocidae	grass pickerel*	*Esox americanus vermiculatus*	
	nothern pike	*Esox lucius*	
Salmonidae	rainbow trout	*Oncoryhnchus mykiss*	
Percopsidae	trout-perch	*Percopsis omiscomaycus*	B
Fundulidae	banded killifish*	*Fundulus diaphanus*	
	blackstripe topminnow*	*Fundulus notatus*	
Poeciliidae	western mosquitofish*	*Gambusia affinis*	
Atherinidae	brook silverside*	*Labidesthes sicculus*	
Moronidae	striped bass	*Morone saxatilis*	
	striped bass x white bass*	*Morone saxatilis x M. chrysops*	
	white bass*	*Morone chrysops*	
	white perch*	*Morone americana*	
	yellow bass*	*Morone mississippiensis*	
	yellow bass x white perch*	*Morone mississippiensis x M. americana*	
Centrarchidae	black crappie*	*Pomoxis nigromaculatus*	
	bluegill*	*Lepomis macrochirus*	
	bluegill x green sunfish*	*Lepomis macrochirus x L. cyanellus*	
	green sunfish*	*Lepomis cyanellus*	
	largemouth bass*	*Micropterus salmoides*	
	longear sunfish*	*Lepomis megalotis*	
	orangespotted sunfish*	*Lepomis humilis*	
	orangespotted sunfish x bluegill*	*Lepomis humilis x L. macrochirus*	
	orangespotted sunfish x green sunfish*	*Lepomis humilis x L. cyanellus*	
	pumpkinseed*	*Lepomis gibbosus*	
	pumpkinseed x green sunfish*	*Lepomis gibbosus x L. cyanellus*	
	redear sunfish*	*Lepomis microlophus*	
	rock bass*	*Ambloplites rupestris*	
	smallmouth bass*	*Micropterus dolomieu*	
	spotted sunfish*	*Lepomis punctatus*	
	warmouth*	*Lepomis gulosus*	
	white crappie*	*Pomoxis annularis*	
Percidae	blackside darter*	*Percina maculata*	B
	bluntnose darter	*Etheostoma chlorosomum*	B
	johnny darter*	*Etheostoma nigrum*	B
	logperch*	*Percina caprodes*	B
	mud darter*	*Etheostoma asprigene*	B
	sauger*	*Stizostedion canadense*	
	slenderhead darter*	*Percina phoxocephala*	B
	walleye*	*Stizostedion vitreum*	
	yellow perch*	*Perca flavescens*	
Sciaenidae	freshwater drum*	*Aplodinotus grunniens*	B
Gobiidae	round goby*	*Neogobius melanostomus*	B

APPENDIX B. Species richness (S) at Long-term Illinois River Fish Population Monitoring (F-101-R) sites.

Description	Site #	Reach	Low S	(year)	High S	(year)
Treats Island	279.8	3	10	(2003)	20	(2007)
Du Page River	277.4	3	11	(1999, 2000)	20	(2006)
Waupecan Island	260.6	4	11	(1996)	25	(2008)
Johnson Island	249.6	4	6	(1993)	16	(1995, 2008)
Ballards Island	248.0	4	10	(1991)	23	(2007, 2008)
Bulls Island Bend	241.5	5	8	(1990)	25	(2007)
Bulls Island	240.8	5	8	(1990, 96, 99)	21	(2007)
Clark Island	215.3	6	11	(1990)	27	(2007, 2008)
Hennepin	207.6	6	2	(1990)	27	(2007)
Upper Twin Sister	203.3	6	8	(1990)	22	(2001, 2008)
Lower Twin Sister	202.8	6	7	(1992)	22	(2007)
Henry Island	193.8	6	12	(1991)	24	(2005)
Chillicothe	180.6	6	14	(1989,91,92,96)	26	(2006)
Lambie's Boat Harbor	170.3	6	9	(1989)	22	(2006, 2008)
Lower Peoria Lake	163.3	6	10	(1989)	21	(2008)
Pekin	155.1	7	6	(1992)	19	(2005)
Turkey Island	148.0	7	8	(2004)	18	(2007)
Upper Bath Chute	113.0	7	12	(1994)	22	(2001, 2007)
Lower Bath Chute	107.1	7	9	(1992)	26	(2008)
Sugar Creek Island	95.1	7	10	(1989, 1999, 2003)	25	(2008)
Grape-Bar Islands	86.5	7	7	(1989)	25	(2008)
Moore's Towhead	75.3	8	6	(2002)	17	(2004, 2005)
Big Blue Island	58.3	8	9	(1990)	20	(2005, 2006)
Crater-Willow Islands	30.0	8	11	(2003)	19	(2007)
Hurricane Island	26.8	8	11	(1990, 1999, 2004)	20	(1997)
Dark Chute	24.7	8	11	(1994, 2004)	18	(2006)
Mortland Island	19.0	8	10	(2003)	19	(2006)
Brickhouse Slough	0.0	26	10	(1990)	20	(2005)

[1]Sites 0.0,26.8-215.3 were not sampled during 1993 (n=19 years) (sites 240.8-279.8 n=20 years).

[2]Sites 19.0, 24.7 were not sampled during 1993, 2008 (n=18 years)

APPENDIX C. Total catch (C) at Long-term Illinois River Fish Population Monitoring (F-101-R) sites.

Description	Site #	Reach	Low C	(year)	High C	(year)
Treats Island	279.8	3	55	(1996)	586	(1995)
Du Page River	277.4	3	88	(1991)	614	(1995)
Waupecan Island	260.6	4	35	(1996)	266	(2006)
Johnson Island	249.6	4	15	(2003)	224	(2007)
Ballards Island	248.0	4	34	(1991)	492	(2005)
Bulls Island Bend	241.5	5	36	(1990)	897	(1995)
Bulls Island	240.8	5	32	(1990)	919	(2006)
Clark Island	215.3	6	45	(1991)	735	(2008)
Hennepin	207.6	6	2	(1990)	523	(2005)
Upper Twin Sister	203.3	6	33	(1990)	222	(2007)
Lower Twin Sister	202.8	6	33	(1990)	218	(2001)
Henry Island	193.8	6	54	(1990)	474	(1996)
Chillicothe	180.6	6	80	(1992)	331	(2007)
Lambie's Boat Harbor	170.3	6	47	(2003)	2293	(2007)
Lower Peoria Lake	163.3	6	83	(1991)	507	(2005)
Pekin	155.1	7	22	(1992)	524	(1996)
Turkey Island	148.0	7	30	(1992)	165	(1995)
Upper Bath Chute	113.0	7	80	(2002, '03)	581	(2007)
Lower Bath Chute	107.1	7	57	(1992)	701	(2007)
Sugar Creek Island	95.1	7	37	(2003)	238	(1996)
Grape-Bar Islands	86.5	7	42	(1990)	538	(2008)
Moore's Towhead	75.3	8	31	(2003)	263	(2005)
Big Blue Island	58.3	8	25	(1990)	240	(2005)
Crater-Willow Islands	30.0	8	57	(2003)	207	(1994)
Hurricane Island	26.8	8	50	(1999)	304	(2005)
Dark Chute	24.7	8	47	(2004)	237	(1991)
Mortland Island	19.0	8	28	(2004)	195	(1991)
Brickhouse Slough	0.0	26	53	(1996)	267	(2006)

[1]Sites 0.0,26.8-215.3 were not sampled during 1993 (n=19 years) (sites 240.8-279.8 n=20 years).
[2]Sites 19.0, 24.7 were not sampled during 1993, 2008 (n=18 years)

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Appendix D (Job 5). Publications, reports, and presentations that resulted from research conducted during segments 6-15 of project F-101-R, the Long-term Illinois River Fish Population Monitoring Program (funded under Federal Aid in Sportfish Restoration Act, P.L. 81-681, Dingell-Johnson, Wallup-Breaux).

I. Publications

Irons, K.S., G.G. Sass, M.A. McClelland, and J.D. Stafford. 2007. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carps in the Illinois River, USA: Evidence for Competition and Reduced Fitness? Journal of Fish Biology 71 (Supplement D), 258-273.

Koel, T.M. and Richard E. Sparks. 2000. Ecohydrology of the Illinois River and development of ecological criteria for operation of dams. Regulated Rivers: Research and Management.

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Koel, T.M. 2000. Abundance of age-0 fishes correlated with hydrologic indicators. Project Status Report 2000-03. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, Onalaska, Wisconsin.

Koel, T.M. 1998. Channel catfish (*Ictalurus punctatus*) in the Upper Mississippi River System. Project Status Report 98-11. U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin.

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Pegg, M. A. 2002. Invasion and transport of non-native aquatic species in the Illinois River. Pages 203-209 in A.M. Strawn, editor. Proceedings of the 2001 Governor's conference on the management of the Illinois River System, Special Report Number 27, Illinois Water Resources Center, Champaign, Illinois.

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II. Essays

Pegg, M.A. 2002. Aquatic resource monitoring in the Upper Mississippi River Basin. INHS Reports. Number 371:8-9.

III. Technical Papers (presenters in bold)

Michael A. McClelland, Greg G. Sass, Thad R. Cook, Kevin S. Irons, T. Matt O'Hara, Camilla S. Smith, Nerissa N. Michaels, and Mathew R. Stroub. Fifty Years of the Long-Term Illinois River Fish Population Monitoring Program, 1957-2007. Presented at the 40th Annual Meeting of the Mississippi River Research Consortium, Dubuque, IA, 24-25 April, 2008.

G.G. Sass, T.R. Cook, K.S. Irons, M.A. McClelland, N.N. Michaels, T.M. O'Hara, and M.R. Stroub. Environmental and Economic Impacts of Asian Carps in the Illinois River. Presented at the 40th Annual Meeting of the Mississippi River Research Consortium, Dubuque, IA, 24-25 April, 2008.

Thad R. Cook, Kevin S. Irons, Michael A. McClelland, Greg G. Sass, T. Mathew O'Hara, Nerissa N. Michaels, and Matt R. Stroub. Long-Term Trends in Illinois River Water Quality: Reflective of Global Changes? Poster presented at the 40th Annual Meeting of the Mississippi River Research Consortium, Dubuque, IA, 24-25 April, 2008.

Kevin S. Irons, Greg G. Sass, Thad R. Cook, T. Matt O'Hara, Michael A. McClelland, Nerissa N. Michaels, and Mathew R. Stroub. An Overview of the Illinois River Biological Station's Asian Carps Research. The 64th Annual Meeting of the UMRCC & 15th Annual Meeting of the LMRCC, Collinsville, IL, 18-20 March 2008.

Kevin S. Irons, Greg G. Sass, Thad R. Cook, T. Mathew O'Hara, Michael A. McClelland, Nerissa N. Michaels, and Mathew R. Stroub. An Overview of the Illinois River Biological Station's Asian Carp's Research. Presented at the 46th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, IL, February 26-28, 2008.

Michael A. McClelland, Greg G. Sass, Thad R. Cook, Kevin S. Irons, T. Matt O'Hara, Camilla S. Smith, Nerissa N. Michaels, and Mathew R. Stroub. Fifty Years of the Long-Term Illinois River Fish Population Monitoring Program, 1957-2007. Presented at the 46th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, IL, February 26-28, 2008.

Kevin S. Irons, Greg G. Sass, Michael A. McClelland, and Joshua D. Stafford. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carps in the Illinois River, USA: Evidence for Competition and Reduced Fitness? Fisheries Society of the British Isles International Symposium: Non-native Fishes: Integrated Biology of Establishment Success and Dispersal. University of Exeter, Exeter, U.K., July 23-27.

Kevin S. Irons, Greg G. Sass, Michael A. McClelland, and Joshua D. Stafford. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carp in the Illinois River: Evidence for Competition and Reduced Fitness? Presented at the 39th Annual Meeting of the Mississippi River Research Consortium, La Crosse, WI, April 12-13, 2007.

Michael A. McClelland and Greg G. Sass. Trends in Largemouth Bass and Bluegill Populations Among the Upper and Lower Illinois River, 1957-2006. Presented at the 39th Annual Meeting of the Mississippi River Research Consortium, La Crosse, WI, April 12-13, 2007.

Kevin S. Irons, Greg G. Sass, Michael A. McClelland, and Joshua D. Stafford. Reduced Condition Factor of Two Native Fish Species Coincident with Invasion of Non-native Asian Carp in the Illinois River: Evidence for Competition and Reduced Fitness? Presented at the 45th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Lake Shelbyville, IL, February 27-March 1, 2007.

Michael A. McClelland and Greg G. Sass. Trends in largemouth bass and bluegill populations among the upper and lower Illinois River, 1957-2006. Presented at the 45th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Lake Shelbyville, IL, February 27-Mar 1, 2007.

Michael A. McClelland, Mark A. Pegg, Kevin S. Irons, and T. Matt O'Hara. Fish Abundances of Backwater Lakes with Connectivity Gradients in the La Grange Reach, Illinois River. Presented at the 37th Annual Meeting of the Mississippi River Research Consortium, La Crosse, WI, April 28-29, 2005.

McClelland, **Michael A.**, Kevin S. Irons, T. Matt O'Hara, Mark A. Pegg, and Thad R. Cook. A Comparison of Two Electrofishing Gears Used for Fish Monitoring on the Illinois River. Presented at the 36th Annual Meeting of the Mississippi River Research Consortium, LaCrosse, WI, April 1-2, 2004.

McClelland, Michael A. and Mark A. Pegg. Longitudinal Patterns of the Illinois Waterway Fish Community. Presented at the 64th Annual Midwest Fish and Wildlife Conference, Kansas City, MO, December 7-10, 2003.

Pegg, M.A. and M.A. McClelland. Assessment of spatial and temporal fish community patterns in the Illinois River. Presented at the American Fisheries Society meeting, Quebec City, Quebec Canada, August, 2003.

O'Hara, T.M., K.S. Irons, M.A. McClelland, and M.A. Pegg. Status of bighead carp and silver carp in the La Grange Reach, Illinois River and possible impacts to the commercial fishery. 41st Annual Meeting of the Illinois Chapter of the American Fisheries Society, Mt. Vernon, Illinois, 4-6 March, 2003.

Irons, K.S., T.M. O'Hara, M.A. McClelland, and M.A. Pegg. Status of non-native fish species in the Illinois River. 41st Annual Meeting of the Illinois Chapter of the American Fisheries Society, Mt. Vernon, Illinois, 4-6 March, 2003.

O'Hara, T.M., K.S. Irons, M.A. McClelland, and M.A. Pegg. Status of bighead carp and silver carp in the La Grange Reach, Illinois River and possible impacts to the commercial fishery. Presented at the 34th Annual Meeting of the Mississippi River Research Consortium, LaCrosse, Wisconsin, April, 2002.

Irons, K.S., T.M. O'Hara, M.A. McClelland, and M.A. Pegg. White perch distributions in the Illinois River: detecting an invasive species with the Long Term Resource Monitoring Program. Presented at the 34th Annual Meeting of the Mississippi River Research Consortium, LaCrosse, Wisconsin, April, 2002.

O'Hara, T.M., K.S. Irons, M.A. McClelland, and M.A. Pegg. Status of bighead carp and silver carp in the La Grange Reach, Illinois River and possible impacts to the commercial fishery. Presented at the 2002 North Central Division American Fisheries Society River and Streams Technical Committee Meeting, Moline, Illinois, March 2002.

McClelland, M.A., Irons, K.S., and T.M. O'Hara, and M.A. Pegg. White perch (morone americana) occurrence in the Illinois River, Upper Mississippi River System. Presentation at the Illinois-Iowa American Fisheries Society Annual Meeting, Moline, Illinois, February , 2002.

Pegg, M.A. Invasion and transport of non-native aquatic species in the Illinois River. 2001 Governor's conference on the management of the Illinois River System, Peoria, Illinois, October, 2001.

Koel, T.M. and Richard E. Sparks. Ecohydrology of the Illinois River: development of criteria for operation of the La Grange and Peoria locks and dams. 32nd Annual Meeting of the Mississippi River Research Consortium, La Crosse, Wisconsin, April 13-14, 2000.

Koel, T.M., T.R. Cook, and K.S. Irons. Criteria for biota-friendly operations of the Peoria and La Grange locks and dams, Illinois River Waterway. 61st Midwest Fish and Wildlife Conference, Chicago, Illinois December 5-8, 1999.

Koel, T.M. and R.E. Sparks. Interannual variation in catches of young-of-year fish correlated with hydrology of the Upper Mississippi River System. 47th Annual Meeting of the North American Benthological Society, Duluth, Minnesota, May 23-24, 1999.

Koel, T.M. Changes in fish community structure: effects of hydrological variability in the Upper Mississippi River System. Presented to the Illinois Natural History Survey, Center for Aquatic Ecology, Havana Field Station Director Search Committee and Senior Staff, March 24, 1999.

Koel, T.M. Spatial and temporal variability of channel catfish populations in the Upper Mississippi River System. Illinois Department of Natural Resources LTRMP field station biannual retreat, Dickson Mounds, Illinois, December 15, 1998.

Koel, T.M. Long Term Resource Monitoring Program Showcase: analysis of catfish catch. Environmental Management Program Coordinating Committee, Fall Quarterly Meeting, Rock Island, Illinois, November 19-20, 1998.

Koel, T.M. and K.D. Blodgett. Fish-environment associations: effects of inter-annual hydrological variability on fish populations of the Illinois River waterway, 1957-1997. Upper Mississippi River Conservation Committee, Fish Technical Section Annual Fall Meeting, Dubuque, Iowa, September 15-17, 1998.

Koel, T.M., K.S. Irons, T.M. O'Hara, K.D. Blodgett, and R.E. Sparks. Changes in fish community structure: effects of hydrological variability in the Upper Mississippi River System. 128th Annual Meeting of the American Fisheries Society, Hartford, Connecticut, August 23-27, 1998.

Koel, T.M., T.M. Mihuc, R.E. Sparks, and K.D. Blodgett. Upper Mississippi River System status and trends report. Fish species-environment relationships: LTRMP data analysis and preliminary results. 54th Annual Meeting of the Upper Mississippi River Conservation Committee, Moline, Illinois, 17-19 March 1998.

Blodgett, K.D. and T.M. Mihuc. Decision support using Long Term Resource Monitoring Program component data and supplementary data on the Illinois River. 54th Annual Meeting of the Upper Mississippi River Conservation Committee, Moline, Illinois, 17-19 March 1998.

Koel, T.M. and T.M. Mihuc. Fish abundance in the La Grange Reach of the Illinois River correlated with environmental factors: problems of cross-component analysis. Presented at the Long Term Resource Monitoring Program Annual Winter Meeting, Davenport, Iowa, 13 January 1998.

Lerczak, T.V., R.E. Sparks, and K.D. Blodgett. Some upstream-to-downstream differences in Illinois River fish communities. Contributed paper presented at the Illinois State Academy of Science Annual Meeting, Galesburg, Illinois, 7 October 1994.

Sparks, R.E. Large river-floodplain ecosystems of the Midwest: status, trends, and management needs. Presented at the U.S. Environmental Protection Agency's "Ecological Seminar Series" held in Chicago, Illinois, 14 March.

IV. Poster Presentations (presenter in bold)

Koel, T.M. and R.E. Sparks. The Long-term Illinois River Fish Population Monitoring Program. National Meeting of the Ecological Society of America, Spokane, Washington, August 10-14, 1998.

Lerczak, T.V., R.E. Sparks, and K.D. Blodgett. Long-term trends (1959-1994) in fish populations of the Illinois River. Poster presented at the 56th Midwest Fish and Wildlife Conference, Indianapolis, Indiana, 4-7 December 1994.

Lerczak, T.V., R.E. Sparks, and K.D. Blodgett. Long-term trends (1959-1994) in fish populations of the Illinois River. Poster presented at the Illinois State Academy of Science Annual Meeting, Charleston, Illinois, 6 October 1995.

Lerczak, T.V., R.E. Sparks, and K.D. Blodgett. Long-term trends (1959-1994) in fish populations of the Illinois River with emphasis on upstream-to-downstream differences. Poster presented at the annual meeting of the Mississippi River Research Consortium, La Crosse, Wisconsin, 26-28 April 1995.

Michael A. McClelland, Greg G. Sass, Thad R. Cook, Kevin S. Irons, T. Matt O'Hara, Camilla S. Smith, Nerissa N. Michaels, and Mathew R. Stroub. Fifty Years of the Long-Term Illinois River Fish Population Monitoring Program, 1957-2007. Presented at the 46th Annual Meeting of the Illinois Chapter of the American Fisheries Society, Rockford, IL, February 26-28, 2008.

Pegg, M.A. and M.A. McClelland. Long-term fish population trends along the Illinois River. Poster presented at the 63rd Midwest Fish and Wildlife Conference, Des Moines, Iowa, December, 2001.

Pegg, M.A. and M.A. McClelland. Long-term fish population trends along the Illinois River. Poster presented at the 131st Annual Meeting of the American Fisheries Society, Phoenix, Arizona, August, 2001.

V. Popular Presentations

Lerczak, T.V. Wintering bald eagles along the Illinois River and factors affecting their environment. Invited presentation to the Peoria Audubon Society, Peoria, Illinois, 8 March 1995.

Lerczak, T.V. Seminar on Illinois River environmental issues. Conducted for Biology 140 (Human Ecology) at Spoon River College, 27 June 1994.

Lerczak, T.V. A photo trip up the Illinois River. After dinner talk presented to Havana Rotary Club, Havana, Illinois, 17 April 1995.

Blodgett, K.D. Ecosystem management for the Illinois River: can biological integrity be restored? Invited lecture for Earth Day celebration at Spoon River College, Canton, Illinois, 19 April 1995.

McClelland, M.A. The Long Term Illinois River Fish Population Monitoring Program. After dinner talk presented to Central Christian Men's 10th Annual Fish Fry, August 2003.

VI. Data Requests

1. Sam Cull, City of Peru, Electrical Department, Peru, Illinois
2. Stanley and Associates, Muscatine, Iowa
3. U.S. Army Corps of Engineers, Rock Island, Illinois
4. Shelly Miller, Aquatic Ecologist, The Nature Conservancy, Peoria, Illinois
5. K. Douglas Blodgett, Project Manager, The Nature Conservancy, Havana, Illinois
6. Kevin Irons, Fishery Biologist, LTRMP, Havana, Illinois
7. Matt O'Hara, Fishery Biologist, LTRMP, Havana, Illinois
8. Scott Langloss, Writer for Adventure Sports Outdoors
9. Richard Sparks, Director of Research National Great Rivers Research & Education Center
10. Jim Mick, Illinois Department of Natural Resources
11. James B. McLaren, ASA Analysis & Communication, Inc.
12. Ximing Cai, University of Illinois
13. Rob Maher, Illinois Department of Natural Resources
14. Karen Haggerty, U.S. Army Corps of Engineers
15. Mike Kacinski, EA Engineering
16. Sam McCord, EA Engineering
17. Kelly Baewaldt, U.S. Army Corps of Engineers
18. Dave Thomas, Former Chief of Illinois Natural History Survey

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PC# 1293 (Attachments 1-7)

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

ATTACHMENT 5

IDNR response to FOIA request -
October 7, 2011 email with 5 attachments

---------- Forwarded message ----------
From: **Santucci, Vic** <Vic.Santucci@illinois.gov>
Date: Fri, Oct 7, 2011 at 4:33 PM
Subject: RE: FOIA regarding recent data on asian carp above Dresden Island Lock and Dam
To: Albert Ettinger <ettinger.albert@gmail.com>
Cc: "Rogner, John" <John.Rogner@illinois.gov>

Dear Mr. Ettinger,

Please find attached files containing 2010 and 2011 data summaries for Asian carp sampling upstream and downstream of the dispersal barrier. The 2010 summary tables were created from data that has undergone QA/QC measures and may be considered final, whereas 2011 summaries were created from field data sheets and are considered provisional and subject to revision. These summaries should address Question 1 below.

The extensive sampling results included in the attached summaries may also provide information on Asian carp reproduction upstream of Dresden Lock and Dam (Question 2). To date, we have not collected any young-of-year bighead or silver carp upstream of Starved Rock Lock and Dam. The Monitoring and Rapid Response Workgroup is currently in the process of developing a white paper summarizing distribution of Asian carp in the Illinois Waterway. I have attached an abstract for an oral presentation that will be given at the upcoming Midwest Fish and Wildlife Conference (Dec 4-7, 2011) by Kevin Irons et al.

In response to question 3, IDNR is planning for a small-scale rotenone at the Dispersal Barrier on October 26, 2011. This rotenone action is a fallback option to clear fish from between Barrier 2A and 2B so that Barrier 2B can be taken down for maintenance. We will attempt to clear fish by mechanical means prior to the rotenone and will only employ a rotenone action, if the mechanical clearing is unsuccessful. I have attached a copy of the barrier maintenance fish suppression plan, which should provide additional information.

Sincerely,

Vic Santucci

IDNR Fisheries

Aquatic Nuisance Species Program

2050 W. Stearns Rd.

Bartlett, IL 60103

847-608-3100 x2011

fax: 847-608-3109
Vic.Santucci@illinois.gov

From: Albert Ettinger [mailto:ettinger.albert@gmail.com]
Sent: Wednesday, September 21, 2011 10:37 AM
To: Santucci, Vic
Cc: Rogner, John
Subject: FOIA regarding recent data on asian carp above Dresden Island Lock and Dam

Dear Mr. Santucci:

Pursuant to the Illinois Freedom of Information Act, my clients, the Illinois Chapter of the Sierra Club and Prairie Rivers Network, request the Illinois Department of Natural Resources to provide data and other documents and information available to it regarding the following subjects:

1. The number of Silver and Big Head carp present in the Illinois River, the Des Plaines River or the Sanitary and Ship Canal above the Dresden Island Lock and Dam, including data of such carp caught above the Dresden Island Lock and Dam in 2010 or 2011.

2. The existence or nonexistence of successful breeding by Silver carp or Big Head carp above the Dresden Island Lock and Dam.

3. Any current plans by IDNR, the Corps of Engineers or other entities to apply rotenone in any area above the Dresden Island Lock and Dam to prevent the spread of Asian carp.

Your prompt attention to this request would be appreciated. Please call me at the number below if you have any questions.

Thank you.

--
Albert Ettinger
53 W. Jackson #1664
Chicago, Illinois 60604

Ettinger.Albert@gmail.com

773 818 4825

Attachments to October 7, 2011 email from Vic Santucci of IDNR:

Distribution of small bighead and silver carps in the Illinois Waterway

Electrofishing theory and recent assessment (Holliman 2011) suggest the Aquatic Nuisance Species Barrier in the Chicago Sanitary and Shipping Canal near Romeoville, Illinois is currently (Sep 2011) operating at parameters that will deter large fish from crossing, and further recommends operating parameters that are optimal for deterring small fish, less than 5 inches. The presence of adult bighead and silver carp in Dresden Island Pool since 2007, as detected by traditional fisheries gear represents the upstream limits of low to moderate populations of these fishes in the Upper Illinois Waterway to date, while rare occurrences of fish upstream of that has been noted. The understanding of the distribution of small fish is less widely known to management agencies and this project strives to document the current knowledge of and distribution of small fish within the Illinois River and document that information in the Mississippi/Missouri river basins where information exists. To gather the information datasets from agencies working under the AC Control Strategy Framework was assembled. In addition to these efforts, state, academic, and private consulting agencies were queried to share information on distribution of small and large asian carp collection records. To date, re-occuring numbers of small Asian carp (bighead and silver carp) have only been captured at approximately RM 180 on the Illinois River near Chillicothe, IL. In 2000, small bighead carp were documented in Starved Rock pool by bait fishers using a throw net pursuing gizzard shad; none have been collected since this record. Surveillance of the river above Starved Rock, specifically for small Asian carps, larvae, and eggs with multiple methods in 2010-2011, has yielded no specimens. The efficacy of the current ANS barrier is differential by size, and knowledge of the distribution of these small fish may offer more flexible and cost effective barrier operation. This information is also critical to define the ability of these species to reproduce in Midwestern rivers and may add information to models that may predict where AC may reproduce in Great Lake tributaries.

Fixed sites Upstream of Barrier – 2011
DC Electrofishing

Sampling trips	13
Date	23 Mar - 21 Sep
Transects	604
Effort hrs	151
Person-hrs	1630
Species	
Gizzard shad >6.0 in.	5254
Gizzard shad <6.0 in.	10158
Alewife	660
Common carp	5055
Goldfish	230
Carp x goldfish hybrid	7
Freshwater drum	108
Smallmouth buffalo	19
Bigmouth buffalo	4
Black buffalo	24
Quillback	32
White sucker	785
Channel catfish	62
Yellow bullhead	174
Black bullhead	66
Largemouth bass	2306
Smallmouth bass	99
Bluegill	2590
Green sunfish	683
Pumpkinseed	2809
Hybrid sunfish	52
Rock bass	68
White crappie	24
Black crappie	115
Golden shiner	1254
Bluntnose minnow	1694
Fathead minnow	101
Spotfin shiner	1293
Emerald shiner	741
Spottail shiner	147
Yellow perch	250
Walleye	6
Brook silverside	361
White perch	188
White bass	64
Yellow bass	38
Orangespotted sunfish	66
Ghost shiner	3
Warmouth	1
Creek chub	21
Rainbow trout	10
Northern pike	3
Round goby	39
Oriental weatherfish	56
Banded killifish	5
Grass carp	4
Sand shiner	7
Salmonid smolt	8
Brown bullhead	29
Central mudminnow	6
Spotted sucker	2
River shiner	1
Blackstripe topminnow	132
Rainbow smelt	1
Bowfin	1
Flathead catish	2
Mosquitofish	35
Chinook Salmon	1
Grass pickerel	3
Number caught	37957
Species	56
Hybrid groups	2

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PC# 1293 (Attachments 1-7)

Fixed Sites Upstream of Barrier – 2011 Trammel/Gill nets	
Sampling trips	13
Date	29 Mar - 21 Sep
Sets	255
Effort mile	43.2
Person-hrs	1610
Species	
Gizzard shad	162
Common carp	2262
Goldfish	26
Carp x goldfish hybrid	49
Freshwater drum	1202
Smallmouth buffalo	102
Bigmouth buffalo	23
Black buffalo	271
Quillback	159
Channel catfish	112
Largemouth bass	6
Smallmouth bass	3
White bass	1
Grass carp	3
Flathead catfish	4
River carpsucker	1
All species	4386
Species	15
Hybrid groups	1

Fixed Sites Downstream of Barrier - 2011

DC Electrofishing

Sampling trips	7				
Date	21 Mar - 9 Sep				
Transects	28	28	28	28	112
Effort hrs	7	7	7	7	28
Person-hrs	180		210		570
Species	Lockport	Brandon	Dresden	Marseilles	All pools
Gizzard shad > 6"	132	114	242	265	753
Gizzard shad < 6"	1292	1077	525	1471	4365
Common carp	238	219	270	48	775
Goldfish	2	14	10	2	28
Carp x goldfish hybrid		1			1
Grass carp		1			1
Silver carp				65	65
Bighead carp				8	8
Freshwater drum	2	8	10	28	48
Longnose gar	2		41	32	75
Shortnose gar				5	5
Channel Catfish	1	19	19	4	43
Flahead Catfish		1		1	2
Yellow bullhead	5	25	9	0	39
Smallmouth buffalo		1	78	244	323
Bigmouth buffalo			1	53	54
Black buffalo				5	5
River carpsucker			5	50	55
Quillback				22	22
White sucker		12	1	1	14
Golden redhorse			10	53	63
Shorthead redhorse			2	11	13
Silver redhorse			1	3	4
Northern hog sucker			1	1	2
Largemouth bass	23	22	129	45	219
Smallmouth bass		7	28	34	69
Bluegill	8	68	248	71	395
Green sunfish	35	38	72	13	158
Rock bass			5		5
Pumpkinseed	20	23	16	2	61
Orangespotted sunfish		16	3	2	21
Hybrid sunfish	5	2	15	4	26
Black crappie		1	6	4	11
White crappie	2	4		3	9
Northern pike		5	1		6
White bass		1	2	29	32
Yellow bass	1		1	6	8
Spottail shiner		3	16	15	34
Golden shiner	1	4	3	4	12
Emerald shiner	22	39	45	204	310
Spotfin shiner	1	2		39	42
Bluntnose minnow	5	15	47	10	77
Walleye			1	2	3
Sauger		1		2	3
White perch		2		4	6
Skipjack herring	1		1	3	5
Brown bullhead			3		3
River shiner				4	4
Mosquitofish		2	1		3
Goldeye				1	1
Sand shiner		1			1
Longear sunfish			1	2	3
Grass pickerel	1	3			4
Oriental weatherfish	1				1
Logperch				5	5
Suckermouth minnow			1	2	3
Warmouth			1		1
Blackstripe topminnow	1		1		2
Round goby		2			2
Brook silverside				3	3
Banded darter				2	2
Bullhead minnow			1	11	12
Common shiner			2		2
White perch hybrid			1		1
Threadfin				43	43
Unidentified minnow		1			1
All species	1801	1754	1876	2941	8372
Species	21	31	40	48	60
Hybrid groups	1	2	2	1	3

Fixed Sites Downstream of Barrier -2011
Trammel/gill nets

Sampling trips	7				
Date	21 Mar – 22 Sep				
Gear	TRA/GN	TRA/GN	TRA/GN	TRA/GN	
Sets	22	28	28	28	106
Effort (yds)	3.6	3.0	3.6	3.7	13.9
Person-hours	210		210		420
Site	Lockport	Brandon	Dresden	Marseilles	All Pools
Gizzard shad			1		1
Common carp	11	249	241	13	514
Goldfish		4	1		5
Carp x goldfish hybrid		22	2		24
Grass carp		2	2	5	9
Silver carp				83	83
Bighead carp			8	65	73
Freshwater drum		4	17	5	26
Longnose gar		1	2		3
Shortnose gar			0	1	1
Channel catfish		17	30	1	48
Flahead catfish			1	1	2
Yellow bullhead			1		1
Smallmouth buffalo		3	149	8	160
Bigmouth buffalo			6	29	35
Black buffalo			37	7	44
River carpsucker			3	5	8
Quillback			2	2	4
Northern pike			2		2
Skipjack herring			1		1
All species	11	302	506	225	1044
Species	1	7	18	13	19
Hybrid groups	0	1	1	0	1

Warm Water Discharge Sampling

Table 1. Electrofishing (AC and DC) catch, effort, and summary statistics for various waterways in the Chicago Area Waterway System sampled during Asian carp warmwater discharge sampling, 2 February - 25 March 2010. Catch-per-unit-effort (CPUE) includes only effort data from samples where fish were counted. Waterways are: CSSC = Chicago Sanitary and Ship Canal; CalSag = Calumet-Sag Channel; NSC = North Shore Channel; SBCR = South Branch Chicago River; LCal = Lake Calumet; CalR = Calumet River; LCalR = Little Calumet River; NBCR = North Branch Chicago River. FNC indicates fish were not counted during sampling.

	Waterway											All
Species	CSSC	CSSC& CalSag	CSSC& SBCR	LCal	LCal& CalR	LCalR	NSC	NSC&NBCR	SBCR	LCalR& CalSag	CalSag	waterways
Gizzard shad	4076		1037	92		177	539	220	794			6935
Common carp	760	50	497	108	47	392	85	38	329			2306
Bluntnose minnow	710		2		1		7					720
Goldfish	571		3			2	1	1				578
Bluegill	74	2	9		1		193	100	24			403
Yellow perch					323							323
Largemouth bass	125	2	72	23		3	40	7	50			322
Sunfish sp.	130		43				5	100				278
Minnow sp.	150								100			250
Channel catfish	113		16	2				5	1			137
Pumpkinseed	111		4		1				15			131
Mosquitofish	120											120
White sucker	3		2			51	60					116
Emerald shiner	62		1	20	1	5						89
Round goby	55		1									56
Golden shiner	35		2		1		1					39
Bigmouth buffalo				5	18	2						25
Black crappie			11		1		1	3	2			18
Black bullhead	10							2				12
Yellow bullhead	9		2									11
Quillback						10						10
White crappie			8				1	1				10
White perch	5		5									10
Freshwater drum	4		1	2		1						8
Green sunfish	5		3									8
Smallmouth bass				5								5
Banded killifish					2							2
Hybrid sunfish			2									2
Brook silverside					2							2
Grass carp	1					1						2
Rainbow trout			2									2
Rock bass					2							2
Walleye			2									2
Black buffalo			1									1
Smallmouth buffalo				1								1
Sand shiner									1			1
Spottail shiner					1							1
White bass				1								1
All species	7129	54	1726	259	401	644	933	477	1316	FNC	FNC	12939
Effort (hours)	12.7	2.4	16.9	2.3	5.4	14.0	2.3	1.5	2.5	6.0	6.0	71.9
CPUE (*N*/minute)	17.7	0.4	2.7	1.9	1.2	1.4	6.9	5.2	8.8	--	--	5.2
Species (*N*)	19	3	21	9	13	7	9	8	8	--	--	35
Hybrids (*N*)	1	0	1	0	0	1	1	1	0	--	--	1
Bighead carp	0	0	0	0	0	0	0	0	0	0	0	0
Silver carp	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. Trammel/gill net catch, effort, and summary statistics for various waterways in the Chicago Area Waterway System sampled during Asian carp warmwater discharge sampling, 2 - 26 February 2010. Catch-per-unit-effort (CPUE) includes only effort data from samples where fish were counted. Waterways are: CSSC = Chicago Sanitary and Ship Canal; CalSag = Calumet-Sag Channel; NSC = North Shore Channel; SBCR = South Branch Chicago River; LCalR = Little Calumet River.

	Waterway						All
Species	CSSC	CSSC&CalSag	CSSC&SBCR	LCalR	NSC	SBCR	waterways
Common carp	79	18	302	44	2	19	464
Channel catfish	1		1				2
Gizzard shad	1						1
All Species	81	18	303	44	2	19	467
Effort (yards)	4735	1900	2867	833	133	133	10602
CPUE (*N*/100 yards)	5.3	0.9	10.6	5.3	1.5	14.3	6.3
Species (*N*)	3	1	2	1	1	1	3
Hybrids (*N*)	0	0	0	0	0	0	0
Bighead carp	0	0	0	0	0	0	0
Silver carp	0	0	0	0	0	0	0

Fixed Sites Upstream of Barrier

Table 1. Electrofishing (DC) catch, effort, and summary statistics for various waterways in the Chicago Area Waterway System sampled twice monthly (once in November) during Asian carp fixed site sampling, 22 June - 18 November 2010. Catch-per-unit-effort (CPUE) includes only effort data from samples where fish were counted. Waterways are: LCal = Lake Calumet; LCalR = Little Calumet River; CSSC&SBCR = Chicago Sanitary and Ship Canal and South Branch Chicago River (Jackson Ave. to Western Ave.); NSC&NBCR = North Shore Channel and North Branch Chicago River (Peterson Ave. to Montrose Ave); and NSC = North Shore Channel (Wilmette Pumping Station to Golf Road).

	Waterway					All
Species	LCal	LCalR	CSSC&SBCR	NSC&NBCR	NSC	waterways
Gizzard shad	306	2714	103	249	43	3415
Gizzard shad <6.0 in.	47	334	1039	313	123	1856
Gizzard shad >6.0 in.	2648	4918	2176	1305	787	11834
Common carp	928	2490	662	526	596	5202
Largemouth bass	1148	1050	330	116	244	2888
Bluntnose minnow	678	199	180	52	56	1165
Bluegill	289	349	270	95	101	1104
Emerald shiner	291	277	139	96	70	873
Pumpkinseed	152	228	82	60	285	807
Golden shiner	49	52	146	84	408	739
Spotfin shiner	11	37	224	245	111	628
White sucker	7	239		175	93	514
Brook silverside	248	140	6	2		396
Yellow perch	104	19	1	2	214	340
Goldfish	5	199	29	15	37	285
White perch	23	206	3		2	234
Green sunfish	10	71	30	3	33	147
Freshwater drum	84	58	2			144
Fathead minnow	48	69	1	3		121
Smallmouth bass	60	29				89
Yellow bullhead	16	24	13	25	9	87
Yellow bass		76	9			85
White bass	10	58	9			77
Channel catfish	24	10	9	13	19	75
Alewife	7	39	1		24	71
Spottail shiner		19	21	3	29	72
Black crappie	5	12	8	3	26	54
Black bullhead	3	17	21	3	1	45
Rock bass	21	5	3	2	11	42
Smallmouth buffalo	12	22	1			35
Quillback	4	31				35
Round goby	18	3	2	1	8	32
Hybrid sunfish	7	2	20	1		30
Chinook salmon	15	5		2	1	23
White crappie	8	14			1	23
Central mudminnow		20				20
Orangespotted sunfish	17		1	1		19
Threadfin shad	12	1				13
Oriental weatherfish		1	6	2	3	12
Blackstripe topminnow			7		1	8
Bigmouth buffalo	7					7
Goldfish x Common carp hybrid		3	3	1		7
Coho salmon	1	1			2	4
Ghost shiner		4				4
Banded killifish	2	1				3
Black buffalo	2	1				3
Creek chub			1		2	3
Mosquitofish			3			3
Walleye			3			3
Bowfin		2				2
Brown bullhead		2				2
Northern pike					2	2
Sand shiner					2	2
Brown trout					1	1
Buffalo sp.		1				1
UID minnow		1				1
Pumpkinseed x Bluegill hybrid		1				1
Rainbow trout	1					1
All species	900	2685	2220	990	990	7785
Effort (hours)	15.0	44.8	37.0	16.5	16.5	129.8
CPUE (*N*/minute)	9.0	6.9	3.5	4.7	4.6	5.7
Species (*N*)	37	41	33	25	31	51
Hybrids (*N*)	1	3	2	2	0	3
Bighead carp	0	0	0	0	0	0
Silver carp	0	0	0	0	0	0

Table 2. Trammel and gill net catch, effort, and summary statistics for various waterways in the Chicago Area Waterway System sampled twice monthly (once in November) during Asian carp fixed site sampling, 22 June - 16 September 2010. Waterways are: LCal = Lake Calumet; LCalR = Little Calumet River; CSSC&SBCR = Chicago Sanitary and Ship Canal and South Branch Chicago River (Jackson Ave. to Western Ave.); NSC&NBCR = North Shore Channel and North Branch Chicago River (Peterson Ave. to Montrose Ave); and NSC = North Shore Channel (Wilmette Pumping Station to Golf Road).

	Waterway					All
Species	LCal	LCalR	CSSC&SBCR	NSC&NBCR	NSC	waterways
Common carp	1090	520	217	15	17	1859
Black buffalo	233	15				248
Smallmouth buffalo	108	2				110
Freshwater drum	79	5		1		85
Channel catfish	45	1		1		47
Goldfish x Common carp hybrid	1	9	11	9	4	34
Smallmouth bass	14					14
Bigmouth buffalo	8	3				11
Quillback	8					8
Gizzard shad	6					6
Flathead catfish	5					5
Grass carp	3					3
Alewife		2				2
Goldfish		2				2
Largemouth bass	2					2
Bighead carp	1					1
Bluegill				1		1
Walleye			1			1
All species	1603	559	229	27	21	2439
Effort (yards)	14500	14700	7200	2800	2800	42000
CPUE (*N*/100 yards)	11.1	3.8	3.2	1.0	0.8	5.8
Species (*N*)	13	8	2	4	1	17
Hybrids (*N*)	1	1	1	1	1	1
Bighead carp	1	0	0	0	0	1
Silver carp	0	0	0	0	0	0

Table 3. Mean, minimum, and maximum total lengths for a subsample of fish sampled with DC electrofishing gear at various waterways in the Chicago Area Waterway System during Asian carp fixed site sampling, 14-15 September 2010. Waterways are LCal = Lake Calumet; LCalR = Little Calumet River; CSSC&SBCR = Chicago Sanitary and Ship Canal and South Branch Chicago River (Jackson Ave. to Western Ave.); NSC&NBCR = North Shore Channel and North Branch Chicago River (Peterson Ave. to Montrose Ave); and NSC = North Shore Channel (Wilmette Pumping Station to Golf Road).

	LCal				LCalR				CSSC&SBCR			
Species	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)
Alewife												
Hybrid sunfish									3	6.8	5.4	7.8
Black bullhead	1	--	8.0	8.0	1	--	11.6	11.6				
Black crappie	1	--	7.5	7.5	5	3.1	2.8	3.3	4	6.7	4.8	8.2
Bluegill	10	3.2	2.0	6.3	10	2.9	1.9	4.9	10	3.3	1.9	7.0
Bluntnose minnow	10	2.4	1.8	2.8	10	2.7	2.1	3.1	10	3.0	2.7	3.3
Blackstripe topminnow												
Brook silverside	8	2.1	1.6	2.8					1	--	3.1	3.1
Common carp	10	23.3	21.2	24.7	10	22.7	20.2	25.9	6	17.3	6.7	24.8
Channel catfish	1	--	17.8	17.8					1	--	17.4	17.4
Central mudminnow					4	3.6	3.4	3.9				
Emerald shiner	10	3.9	3.4	4.3	10	3.1	2.0	4.4				
Fathead minnow				0.0	5	2.6	2.6	2.8				
Freshwater drum	10	13.8	10.5	16.5	6	10.4	3.7	17.9				
Goldfish					10	8.4	4.7	12.1	10	5.6	3.9	11.3
Golden shiner	10	4.6	3.1	6.4	5	5.2	4.3	5.8	10	2.9	1.5	5.9
Green sunfish	1	--	3.4	3.4	8	2.9	1.9	4.8	5	3.1	1.7	4.4
Gizzard shad <6.0 in.	10	3.9	3.0	4.9	10	3.6	2.9	4.8				
Gizzard shad >6.0 in.	5	11.5	10.2	12.8	10	10.9	9.4	13.3	20	6.8	4.1	10.7
Largemouth bass	10	4.9	3.7	6.0	10	6.5	3.5	12.6				
Orangespotted sunfish									2	5.9	4.5	7.3
Pumpkinseed	10	3.7	2.4	5.0	10	4.2	2.8	5.6	10	4.8	3.8	5.9
Round goby	2	4.1	3.4	4.8								
Smallmouth buffalo	7	24.5	18.0	27.5	4	16.2	4.8	28.1				
Sand shiner												
Spotfin shiner					1	--	3.0	3.0	7	2.5	1.6	3.5
Smallmouth bass	6	6.9	3.7	15.8	3	4.7	3.3	6.6				
Spottail shiner												
White bass	2	13.7	12.6	14.8	10	6.9	4.8	11.7				
White crappie	5	8.6	7.9	10.7	2	7.4	7.1	7.7				
White perch	6	6.1	3.8	8.3								
White sucker					10	14.4	10.1	16.7				
Yellow bullhead					6	7.4	3.9	12.2	2	7.9	6.9	8.9
Yellow perch	3	7.4	7.0	7.9	4	4.6	3.5	5.1	1	--	3.1	3.1
Yellow bass					10	4.0	2.7	6.5				
All species	138	8.0	1.6	27.5	174	7.1	1.9	28.1	102	5.6	1.5	24.8

Table 3. Extended.

Species	NSC&NBCR Number measured	NSC&NBCR Mean total length (inches)	NSC&NBCR Minimum total length (inches)	NSC&NBCR Maximum total length (inches)	NSC Number measured	NSC Mean total length (inches)	NSC Minimum total length (inches)	NSC Maximum total length (inches)
Alewife					1	--	2.6	2.6
Hybrid sunfish								
Black bullhead								
Black crappie	1.0	--	8.9	8.9	3	6.4	5.3	8.4
Bluegill	7.0	5.3	4.6	6.9	6	3.0	2.0	5.4
Bluntnose minnow	2.0	2.9	2.9	2.9	1	--	1.8	1.8
Blackstripe topminnow					1	--	1.4	1.4
Brook silverside								
Common carp	10.0	22.5	10.4	26.7	3	--	3.9	4.3
Channel catfish	1.0	--	16.5	16.5				
Central mudminnow								
Emerald shiner	10.0	4.1	3.6	4.4				
Fathead minnow	1.0	--	2.7	2.7				
Freshwater drum								
Goldfish					1	--	6.5	6.5
Golden shiner	10.0	4.5	2.4	7.0	10	3.8	2.2	5.6
Green sunfish					2	2.2	2.0	2.4
Gizzard shad <6.0 in.	10.0	5.1	4.4	5.9	10	5.1	4.5	5.7
Gizzard shad >6.0 in.	10.0	10.5	8.3	12.3	10	9.5	7.6	11.6
Largemouth bass	10.0	10.2	3.0	14.6	10	6.2	3.3	11.5
Orangespotted sunfish								
Pumpkinseed	4.0	5.1	4.8	5.2	10	5.3	4.8	6.1
Round goby								
Smallmouth buffalo								
Sand shiner					1	--	2.6	2.6
Spotfin shiner	10.0	3.0	2.7	3.6	10	3.2	2.8	3.6
Smallmouth bass								
Spottail shiner					4	2.7	2.5	3.1
White bass								
White crappie								
White perch					1	--	8.8	8.8
White sucker	10.0	13.3	9.6	17.1	6	11.1	8.3	16.0
Yellow bullhead	3.0	8.8	8.4	9.3				
Yellow perch	2.0	3.5	3.4	3.5	10	3.5	3.1	4.1
Yellow bass								
All species	101.0	8.5	2.4	26.7	100	5.2	1.4	16.0

Table 1. Rotenone, DC electrofishing, and trammel/gill net catch, effort, and summary statistics for the Little Calumet River sampled during the Operation Pelican Rapid Response, 20-26 May 2010. Electrofishing took place on 20, 21, and 23 May and netting operations on 20-23 May.

Species	Rotenone	DC Electrofishing All species	DC Electrofishing Sport fish only	Trammel or gill nets	All gears
Gizzard shad	22298	45		148	22491
Common carp	9820	272		561	10653
Ghost shiner	6945				6945
Emerald shiner	4342	73	1		4416
Alewife	3485	7	1		3493
Freshwater drum	3178	5	5	174	3362
Bluntnose minnow	2374	52			2426
Goldfish	2293	72		5	2370
Round goby	2109	100			2209
Channel catfish	1959	24	1	33	2017
Rock bass	1244	5	1		1250
Pumpkinseed	1098	97	26		1221
White perch	1059	24		1	1084
Bluegill	783	25	9		817
Spotfin shiner	464				464
Golden shiner	434	1			435
Yellow bullhead	366	2		2	370
Black crappie	333		10		343
White sucker	319	21	3		343
Fathead minnow	325	11			336
White crappie	319	1	1		321
Largemouth bass	219	21	61		301
Yellow perch	268	5	3		276
Black bullhead	264	7			271
Black buffalo	205			16	221
Spottail shiner	213				213
Orangespotted sunfish	174				174
White bass	82	2	1		85
Green sunfish	49	10	1		60
Goldfish x Common carp hybrid	53			5	58
Smallmouth bass	45		2		47
Grass carp	43				43
Warmouth	18				18
Yellow bass	10	5		1	16
Smallmouth buffalo	12				12
Brown bullhead	8				8
Flathead catfish	8				8
Hybrid sunfish	2	1			3
Grass pickerel	2				2
Bigmouth buffalo		2			2
Johnny darter	1				1
Oriental weatherfish		1			1
Rainbow trout		1			1
All species	67224	892	126	946	69188
Effort (acres, hours, or yards)	173	4	6	4800	--
CPUE (N/acre, minute, or 100 yards)	388.6	3.7	0.4	19.7	--
Species (*N*)	38	27	15	9	41
Hybrids (*N*)	2	1	0	1	2
Bighead carp	0	0	0	0	0
Silver carp	0	0	0	0	0

Table 2. Estimated total number and percentage, total weight and percentage, and standing stock for 38 species of fish and two hybrid groups recovered from the Little Calumet River near T. J. O'Brien Lock and Dam during six days of recovery after rotenone application on May 20, 2010. Weight was not measured for most minnow and darter species.

Species	Estimated Total Number	Percent	Estimated Total Weight	Percent	Estimated Standing Stock: Number per acre	Estimated Standing Stock: Pounds per acre
Gizzard shad	22298	33.2	19489.7	19.9	129	112.66
Common carp	9820	14.6	61744.5	63.2	57	356.90
Ghost shiner	6945	10.3	--	--	40	--
Emerald shiner	4342	6.5	101.9	0.1	25	0.59
Alewife	3485	5.2	215.6	0.2	20	1.25
Freshwater drum	3178	4.7	7669.1	7.8	18	44.33
Bluntnose minnow	2374	3.5	--	--	14	--
Goldfish	2293	3.4	1398.4	1.4	13	8.08
Round goby	2109	3.1	8.4	0.0	12	0.05
Channel catfish	1959	2.9	2480.7	2.5	11	14.34
Rock bass	1244	1.8	390.8	0.4	7	2.26
Pumpkinseed	1098	1.6	120.1	0.1	6	0.69
White perch	1059	1.6	203.8	0.2	6	1.18
Bluegill	783	1.2	85.1	0.1	5	0.49
Spotfin shiner	464	0.7	--	--	3	--
Golden shiner	434	0.6	54.7	0.1	3	0.32
Yellow bullhead	366	0.5	256.4	0.3	2	1.48
Black crappie	333	0.5	40.9	0.0	2	0.24
Fathead minnow	325	0.5	--	--	2	--
White crappie	319	0.5	90.0	0.1	2	0.52
White sucker	319	0.5	306.4	0.3	2	1.77
Yellow perch	268	0.4	50.2	0.1	2	0.29
Black bullhead	264	0.4	53.5	0.1	2	0.31
Largemouth bass	219	0.3	246.9	0.3	1	1.43
Spottail shiner	213	0.3	--	--	1	--
Black buffalo	205	0.3	1424.1	1.5	1	8.23
Orangespotted sunfish	174	0.3	2.4	0.0	1	0.01
White bass	82	0.1	84.1	0.1	0	0.49
Goldfish x Common carp hybrid	53	0.1	137.9	0.1	0	0.80
Green sunfish	49	0.1	2.8	0.0	0	0.02
Smallmouth bass	45	0.1	32.9	0.0	0	0.19
Grass carp	43	0.1	872.6	0.9	0	5.04
Warmouth	18	<0.1	2.9	0.0	0	0.02
Smallmouth buffalo	12	<0.1	90.0	0.1	0	0.52
Yellow bass	10	<0.1	2.0	0.0	0	0.01
Brown bullhead	8	0.0	5.4	0.0	0	0.03
Flathead catfish	8	<0.1	55.3	0.1	0	0.32
Grass pickerel	2	<0.1	0.2	0.0	0	0.00
Hybrid sunfish	2	<0.1	0.2	0.0	0	0.00
Johnny darter	1	<0.1	--	--	0	--
All species	67224		97720.0		389	564.86

Table 3. Number and percentage of fish recovered and counted from the Little Calumet River near T. J. O'Brien Lock and Dam during the first three days after rotenone application on May 20,2010.

	Number				Percent		
Species	Day 1	Day 2	Day 3	Total	Day 1	Day 2	Day 3
Gizzard shad	2861	2667	5374	10902	38.00	12.37	59.39
Ghost shiner	54	6786	105	6945	0.72	31.46	1.16
Common carp	2088	1215	1498	4801	27.74	5.63	16.56
Bluntnose minnow	170	2168	36	2374	2.26	10.05	0.40
Emerald shiner	186	1893	44	2123	2.47	8.78	0.49
Alewife	505	1040	159	1704	6.71	4.82	1.76
Freshwater drum	381	1045	128	1554	5.06	4.85	1.41
Goldfish	37	709	375	1121	0.49	3.29	4.14
Round goby	122	875	34	1031	1.62	4.06	0.38
Channel catfish	92	426	440	958	1.22	1.98	4.86
Rock bass	83	450	75	608	1.10	2.09	0.83
Pumpkinseed	178	251	108	537	2.36	1.16	1.19
White perch	89	341	88	518	1.18	1.58	0.97
Spotfin shiner	8	449	7	464	0.11	2.08	0.08
Bluegill	101	106	176	383	1.34	0.49	1.95
Fathead minnow	27	293	5	325	0.36	1.36	0.06
Spottail shiner	2	204	7	213	0.03	0.95	0.08
Golden shiner	86	108	18	212	1.14	0.50	0.20
Yellow bullhead	30	56	93	179	0.40	0.26	1.03
Black crappie	24	93	46	163	0.32	0.43	0.51
White crappie	29	70	57	156	0.39	0.32	0.63
White sucker	67	32	57	156	0.89	0.15	0.63
Yellow perch	17	102	12	131	0.23	0.47	0.13
Black bullhead	23	56	50	129	0.31	0.26	0.55
Largemouth bass	63	17	27	107	0.84	0.08	0.30
Black buffalo	89	10	1	100	1.18	0.05	0.01
Orangespotted sunfish	9	70	6	85	0.12	0.32	0.07
White bass	28	5	7	40	0.37	0.02	0.08
Goldfish x Common carp hybrid	9	16	1	26	0.12	0.07	0.01
Green sunfish	16	1	7	24	0.21	0.00	0.08
Smallmouth bass	12	8	2	22	0.16	0.04	0.02
Grass carp	21	0	0	21	0.28	0.00	0.00
Warmouth	6	0	3	9	0.08	0.00	0.03
Smallmouth buffalo	1	4	1	6	0.01	0.02	0.01
Yellow bass	5	0		5	0.07	0.00	0.00
Brown bullhead	3	1	0	4	0.04	0.00	0.00
Flathead catfish	4	0	0	4	0.05	0.00	0.00
Grass pickerel	1	0	0	1	0.01	0.00	0.00
Hybrid sunfish	1	0	0	1	0.01	0.00	0.00
Johnny darter	0	0	1	1	0.00	0.00	0.01
All species	7528	21567	9048	38143	100.00	100.00	100.00

Table 4. Mean, minimum, and maximum total lengths and weights for a subsample of fish recovered from the Little Calumet River near T. J. O'Brien Lock and Dam during the first two days after rotenone application on May 20, 2010.

Species	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)	Number weighed	Mean weight (pounds)	Minimum weight (pounds)	Maximum weight (pounds)
Alewife	24	6.3	5.5	7.0	24	0.06	0.04	0.11
Black buffalo	74	23.1	18.4	29.3	74	6.96	1.73	13.20
Black bullhead	46	6.9	5.2	12.6	46	0.20	0.07	0.93
Black crappie	83	5.7	2.6	9.6	79	0.12	0.01	0.45
Bluegill	79	4.9	1.3	8.0	76	0.11	0.00	0.39
Bluntnose minnow	8	2.8	1.3	4.3	0	--	--	--
Brown bullhead	3	10.6	9.6	12.2	3	0.66	0.37	1.02
Channel catfish	76	13.5	5.0	23.0	76	1.27	0.01	5.53
Common carp	103	21.9	9.7	29.6	103	6.29	0.67	18.15
Emerald shiner	11	3.4	1.1	4.6	3	0.02	0.02	0.03
Fathead minnow	8	2.1	1.6	2.9	0	--	--	--
Flathead catfish	4	23.0	17.7	32.4	4	6.76	2.20	16.02
Freshwater drum	51	16.3	12.9	20.9	51	2.41	0.98	6.13
Ghost shiner	16	1.9	1.1	2.5	0	--	--	--
Gizzard shad	81	11.8	4.0	19.0	80	0.87	0.03	2.73
Golden shiner	54	6.2	2.0	8.4	49	0.13	0.02	0.24
Goldfish	61	8.9	4.8	13.2	61	0.61	0.15	2.09
Goldfish x Common carp hybrid	9	15.3	7.9	19.0	9	2.59	0.30	4.78
Grass carp	21	34.1	25.6	43.0	21	20.32	8.25	39.60
Grass pickerel	1	7.9	7.9	7.9	1	0.10	0.10	0.10
Green sunfish	16	4.2	3.3	5.9	16	0.06	0.03	0.13
Hybrid sunfish	1	5.1	5.1	5.1	1	0.09	0.09	0.09
Johnny darter	0	--	--	--	0	--	--	--
Largemouth bass	51	12.6	3.5	16.1	51	1.13	0.02	2.24
Orangespotted sunfish	30	2.6	1.3	3.7	24	0.01	0.00	0.04
Pumpkinseed	91	4.9	1.8	7.5	90	0.11	0.00	0.35
Rock bass	76	6.7	1.7	10.2	72	0.31	0.03	0.63
Round goby	8	2.7	1.6	4.4	0	--	--	--
Smallmouth bass	20	10.3	4.1	16.9	20	0.73	0.02	2.40
Smallmouth buffalo	5	23.1	21.4	25.2	5	7.33	5.76	9.16
Spotfin shiner	8	2.9	1.7	4.1	0	--	--	--
Spottail shiner	4	4.4	3.0	5.4	0	--	--	--
Warmouth	6	5.5	4.4	7.0	6	0.16	0.06	0.32
White bass	26	12.6	10.1	15.2	26	1.03	0.46	1.86
White crappie	75	8.1	2.7	10.7	74	0.28	0.01	0.66
White perch	51	6.7	1.3	9.1	50	0.19	0.01	0.41
White sucker	66	13.3	5.2	19.1	66	0.96	0.06	2.50
Yellow bass	5	6.6	3.5	8.6	5	0.19	0.02	0.45
Yellow bullhead	58	10.1	4.9	13.2	58	0.70	0.09	1.45
Yellow perch	59	7.5	3.9	9.9	59	0.19	0.02	0.51
Grand Total	1469				1383			

Bubbly Creek Rapid Response

Table 1. Electrofishing (DC) catch, effort, and summary statistics for various waterways in the Chicago Area Waterway System sampled during the Bubbly Creek Rapid Response, 15 - 16 June 2010. Waterways are: BubCr = Bubbly Creek; CSSC = Chicago Sanitary and Ship Canal; and SBCR = South Branch Chicago River.

	Waterway			All
Species	BubCr	CSSC	SBCR	waterways
Gizzard shad	38	12	203	253
Common carp	30	65	97	192
Golden shiner	43	9	68	120
Bluegill	23	10	76	109
Bluntnose minnow	6	27	70	103
Pumpkinseed	22	13	58	93
Largemouth bass	4	8	59	71
Spotfin shiner	12		34	46
Green sunfish	1	3	23	27
Hybrid sunfish		2	19	21
Fathead minnow			9	9
Goldfish	1		6	7
Black crappie	3		3	6
Yellow bass			6	6
Black bullhead	1	2		3
Smallmouth buffalo			3	3
Spottail shiner		3		3
White crappie			3	3
Rock bass			2	2
Yellow bullhead			2	2
Blackstripe topminnow		1		1
Bowfin			1	1
Creek chub			1	1
Emerald shiner			1	1
Freshwater drum		1		1
Orangespotted sunfish			1	1
Oriental weatherfish		1		1
All species	184	157	745	1086
Effort (hours)	1.0	1.0	2.0	4.0
CPUE (*N*/minute)	3.1	2.6	6.2	4.5
Species (*N*)	12	13	21	26
Hybrids (*N*)	0	1	1	1
Bighead carp	0	0	0	0
Silver carp	0	0	0	0

Table 2. Trammel net catch, effort, and summary statistics for various waterways in the Chicago Area Waterway System sampled during the Bubbly Creek Rapid Response, 15 - 16 June 2010. Waterways are: BubCr = Bubbly Creek; CSSC = Chicago Sanitary and Ship Canal; and SBCR = South Branch Chicago River.

	Waterway			All
Species	BubCr	CSSC	SBCR	waterways
Common carp	40	55	34	129
Goldfish	2	3	1	6
Channel catfish	1		1	2
Goldfish x Common carp hybrid	2			2
All species	45	58	36	139
Effort (yards)	400	400	600	1400
CPUE (*N*/100 yards)	11.3	14.5	6.0	9.9
Species (*N*)	3	2	3	3
Hybrids (*N*)	1	0	0	1
Bighead carp	0	0	0	0
Silver carp	0	0	0	0

North Shore Channel Rapid Response

Table 1. Trammel and gill net catch, effort, and summary statistics for the North Shore Channel sampled during the North Shore Channel Rapid Response, 11-13 May 2010. Catch-per-unit-effort (CPUE) includes only effort data from samples where fish were counted. Samples with no fish counted included 20 hours of DC electrofishing on 12 May and 1467 yards of trammel/gill net retrieved on 13 May.

Species	Trammel net	Gill net	All gears
Common carp	461	8	469
Gizzard shad	10	30	40
Goldfish x Common carp hybrid	25	2	27
White sucker		11	11
Largmouth bass	2	7	9
Goldfish	5	2	7
Channel catfish	4	1	5
Black bullhead		2	2
Rock bass	1	1	2
Northern pike		1	1
All species	508	65	573
Effort (yards)	1533	50	--
CPUE (*N*/100 yards)	33.1	130.0	--
Species (*N*)	6	9	9
Hybrids (*N*)	1	1	1
Bighead carp	0	0	0
Silver carp	0	0	0

Lake Calumet Rapid Response

Table 1. Electrofishing (DC) catch, effort, and summary statistics for various waterways sampled during the Lake Calumet Rapid Response, 25 June - 9 July 2010. Catch-per-unit-effort (CPUE) includes only effort data from samples where fish were counted. Waterways are: LCal = Lake Calumet; and CalR = Calumet River.

	Waterway		All
Species	LCal	CalR	waterways
Emerald shiner	1	2010	2011
Bluntnose minnow	4	2000	2004
Largemouth bass	135	43	178
Rock bass	8	163	171
Common carp	6	150	156
Smallmouth bass	9	123	132
Gizzard shad	10	114	124
Yellow perch	77	21	98
White sucker		79	79
Bluegill	49	20	69
Freshwater drum	2	62	64
Orangespotted sunfish	9	25	34
Quillback		30	30
Round goby		29	29
Bigmouth buffalo		27	27
Smallmouth buffalo		11	11
Green sunfish		9	9
Channel catfish	4		4
White bass	2	2	4
Hybrid sunfish		3	3
Goldfish		3	3
Golden shiner	1	2	3
White crappie	3		3
Brown bullhead	1		1
All species	321	4926	5247
Effort (hours)	10.4	44.1	54.5
CPUE (N/minute)	0.8	1.9	1.7
Species (N)	16	18	23
Hybrids (N)	0	1	1
Bighead carp	0	0	0
Silver carp	0	0	0

Table 1. Trammel net and commercial seine catch, effort, and summary statistics for Lake Calumet sampled during the Lake Calumet Rapid Response, 23 June-9 July 2010.

	Gear		
Species	Trammel net	Commercial seine	All gears
Bigmouth buffalo	34		34
Black buffalo	350	2	352
Common carp	2054	3943	5997
Channel catfish	40	284	324
Goldfish x Common carp hybrid	2		2
Flathead catfish	1		1
Freshwater drum	221	365	586
Grass carp	2	10	12
Gizzard shad	35	2193	2228
Smallmouth buffalo	161	9	170
Smallmouth bass	11		11
Quillback	3		3
White perch	1		1
White crappie		11	11
Largemouth bass		4	4
White bass		14	14
All species	2915	6835	9750
Effort (yards)	16600	1760	--
CPUE (N/100 yards)	17.6	388.4	--
Species (N)	12	10	15
Hybrids (N)	1	0	1
Bighead carp	0	0	0
Silver carp	0	0	0

Lockport Pool Sampling

Table 1. Catch, effort, and summary statistics for various gears used to sample the Chicago Sanitary and Ship Canal during the Lockport Pool Barrier Maintenance Targeted Response, 19-21 October 2010. Effort is hours for electrofishing, yards of net for trammel and experimental gill nets, net-nights for mini-fyke nets, 10-minute tows for midwater trawl, and hauls for purse seine. CPUE is *N*/minute for electrofishing, *N*/100 yards of net for trammel and experimental gill nets, *N*/net-night for mini-fyke nets, *N*/10-minute tow for midwater trawl, and *N*/haul for purse seine.

	Gear						
Species	DC electro-fishing	Trammel net	Experimental gill net	Mini-fyke net	Midwater trawl	Purse seine	All gears
Gizzard shad <6 in.	2351		25	50			2426
Gizzard shad >6 in.	126		93				219
Emerald shiner	356			28		5	389
Green sunfish	2		3	249	1		255
Common carp	8	64	65				137
Bluegill	1			118			119
White perch	1		98	6	3		108
Channel catfish	5	1	18	76	1		101
Threadfin shad	53		1			16	70
Freshwater drum	5	1	48				54
Largemouth bass	47		7				54
Yellow bullhead			18	19			37
Bluntnose minnow				26			26
Spottail shiner				22			22
Pumpkinseed	5		2	9			16
Black crappie				12			12
Orangespotted sunfish				9			9
Skipjack herring			7				7
Goldfish	1	1	4				6
Black bullhead			1	4			5
Oriental weatherfish				5			5
White bass	3			1			4
White perch hybrid					4		4
Yellow bass			1	3			4
Central mudminnow	2						2
Golden shiner				2			2
Warmouth				2			2
White crappie				2			2
White sucker			2				2
Hybrid sunfish	1						1
Goldfish x Common carp hybrid			1				1
Fathead minnow	1						1
All species	2968	67	394	643	9	21	4102
Effort (hours, yards, net-nights, tows, or hauls)	6	1500	750	20	10	10	--
CPUE (*N*/min., 100 yds. of net, net-night, tow, or hawl)	8.2	4.5	52.5	32.2	0.9	2.1	--
Species (*N*)	15	5	15	18	4	3	28
Hybrids (*N*)	1	0	1	0	1	0	3
Bighead carp	0	0	0	0	0	0	0
Silver carp	0	0	0	0	0	0	0

Table 2. Catch, effort, and summary statistics for various gears used to sample the Chicago Sanitary and Ship Canal during the Lockport Pool Barrier Maintenance Targeted Response, 16-18 November 2010. Effort is hours for electrofishing, yards of net for trammel and experimental gill nets, and net-nights for mini-fyke nets and dual frame trap nets. CPUE is *N*/minute for electrofishing, *N*/100 yards of net for trammel and experimental gill nets, *N*/net-night for mini-fyke nets and dual frame trap nets.

	Gear					
Species	DC electro-fishing	Trammel net	Experimental gill net	Mini-fyke net	Dual frame trap net	All gears
Gizzard shad <6 in.	800		52	15	2	869
Gizzard shad >6 in.	43		229	6	3	281
Channel catfish	2		13	168	2	185
Emerald shiner	122			30		152
White perch			83	9	43	135
Bluntnose minnow	45			76		121
Green sunfish	7		1	96	7	111
Bluegill				69	8	77
Threadfin shad	67					67
Common carp	11	9	44	1	1	66
Pumpkinseed	2			16	26	44
Yellow bullhead	14		7	19	2	42
Largemouth bass	34		5			39
Yellow bass			8	4	26	38
Black bullhead	1		4	3	7	15
Round goby	6			3		9
Skipjack herring	1		6			7
Black crappie				4	2	6
Orangespotted sunfish				3	3	6
Goldfish	2		2	1		5
White sucker	1		3			4
Spottail shiner				3		3
White bass			2		1	3
White crappie			3			3
Golden shiner	2					2
Sauger			2			2
White perch hybrid					2	2
Black buffalo			1			1
Goldfish x Common carp hybrid	1					1
Coho salmon				1		1
Freshwater drum	1					1
Golden redhorse			1			1
Mosquitofish				1		1
Oriental weatherfish				1		1
Spotted sucker			1			1
Grand Total	1162	9	467	529	135	2302
Effort (hours, yards, or net-nights)	6	3700	1200	20	8	--
CPUE (N/minute, 100 yards of net, or net-night)	3.2	0.2	38.9	26.5	16.9	--
Species (N)	17	1	18	20	13	32
Hybrids (N)	1	0	0	0	1	2
Bighead carp	0	0	0	0	0	0
Silver carp	0	0	0	0	0	0

Table 3. Mean, minimum, and maximum total lengths for a subsample of fish sampled by DC electrofishing, trap nets, experimental gill nets, mini-fyke nets, dual frame trap nets, midwater trawl, and purse seine in the Chicago Sanitary and Ship Canal (CSSC) during the Lockport Pool Barrier Maintenance Targeted Response, 19-21 October and 16-18 November 2010.

	CSSC- Lockport Pool			
Species	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)
Black buffalo	1	--	9.9	9.9
Black bullhead	19	5.5	4.4	7.2
Black crappie	15	4.2	3.3	6.0
Bluegill	29	3.0	2.2	4.2
Bluntnose minnow	35	2.7	1.8	3.3
Central mudminnow	1	--	3.4	3.4
Channel catfish	54	9.5	2.0	21.6
Coho salmon	1	--	24.0	24.0
Common carp	111	16.9	5.7	31.2
Emerald shiner	65	3.0	1.8	4.3
Fathead minnow	1	--	2.9	2.9
Freshwater drum	18	13.6	5.3	18.1
Gizzard shad <6 in.	108	4.8	3.4	6.1
Gizzard shad >6 in.	157	9.4	5.1	14.4
Golden redhorse	1	--	11.9	11.9
Golden shiner	4	4.7	3.1	6.2
Goldfish	10	7.5	5.8	13.2
Goldfish x Common carp hybrid	1	--	6.9	6.9
Green sunfish	37	3.1	1.6	5.3
Hybrid sunfish	1	--	3.3	3.3
Largemouth bass	59	7.0	3.7	13.8
Mosquitofish	1	--	1.8	1.8
Orangespotted sunfish	15	3.0	2.4	3.5
Oriental weatherfish	6	4.4	3.7	5.3
Pumpkinseed	29	3.9	2.2	5.9
Round goby	1	--	2.1	2.1
Sauger	1	--	10.2	10.2
Skipjack herring	10	10.3	8.4	13.5
Spottail shiner	11	1.9	1.4	2.4
Spotted sucker	1	--	8.4	8.4
Threadfin shad	35	3.6	3.1	5.5
Warmouth	2	3.7	2.8	4.6
White bass	6	5.6	3.1	8.3
White crappie	4	6.2	2.9	9.4
White perch	116	5.0	3.3	9.0
White perch hybrid	6	4.3	3.7	4.7
White sucker	5	8.5	6.6	10.6
Yellow bass	27	4.5	3.0	6.7
Yellow bullhead	56	5.7	2.9	29.0
All species	1060	7.0	1.4	31.2

Reach Sampling

Table 1. Electrofishing (DC) catch, effort, and summary statistics for four reaches in the Chicago Area Waterway System sampled on three occasions during Asian carp reach sampling, 11 July - 31 October 2010. Catch-per-unit-effort (CPUE) includes only effort data from samples where fish were counted. Reaches are: 1 = Chicago Sanitary and Ship Canal from Dispersal Barrier (river mile (RM) 296.1) to Stickney Waste Water Treatment Plant (WRP; RM 316); 2 = Chicago Sanitary and Ship Canal and Cal-Sag Channel junction (RM 303.3) to Calumet Harbor (RM 333.5); 3 = Chicago Sanitary and Ship Canal, South Branch Chicago River, and Chicago River from Stickney WRP (RM 316) to Chicago Lock (RM 326.7; and 4 North Branch Chicago River and North Shore Channel from Wolf Point (RM 325.5) to Wilmette Pumping Station.

	Reach				All
Species	1	2	3	4	reaches
Gizzard shad <6.0 in.	138	220	182	361	912
Gizzard shad >6.0 in.	39	112	117	275	532
Common carp	35	248	174	61	518
Largemouth bass	5	72	26	52	155
Pumpkinseed	3	11	41	62	117
Bluegill	1	20	35	53	109
Emerald shiner	1	75	8	1	85
Smallmouth bass		60	1		61
Golden shiner	1	5	22	24	52
Spotfin shiner			19	9	28
Goldfish	7	7	11	1	26
White sucker		4		20	24
Green sunfish		3	2	10	15
White bass	3	7	4		14
Bluntnose minnow		10		3	13
Yellow bullhead	1	3	7	2	13
Freshwater drum		11			11
Goldfish x Common carp hybrid			2	6	8
Golden redhorse		7			7
Rock bass		5			5
Channel catfish			4		4
Hybrid sunfish			1	2	3
Black crappie		2		1	3
Creek chub		2	1		3
Yellow perch		1		2	3
White crappie				2	2
Yellow bass		1	1		2
Bigmouth buffalo		1			1
Black buffalo			1		1
Bullhead minnow				1	1
Chinook salmon		1			1
Fathead minnow			1		1
Rainbow trout		1			1
Round goby		1			1
Warmouth				1	1
White perch			1		1
All species	234	890	661	949	2734
Effort (hours)	16.3	28.6	12.1	21.0	78.1
CPUE (N/minute)	0.3	0.5	0.9	1.2	0.7
Species (N)	10	25	19	18	33
Hybrids (N)	0	0	2	2	2
Bighead carp	0	0	0	0	0
Silver carp	0	0	0	0	0

Table 2. Mean, minimum, and maximum total lengths for a subsample of fish sampled with DC electrofishing gear at four reaches in the Chicago Area Waterway System during Asian carp reach sampling, , 11 July - 31 October 2010. Reaches are: 1 = Chicago Sanitary and Ship Canal from Dispersal Barrier (river mile (RM) 296.1) to Stickney Waste Water Treatment Plant (WRP; RM 316); 2 = Chicago Sanitary and Ship Canal and Cal-Sag Channel junction (RM 303.3) to Calumet Harbor (RM 333.5); 3 = Chicago Sanitary and Ship Canal, South Branch Chicago River, and Chicago River from Stickney WRP (RM 316) to Chicago Lock (RM 326.7; and 4 North Branch Chicago River and North Shore Channel from Wolf Point (RM 325.5) to Wilmette Pumping Station.

	Reach 1				Reach 2				Reach 3				Reach 4			
Species	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)	Number measured	Mean total length (inches)	Minimum total length (inches)	Maximum total length (inches)
Bigmouth buffalo					1	--	2.8	2.8								
Black buffalo									1	--	8.9	8.9				
Black crappie					2	5.7	4.3	7.0					1	--	8.3	8.3
Bluegill	1	--	8.1	8.1	20	3.8	1.3	6.9	19	6.0	4.3	7.8	53	5.6	2.9	7.8
Bluntnose minnow					10	2.8	2.4	3.3					3	3.0	2.7	3.5
Bullhead minnow													1	--	2.6	2.6
Channel catfish									2	16.5	14.6	18.3				
Chinook salmon					1	--	25.1	25.1								
Common carp	35	21.9	15.8	29.9	134	21.1	3.2	29.6	51	20.0	8.8	27.6	44	20.7	5.3	27.9
Creek chub					2	6.1	6.0	6.2	1	--	3.1	3.1				
Emerald shiner	1	--	3.7	3.7	30	3.7	2.2	4.7					1	--	2.4	2.4
Freshwater drum					8	17.0	7.3	22.4								
Gizzard shad	55	4.7	2.1	13.1	187	6.1	3.0	18.6	46	6.1	3.5	13.0	201	6.6	1.8	15.6
Golden redhorse					7	11.7	3.9	19.8								
Golden shiner	1	--	5.5	5.5	5	4.1	3.4	5.0	3	5.3	4.5	6.4	24	5.1	3.9	7.0
Goldfish	7	12.0	10.8	12.5	7	9.4	3.9	14.3	9	9.6	5.5	11.8	1	--	13.4	13.4
Goldfish x Common carp hybrid													6	10.8	4.3	15.4
Green sunfish					3	2.7	2.0	3.5					10	3.8	2.6	4.9
Hybrid sunfish													1	--	4.3	4.3
Largemouth bass	5	7.8	6.2	8.9	72	6.3	2.0	16.7	16	6.9	3.5	11.4	51	10.5	2.0	22.2
Pumpkinseed	3	5.5	4.8	6.0	11	5.0	3.2	6.4	21	4.6	1.3	6.1	62	5.5	2.4	11.4
Rainbow trout					1	--	22.2	22.2								
Rock bass					5	6.7	6.0	7.5								
Round goby					1	--	3.0	3.0								
Smallmouth bass					60	7.9	2.0	17.0	1	--	15.2	15.2				
Spotfin shiner									2	3.2	3.1	3.3	9	3.5	2.3	4.3
Warmouth													1	--	2.3	2.3
White bass	3	7.4	6.7	7.8	7	10.8	3.0	26.1	4	7.1	3.5	9.1				
White crappie													2	13.5	11.7	15.4
White sucker					4	11.0	6.5	13.7					20	12.2	5.0	16.1
Yellow bass					1	--	6.7	6.7								
Yellow bullhead	1	--	11.8	11.8	3	8.6	7.1	10.8	6	9.1	7.2	10.6	2	9.2	8.3	10.1
Yellow perch					1	--	2.7	2.7					2	3.3	1.8	4.9
All species	112	10.8	2.1	29.9	583	9.9	1.3	29.6	182	10.3	1.3	27.6	495	8.1	1.8	27.9

Fixed Sites Downstream of Barrier

Table 1. Electrofishing (DC) catch, effort, and summary statistics for various pools in the Chicago Area Waterway System, lower Des Plaines River, and upper Illinois River sampled monthly (once in May/June and October /November) during Asian carp fixed site sampling downstream of the Dispersal Barrier, 19 April - 1 November 2010.

	Pool				
Species	Lockport	Brandon Road	Dresden Island	Marseilles	All pools
Gizzard shad	322	196	275	815	1608
Gizzard shad >6.0 in.		16	42	74	132
Gizzard shad <6.0 in.		35	251	218	504
Common carp	100	85	297	46	528
Smallmouth buffalo		2	108	331	441
Bluegill		7	246	63	316
Largemouth bass	6	9	171	53	239
Emerald shiner	131	7	19	45	202
Golden redhorse			14	128	142
River carpsucker			16	95	111
Freshwater drum	5	1	33	58	97
Threadfin shad		1	19	72	92
Smallmouth bass			38	45	83
Channel catfish	4	2	26	47	79
Longnose gar	1		45	30	76
White bass	1		2	67	70
Bigmouth buffalo			8	61	69
Quillback			7	60	67
Silver carp				64	64
Green sunfish	5	4	33	12	54
Shorthead redhorse		2	11	23	36
Spotfin shiner	20	1	3	6	30
Yellow bullhead	4	4	19		27
Northern hog sucker				20	20
Hybrid sunfish			18		18
Pumpkinseed	1	3	13		17
Spottail shiner		4	1	9	14
Silver redhorse			2	10	12
Bluntnose minnow		2	3	3	8
Goldfish	1	1	6		8
Bighead carp			1	6	7
Flathead catfish		1	5	1	7
Northern pike		5	1	1	7
Sauger		1		6	7
White crappie				7	7
Black crappie			4	2	6
Goldfish x Common carp hybrid		1	4	1	6
Logperch		3	1	2	6
Shortnose gar			1	5	6
Highfin carpsucker				5	5
Orangespotted sunfish			5		5
White sucker		2	2	1	5
Golden shiner		1	3		4
Grass carp				4	4
Oriental weatherfish		1	3		4
Skipjack herring				4	4
White perch	1	1	1	1	4
Yellow bass			2	2	4
Longear sunfish			1	2	3
Rock bass		1	1	1	3
Round goby		1	2		3
River redhorse				3	3
Walleye				3	3
Black buffalo				2	2
Redear sunfish			2		2
Alewife	1				1
Blackside darter		1			1
Bowfin			1		1
Grass pickerel				1	1
Paddlefish				1	1
Spotted sucker		1			1
Spotted gar			1		1
All species	603	402	1767	2516	5288
Effort (hours)	4.25	5.25	6	6.25	21.75
CPUE (N/minute)	2.4	1.3	4.9	6.7	4.1
Species (N)	15	29	43	45	58
Hybrids (N)	0	1	2	2	2
Bighead carp	0	0	1	6	7
Silver carp	0	0	0	64	64

Table 2. Trammel and gill net catch, effort, and summary statistics for various pools in the Chicago Area Waterway System, lower Des Plaines River, and upper Illinois River sampled on three occasions (twice in Marseilles Pool and recording only Asian carp) during Asian carp fixed site sampling downstream of the Dispersal Barrier, 9 March - 27 September 2010.

	Pool				
Species	Lockport	Brandon Road	Dresden Island	Marseilles	All pools
Common carp		32	262		294
Smallmouth buffalo		1	172		173
Channel catfish		1	37		38
Bighead carp			1	28	29
Goldfish x Common carp hybrid			9		9
Bigmouth buffalo			4		4
Freshwater drum			4		4
River carpsucker			4		4
Largemouth bass			2		2
Flathead catfish			1		1
Striped bass hybrid			1		1
Silver carp				1	1
Walleye			1		1
All species	0	34	498	29	561
Effort (yards)	1300	1300	3150	1200	6950
CPUE (*N*/100 yards)	0.0	2.6	15.8	2.4	8.1
Species (*N*)	0	3	10	2	11
Hybrids (*N*)	0	0	2	0	2
Bighead carp	0	0	1	28	29
Silver carp	0	0	0	1	1

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

2010 Monitoring and Rapid Response Results Summary

Electrofishing Fixed Sites

- 1,380 person-hours
- 140 hours effort
- 33,907 fish
- 11,200 YOY shad
- 64 species
- **No Asian carp**

Contract Netting Fixed Sites

- 1,260 person-hours
- 208 sets
- 24 miles of net
- 2,267 fish
- 18 species
- **1 bighead carp** (Lake Calumet)

Electrofishing Reaches

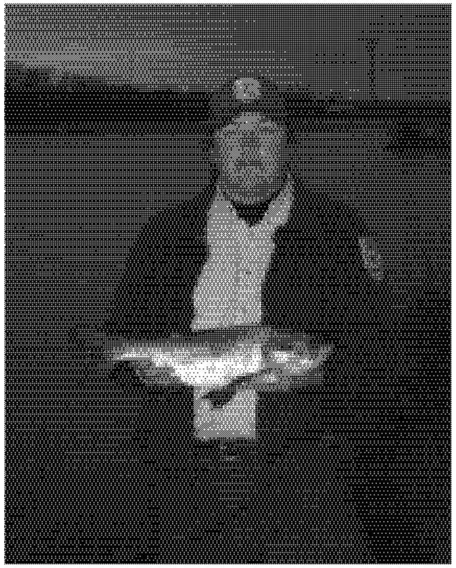
- 692 person-hours
- 73 hours effort
- 2,700 fish
- **No Asian carp**

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

2010 Monitoring and Rapid Response Facts

Efforts above the Electric Barriers:

- 9,800 person-hours
- 2.6 miles (173 acres) treated with rotenone
- 170 hours electrofishing
- 25 miles of trammel/gill net; >108,000 fish



CAWS Efforts Above and Below Electric Barriers:

- Over 18,000 person-hours of effort
- 9.1 miles treated with rotenone
- 383 hours of electrofishing
- 49 miles of netting
- **2 bighead carp** **(One in Lockport Pool below the Electric Barrier; one in Lake Calumet)**

2011 Sampling Plans

Asian Carp Presence and Abundance Monitoring

- Electrofishing and Netting Upstream and Downstream of the Barrier
- eDNA sampling
- Juvenile and Larval Asian Carp Monitoring
- Rapid Response Actions

Applied Research and Gear Development

- Asian Carp Gear Efficiency Testing
- Asian Carp Gear Development
- Fish Population Estimation and Modeling
- Hydrogun Development

Electric Barrier Efficacy

- Barrier Defense
- Near Barrier Telemetry
- DIDSON
- Des Plaines Separation Barrier Monitoring
- Barrier Maintenance Fish Suppression

2011 Preliminary Results Overview

Asian Carp Presence and Abundance Monitoring

- No bighead or silver carp captured above the barrier, or in Lockport or Brandon Road Pools during sampling efforts
- 1,297 eDNA water samples have been processed and analyzed; 17 were positive for silver carp, no positives for bighead carp
- Larval Asian Carp Monitoring is on-going at 16 stations; over 600 samples to date; no Asian carp eggs or larvae sampled upstream of the Starved Rock Lock and Dam; downstream sample processing is ongoing.
- Juvenile Asian Carp Monitoring is ongoing upstream and downstream of the electric barriers. No juveniles <6 inches) sampled to date.
- Lake Calumet Rapid Response completed including over 1000 person-hours, 11 miles of netting set, two ½-mile seine hauls, 22 hours of electrofishing and no bighead or silver carp captured or seen.

2011 Preliminary Results Overview

Applied Research and Gear Development

- Asian Carp Gear Efficiency Testing, Asian Carp Gear Development, Fish Population Estimation and Modeling and Hydrogun Development studies are progressing. Results should come in later this year.

Electric Barrier Efficacy

- DIDSON data are being collected and are under analysis
- New fish (small and large) are being tagged for telemetry
- Over 200 tons of Asian carp harvested to date; most from the Morris, Illinois area 65 miles from Lake Michigan, catches declining over time.

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

Fixed Sites Upstream of Barrier

March-September 2011

<u>DC Electrofishing</u>

- 13 sampling trips
- 1,630 person-hours
- 151 hours of electrofishing
- 37,957 fish
- 10,158 shad <6 inches
- 56 species

<u>Contract Netting</u>

- 13 sampling trips
- 1,610 person-hours
- 255 sets
- 43.2 miles of net
- 4,386 fish
- 15 species

No bighead or silver carp

Lake Calumet Rapid Response
August 1-4, 2011

Photo credit: Kevin Irons

Lake Calumet Rapid Response

- Initiated after three consecutive eDNA sampling events having positive detections for Asian carp DNA
- Conventional gear used to sample for Asian carp in Lake Calumet and the Calumet River for four days (August 1-4, 2011)
- 10 boats and 38 biologists involved for a total effort of 1,066 person-hours
- Over 22 hours of electrofishing, 11 miles of trammel/gill net sets, two ½-mile long seine hauls, 9 hours of hydroacaoustic sonar monitoring, and 22 trap net-days of sampling effort.
- Total catch in all gears was 8,668 fish representing 39 fish species; no bighead or silver carp captured or seen

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

Fixed Sites Downstream of Barrier

March-September 2011

DC Electrofishing

- 7 sampling trips
- 570 person-hours
- 28 hours of electrofishing
- 8,372 fish
- 4,365 shad <6 inches
- 60 species

Contract Netting

- 7 sampling trips
- 420 person-hours
- 106 sets
- 13.9 miles of net
- 1,044 fish
- 19 species

No bighead or silver carp in Lockport or Brandon Road Pools

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

Fixed Sites Downstream of Barrier

March-September 2011

DC Electrofishing

	Pool			
Species	**Lockport/Brandon**	**Dresden**	**Marseilles**	**Total**
Silver carp	**0**	**0**	**65**	**65**
Bighead carp	**0**	**0**	**8**	**8**

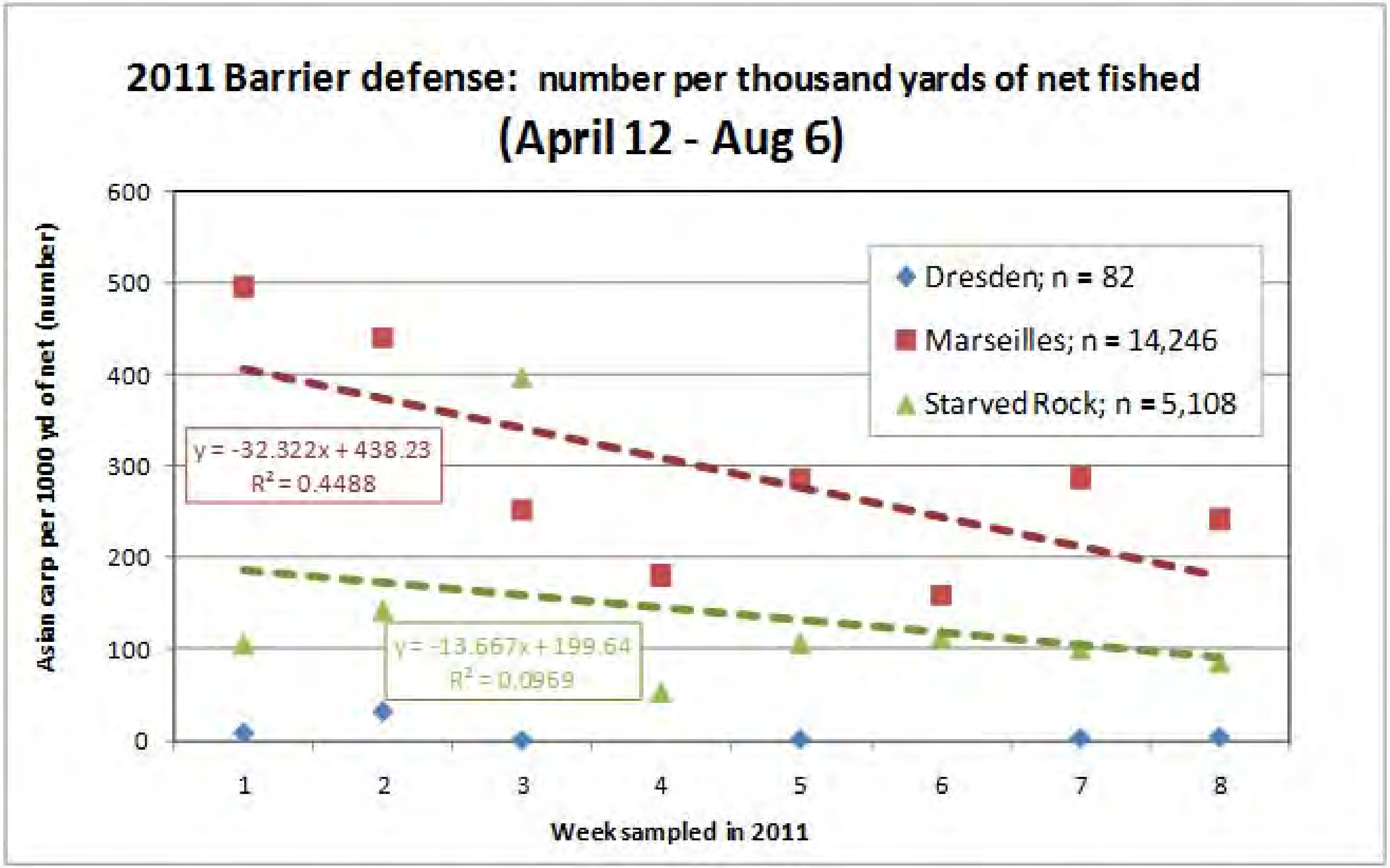
Contract Netting

	Pool			
Species	**Lockport/Brandon**	**Dresden**	**Marseilles**	**Total**
Silver carp	**0**	**0**	**83**	**83**
Bighead carp	**0**	**8**	**65**	**73**

Barrier Defense AC Removal

12 April – 16 September

QUICK SUMMARY:		
Number of Days Fished	**44**	**days**
Number of Net Crews	**220**	**crew-days**
Miles of Nets Fished	**197.5**	**miles**
Number of Bighead Carp	**16,513**	**fish**
Number of Silver Carp	**8,446**	**fish**
Number of Grass Carp	**9**	**fish**
Number of Asian Carp (AC)	**24,968**	**fish**
Tons of AC Harvested	**225.6**	**tons**
Average number AC per 1,000 yards net	**71.8**	**fish**


2011 Barrier defense: number per thousand yards of net fished
(April 12 - Aug 6)
Asian carp per 1000 yd of net (number)
Week sampled in 2011
0
100
200
300
400
500
600
1
2
3
4
5
6
7
8
Dresden; n = 82
Marseilles; n = 14,246
Starved Rock; n = 5,108
y = -32.322x + 438.23
R² = 0.4488
y = -13.667x + 199.64
R² = 0.0969

BARRIER MAINTENANCE FISH SUPPRESSION
October 24-26, 2011

Introduction and Need: The U.S. Army Corps of Engineers (USACE) operates three electric aquatic invasive species barriers (Barrier 1, 2A and 2B) in the Chicago Sanitary and Ship Canal at approximate river mile 296.1 near Romeoville, Illinois. Barrier 1 (formerly the Demonstration Barrier) is located farthest upstream (about 800 feet above Barrier 2B) and is operated at a setting that has been shown to repel adult fish. Barrier IIA is located 220 feet downstream of Barrier 2B and both of these barriers operate at parameters that have been shown to repel fish as small as 5.4 inches long. Barrier 2A and 2B must be shut down for maintenance approximately every 6 months and the Illinois Department of Natural Resources (IDNR) has agreed to support maintenance operations by providing fish suppression at the barrier site. Fish suppression can vary widely in scope and may include application of piscicide (rotenone) to keep fish from moving upstream past the barriers when they are down. This was the scenario for a December 2009 rotenone operation completed in support of Barrier 2A maintenance and before Barrier 2B was constructed. With Barrier 2A and 2B now operational, fish suppression actions will be smaller in scope because one barrier can remain on while the other is taken down for maintenance.

Presently, Barrier 2B is operating at parameters that have been shown to repel most sizes of fish (2.0 volts per inch at the water surface) and Barrier 2A is in warm standby mode. The USACE will increase parameters of Barrier 2A and 2B to levels (2.3 volts per inch) that will repel even very small fish on 10 October 2011, after which on 31 October 2011 Barrier 2B is scheduled for shutdown and maintenance. Because the threat of Asian carp invasion is from downstream waters, there is a need to clear fish from the 220 foot length of canal between Barrier 2A and 2B before Barrier 2A is fully energized and Barrier 2B is shut down for maintenance.

Following is a plan to provide fish suppression at the barriers in support of Barrier 2B maintenance. Operations to clear fish will take place over a 3-day period from 24-26 October 2011 and will include physical fish driving techniques and, if necessary, a small-scale rotenone action. Physical driving techniques will take place during the mornings of 24-25 October and will incorporate water level drawdown to increase current velocity at the barriers combined with either watergun technology or noise making (boat pounding) and electrofishing to drive fish from the target area. If physical techniques prove ineffective at clearing fish then a small-scale rotenone will take place on 26 October. The general plan will be to bring Barrier 2A up to operating levels immediately after fish have been cleared from the target area and then conduct surveys with split beam hydroacoustics, side scan sonar, and DIDSON to evaluate the success of physical fish clearing actions. Clearing will be considered successful when no fish larger than 300 mm (12 inches) are observed between the barriers, after which Barrier 2B can be taken down for maintenance.

Water level drawdown appears to be a good technique with ancillary observations of fish challenging the barrier at low flows. Dr. Jan Hoover (USACE) has been working with swimming ability of sub-adult bighead and silver carp. Dr. Hoover does admit this is a tough question to answer in regards to an open system but suggests that a proposed drawdown would work best with these things in mind: 1) low initial flow in the canal; 2) a rapid rate of increased flow; 3) a prolonged duration of elevated flow; 4) a reach with relatively smooth sides and bottom; 5) cool water temperatures.

We believe that combining a drawdown with physical fish driving techniques would maximize the movement of fish from this area to a more desired location downstream. The increased flows provided by a drawdown are intended to provide > 2.0-2.5 feet/sec velocities. The flows can be coordinated so that we can bring up Barrier 2A during highest flows, and within 30 minutes have reduced flows for remote sensing using hydro acoustic, side scan sonar, and DIDSON imaging techniques. The flows provided by MWRD operations at Lockport Lock and Powerhouse will warrant a Broadcast to Mariners, but will not require a discharge variance and will be within MWRD operating parameters.

Rotenone is considered the fallback method for fish suppression should other clearing efforts prove to be unsuccessful. If necessary, rotenone will be pumped from five boats at a location just upstream of the arched overhead pipe that designates the upstream boundary of the barrier Regulated Navigation Area (RNA) Safety Zone enforced by the U.S. Coast Guard. Upstream application will allow time for mixing and dispersion of chemical throughout the water column before it reaches the target area between the barriers. Florescent dye will be used to mark and track the applied rotenone slug as it travels down the canal toward Barrier 2A, which will be energized as the trailing edge of the chemical slug approaches it. The rotenone slug will be detoxified with liquid sodium permanganate pumped from boats at a location south of the Romeo Road Bridge and downstream border of the barrier RNA. Unlike fish clearing methods proposed above, the effects of rotenone on fish is well known and has been documented often, precluding the need for on-site evaluation. Barrier 2B will be turned down for maintenance once stable operation of Barrier 2A has been confirmed.

Although rotenone is an effective technique for controlling fish populations, there are several reasons for attempting physical removal of fish prior to rotenone application. The proposed rotenone action will be costly (estimated 150-250K), requires extensive labor and permitting (minimum 40-50 persons; NEPA, NPDES, IDNR CERP, and Special Local Needs labeling), and requires a longer duration canal closure than physical fish clearing (estimated 8 hours vs. 0-3 hours). In addition, barrier maintenance must occur regularly at approximately 6 month intervals, thus requiring a clearing operation at least annually. Developing methods that are less expensive and disruptive to canal users is beneficial to all involved stakeholders. In contrast to rotenone, physical clearing methods will not pollute waters or kill many fish. Fish killed with rotenone must be collected and disposed of in an EPA approved toxic waste landfill. Perceptions that rotenone actions “poison” the water have been expressed by potential purchasers of commercially harvested Asian carp from down river locations. These perceptions may adversely affect the success of Asian carp commercial market development projects. Furthermore, while rotenone is used and neutralized successfully in most cases, there is the possibility that mechanical or environmental factors could allow rotenone to travel outside of the treatment area where additional aquatic resources could be unintentionally harmed. And finally, the USACE telemetry program to assess effectiveness of the barriers will be adversely impacted should tagged fish in the vicinity of the barriers be eradicated by rotenone.

Participating Agencies:
Illinois Department of Natural Resources (lead)
U.S. Army Corps of Engineers (barrier operation and coordination)
U.S. Fish and Wildlife Service (evaluation with sonar technology)
U.S. Coast Guard (waterway safety, canal closures, and coordination with waterway users)
U.S. Geological Survey (flow measurements and fluorescent dye tracking)
Metropolitan Water Reclamation District of Greater Chicago (water level manipulation)
Southern Illinois University (evaluation with sonar technology)

Canal Closures Requested:
The IDNR is requesting establishment of a safety zone in conjunction with the Corps of Engineers' scheduled maintenance shutdown of Barrier 2B. Based on 2 years of conventional fish sampling and eDNA sampling in the Chicago Waterway System downstream of the electrical fish barrier, we believe there is a strong possibility that Asian carp could be present in this reach of the waterway, potentially even immediately below Barrier 2B. If this is the case, when Barrier 2B is powered down for maintenance, any Asian carp immediately below Barrier 2B could move upstream with only the original demonstration barrier between the fish and Lake Michigan. We believe this creates an unacceptable level of risk that Asian carp could gain access to the upper CAWS and Lake Michigan, and reduces the redundancy that is considered an essential feature of the entire barrier system. Thus, it is imperative that we conduct fish suppression/clearing operations in support of the planned maintenance shutdown. The intent is to drive fish below Barrier 2A, which would then be brought online and would serve as the primary barrier until Barrier 2B maintenance activities are completed and it resumes normal operations.

The IDNR has requested canal closures for the following days and times:

0730 to 1030 hours on 24 October 2011; Mile marker 296.1 – 296.7
0730 to 1030 hours on 25 October 2011; Mile marker 296.1 – 296.7
0800 to 1800 hours on 26 October 2011; Mile marker 295.7 – 297.0

General Time Line and Anticipated Barrier Operation and Canal Closures:
Tuesday and Wednesday, 4-5 October

- Baseline surveys of the area between barriers with hydro-acoustic, side-scan, and DIDSON.
- Barrier 2B operating.
- Canal closure not necessary.

Monday, 24 October

- Either a) drawdown/fish clearing with waterguns or b) drawdown/fish clearing with boat pounding and electrofishing.
    - Drawdown is provided by MWRD controls at the Lockport Lock and Powerhouse. This drawdown will increase flows over the electric barriers for an extended period of time, which is thought to move fish downstream and away from the barrier. This would also flush fish from the barrier area if waterguns stun fish, further clearing the area of fish.

- After fish clearing is completed, Barrier 2A and 2B operating simultaneously for up to 2.0 hours from 0800-1030 to allow for sonar evaluations and determination of clearing success. Either Barrier 2A or 2B will operate individually pending results of clearing and evaluation (e.g., Barrier 2A will be returned to warm standby if clearing is unsuccessful, whereas Barrier 2B will be brought down for maintenance if clearing is successful).
- Canal closure of 3.0 hours requested (0730-1030)

Tuesday AM, 25 October (necessary if clearing is unsuccessful on Monday)

- Similar operations as Monday, 24 October with additional physical fish clearing trials and sonar evaluations at the barrier.
- Barrier operations will be similar to Monday, 24 October.
- Canal closure of 3.0 hours requested (0730-1030)

Tuesday PM, 25 October (necessary if physical fish clearing trials are unsuccessful)

- Preparation for rotenone action, including travel to site, boat and chemical staging, delivery of lined dumpster for dead fish removal, establishing command post, standing up an Incident Command System, staff operations and safety briefing, etc.
- Barrier 2B operating
- Canal closure not necessary, as all operation will be preparatory and located off of the main channel and away from the barrier RNA.

Wednesday, 26 October

- Rotenone application, detoxification, and dead fish pickup and disposal.
- Barrier 2A energized as trailing edge of rotenone slug approaches and Barrier 2B turned down for maintenance after stable operation of Barrier 2A has been confirmed.
- Canal closure of 10.0 hours requested (0800-1800)

Thursday, 27 October

- Demobilization and continued dead fish collection by reduced crew, if necessary.
- Barrier 2A operating.
- Canal closure not necessary.

Friday, 28 October

- Continued dead fish collection by reduced crew, if necessary. Operation terminated.
- Barrier 2A operating.
- Canal closure not necessary.

Safety and Communication:
Boats will be equipped with required safety equipment and floatation devices. Operators and crews will wear personal flotation devices while working on the water and all required PPE for chemical application.

Throughout work at the barriers, a safety boat will be positioned at the downstream boundary of the RNA Safety Zone and a spotter(s) will be positioned at Barrier 2B on shore to observe activities and provide operation status updates to Incident Command or an operations coordinator in the absence of a formal Incident Command System. In an emergency and in the absence of an Incident Commander or unexpected communication breakdown, safety spotters would have the authority to ask the USACE on-site barrier operator for the barrier to be turned off for safety reasons only. To our understanding, the RNA Safety Zone is located between river miles 296.1 and 296.7 (Romeo Road Bridge upstream to the arched overhead pipe). This zone is located within the broader RNA that extends between river miles 295.5 and 297.2.

During fish clearing without chemicals:

Remote sensing: Hydroacoustic, side scan sonar, and DIDSON surveys of the area immediately downstream of Barrier 2B will assess the fish community in that area both prior to clearing efforts (4-5 October as a pilot) and after 24-25 October clearing actions to assess success of the physical fish clearing techniques. Surveys will be performed by 1-2 boats within the RNA Safety Zone that will need to linger there for a period of time, running multiple transects (up to 16) within the target area downstream of Barrier 2B. In addition to proper boat safety, a safety boat located at the Romeo Road Bridge will observe this operation from this safe position. On site, we will have personnel trained in emergency First Aid, and briefed on the operation of the barrier and challenges of operating in the area. Illinois CPO's will support the USCG in support of the requested safety zone canal closure. Remote sensing boats will have 1 pilot, one assistant to watch canal and potential hazards, and 1-2 operators of remote sensing gear.

Fish clearing: A single 26-foot long pontoon boat capable of supporting waterguns and necessary operating equipment (1 cu. in. or 80 cu. in. hydraulic piston capable of making sonic waves to deter fish) OR three boats >20 feet long to drive fish from the target area by making acoustic stimulus via banging on bottom of boats and electrofishing. Each boat will have a pilot and assistant to aid in navigation and observation of hazards. The watergun will require one operator, and each of the three noise/electrofishing boats would have one person to make noise, THUS all boats would have 3 individuals aboard.

During rotenone application: Fish sampling will take place below the RNA to collect sentinel fish for the rotenone application to verify detoxification of rotenone. Boats applying rotenone will cross the RNA Safety Zone to position above the arched pipe for chemical application. Upon finishing application, boats will return below the RNA Safety Zone to assist with detoxification and fish recovery efforts as needed. All boats crossing through the RNA Safety Zone will be >20 feet long, will not linger in the area, and will proceed through the zone as USCG requirements outline. All requirements of the RNA Safety Zone will be adhered when crossing the zone.

First, any vessel crossing the Dispersal Barrier or entering the RNA will provide advance notification to the Coast Guard Captain of the Port Representative on scene at (630) 336-0296 or VHF-16. Additional RNA requirements include:

a. The vessel cannot be less in than 20 feet in length.

b. The vessel must proceed directly through the RNA, and may not conduct any fishing operations, loiter, or moor within the RNA boundaries. Special permits will be requested for sonar surveys, detoxification, and physical fish suppression operations planned to take place within the RNA.

c. All personnel must remain inside the cabin, or as far inboard as practicable. If personnel must be on open decks, they must wear a Coast Guard approved Type I personal floatation device.

The CSSC is a working ship canal and sampling crews should be aware of potential hazards in the waterway. Note that no boats should operate near barges that are being loaded. In addition to the hazard of being hit by material that misses the target, there are cables that move barges along the wall during loading. These cables may be under the water surface when slack, but can rapidly rise 4-5 feet above the water when tightened. A rising cable could cause severe bodily injury or catch and easily flip a sampling boat. Be aware of your surroundings and avoid potential safety hazards while sampling.

Communication among boats, staff, security, and shore command will be by marine radio or cell phone. A briefing before any crew enters the water will be held and will include a handout of crew leaders and cell phone numbers for each participating boat/crew. This handout will include a map of the sample reach. All boats will be equipped with numbered flags for identification on the water and hand-held Marine radios operating on Channel 12 for the operation, unless emergency communication with USCG or Lockmaster is necessary (Channel 16, 14). Emergency contact numbers (local ambulance, fire/rescue service, Lockmaster, USGC contact info, and MWRD) will be included on the handout if needed for unforeseen reasons, yet the primary communicator to these services will be the Incident Commander.

Daily Activity Overview:
Initial operations on October 4-5 will include calibrating split-beam hydroacoustic, side-scan, and DIDSON sonar at the barriers. This operation will include SIUC and USFWS boats and personnel and will not require a canal closure. For 24 and 25 October, we will initiate a short-term drawdown of the canal to increase water velocity at the barriers to a target of 2.5-2.8 feet/second for 1.0 hour. Physical fish clearing techniques will be combined with the drawdown to attempt to drive fish from the area between Barrier 2A and 2B, and Barrier 2A will be reenergized to normal operating parameters immediately after clearing is completed. Success of the clearing operation will be evaluated by completing a predetermined number of sonar transects of the between-barrier area, essentially viewing the entire water column. Real-time remote sensing images will be viewed by representatives from IDNR,USFWS, and USACE and a consensus-based recommendation will be made to shut down Barrier 2B for maintenance, if the agency representatives all agree that no fish >300 mm are present in the area between Barrier 2A

and 2B. If large fish are present in the target area between barriers, then the fish clearing operation will be deemed unsuccessful and Barrier 2A will be returned to warm standby mode.

Tuesday and Wednesday, 4-5 October– IDNR, USFWS, SIUC, USACE
-Travel to Romeoville
-Sonar testing and calibration at barrier site (0700 - 1000 hours). This operation will work around commercial and recreational navigation at the barriers.
-Normal flows
-Barrier 2B operating

Operations during 24-26 October will include drawdown/physical fish clearing operations and a small-scale rotenone, if necessary. A small-scale rotenone action will take place if drawdown/physical suppression measures fail to drive fish from the area. In all, we anticipate a 3-4 day operation with 12-15 boats, 45-50 field crew, and 15-20 IC staff and support crew. This estimate does not include security and safety zone enforcement boats and crews. Day 1 of the rotenone action will include travel to the site, gear preparation, and the collection of sentinel fish for detoxification monitoring. The bulk of the work will occur on the second day of operations and a 10-hour daytime canal closure will be necessary on this day. During Day 2, we will apply 110 gallons of rotenone from five boats located at a station upstream of the RNA. The chemical will be allowed to mix and flow downstream over the barriers killing fish or forcing them out of the area. Fluorescent dye will be used to track the leading and trailing boundaries of the rotenone slug. Reactivation of Barrier IIA must be synchronized with the passing of the tail end of the rotenone slug through the barrier area to prevent movement of fish back into the treatment zone. We will detoxify the rotenone with 730 gallons of sodium permanganate applied from five boats from a location downstream of the RNA Safety Zone. The exact location of the detoxification station will be based on consultations with personnel from the Midwest Generation power plant and their level of concern over permanganate entrainment through the plant cooling system. Cages with sentinel fish will be placed at several downstream locations in the Lockport Pool to ensure that detoxification was successful. Although a large kill is not anticipated, we will have 2-3 recovery boats and crews and one dumpster on hand for the collection and disposal of dead fish. Fish recovery will continue on the second and third day of the event, as needed.

IDNR will stand up an Incident Command System (ICS) for the rotenone action and will coordinate with USCG and USACE during all phases of project planning and implementation to ensure a safe and successful event. A Unified Command situation may be considered necessary pending further discussions among participating agencies. An Incident Action Plan (IAP) is currently under development by IDNR's Incident Management Team and it will be shared with participating agencies upon completion. The IAP will include detailed plans and assignments for fish clearing actions, but a general overview is presented below.

Sunday, 23 October – IDNR, MWRD, SIUC, USGS
-Travel to Romeoville
-Boat staging, gear preparation, staff briefing and safety meeting
-Normal flows during day; shutdown of power generation at Lockport Power Plant at night to increase water level in pool prior to drawdown

Monday, 24 October – IDNR, USFWS, SIUC, USGS, USACE, MWRD, USCG
- -Initiate canal drawdown (0700 hours; 30 minute lag time to increased flow at barriers)
- -Precise canal flow/velocity measurements recorded periodically during operation
- -Initiate canal closure (0730 hours)
- -Terminate drawdown (0800 hours)
- -Watergun or noise/electrofishing to clear fish (0815 hours)
- -Barrier 2A energized (about 0830 hours); Barrier 2A and 2B operating simultaneously
- -Sonar evaluation transects (0830 hours)
- -Go-No go decision to power down Barrier 2B (1000 hours)
- -Additional time for remote sensing evaluation and decision making (1000-1030 hours).
- -Terminate canal closure (1030 hours)
- -Normal flows during remainder of day; shutdown of Lockport Power Plant generation at night to increase water level in pool prior to drawdown
- -Additional IDNR crews will begin staging and setup for small scale rotenone (0700-1700 hours)

Tuesday, 25 October – IDNR, USFWS, SIUC, USGS, USACE, MWRD, USCG
- -Repeat of 24 October fish clearing actions including canal closure from 0730-1030, if necessary and upon judgment of action agencies
- -All personnel participating in rotenone event travel to Romeoville, if necessary
- -Final preparation for small-scale rotenone, including operations and safety briefing (1200-1700 hours)

Wednesday, 26 October – IDNR, USACE, USCG, USGS, MWRD
- -Initiate canal closure (0800 hours)
- -Sentinel fish cages deployed downstream of detox station (by 0900 hours)
- -Rotenone applied from five boats upstream of RNA (0900-0930 hours)
- -Dye applied at leading and trailing edge of rotenone slug and tracked (0900-1200 hours)
- -Barrier 2A re-energized as trailing edge dye marker approaches (estimate at 1000-1100 hours)
- -Detoxification with sodium permanganate from five boats downstream of RNA (0930-1300 hours, as needed)
- -Barrier 2B turned down for maintenance after Barrier 2A operation stable (USACE call)
- -Dead fish pickup and disposal downstream of detox station (0930-1500 hours, as needed)

Thursday, 27 October – IDNR
- -Site clean-up and demobilization of most crews (0800-1200 hours)
- -Additional dead fish pickup and disposal, as needed

Friday, 28 October – IDNR
- - Final dead fish pickup and disposal, as needed
- - Final site clean-up and demobilization of remaining crews (0800-1200hours)
- -Targeted project termination (1200 hours)

ADDITIONAL CONTACTS AND EMERGENCY PHONE NUMBERS

USCG
On Scene Representative: xxx-xxx-xxxx or VHF-16

IDNR Conservation Police: xxx-xxx-xxxx/ xxx-xxx-xxxx

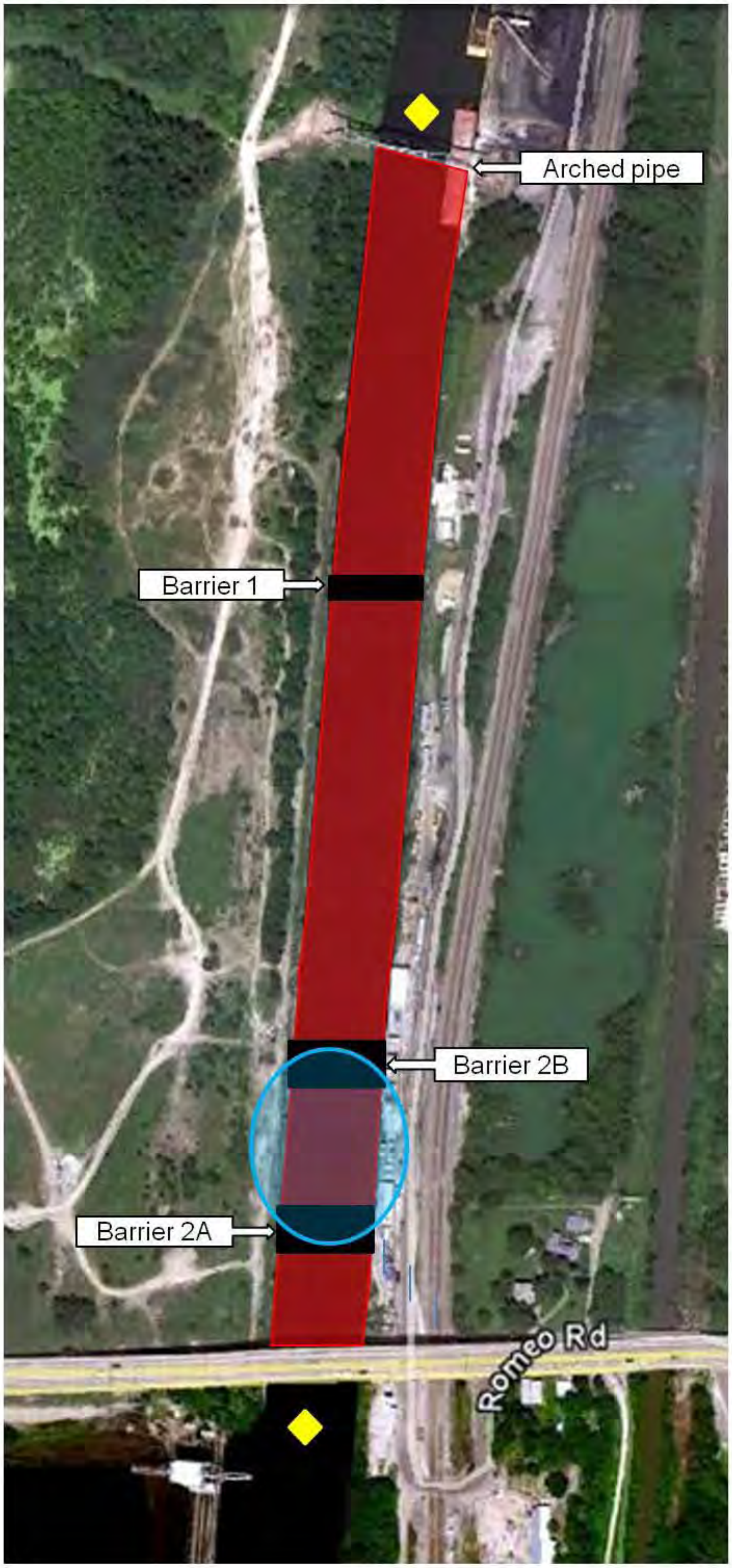
MWRD
Ed Staudacher (Operations Administrator): 312-751-5116
Martin Castro (Lockport Power Station): 312-401-9328
Kaye Heidenreich (MWRD Police): 708-588-4035

Hanson Material Services
Office: 815-838-3421;
Stacy Ann Operator: 815-739-2415 VHF-16 or VHF - 79

Lockport Lockmaster – Pat Wharry: 815-838-0536

Local Emergency
Romeoville Police: (Emergency): 911; (Non-emergency):815-886-7219

Romeoville Fire: 815-886-7227



**Lockport Pool
Physical Clearing Methods
Site Map**

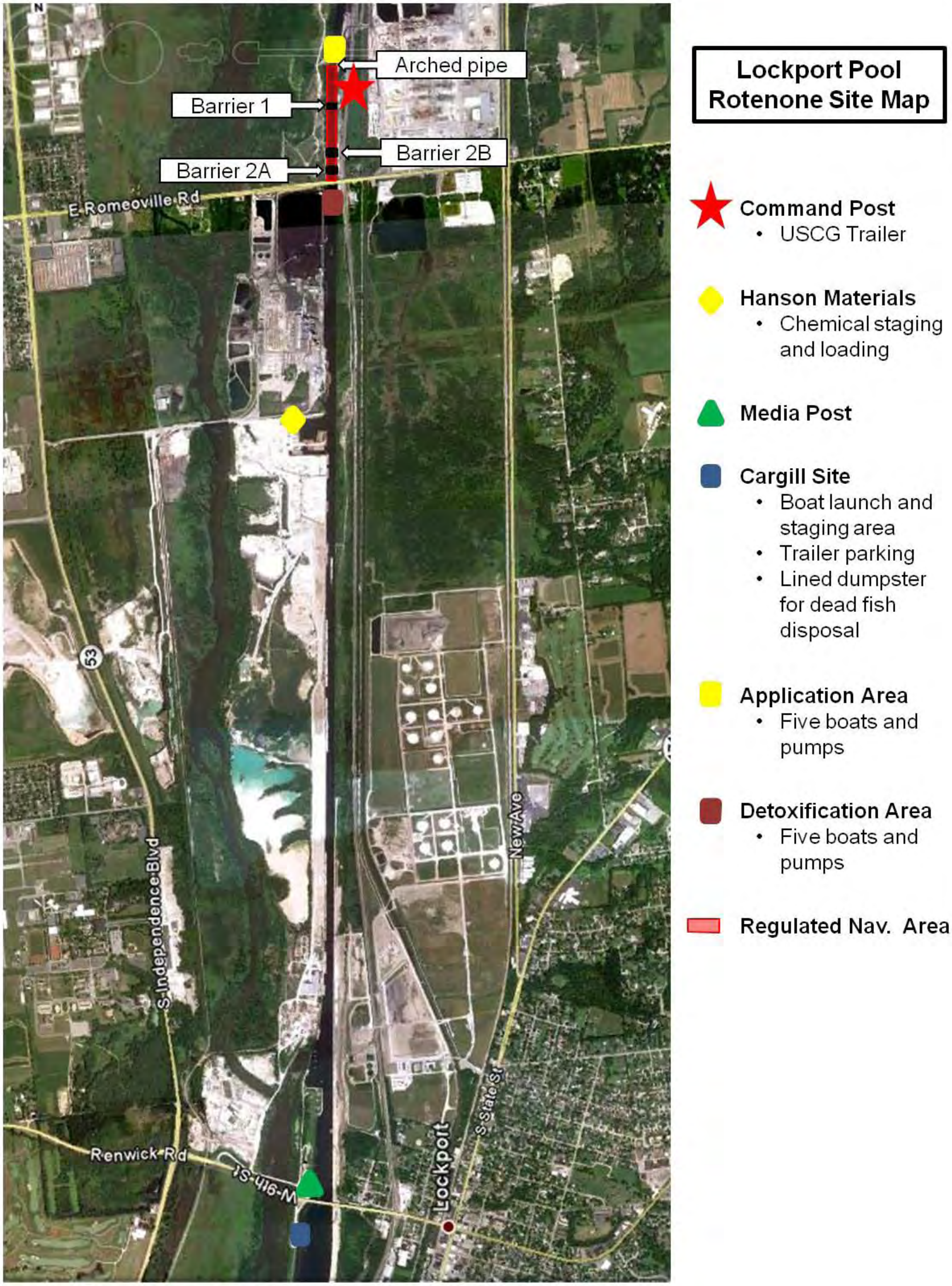
Legend

- Regulated Navigation Area
- Fish Clearing and Sonar EvaluationTarget Area
- IDNR Conservation Police Security Boat

Fish Clearing Methods

**Drawdown + Waterguns or
Drawdown + Boat Pounding
and Electrofishing**

- MWRD releases water at Lockport Power Station to establish water velocity of >2.5 - 2.8 feet/sec at barriers for minimum of 1.0 hour.
- Waterguns (if approved) deployed from a single 24-foot long pontoon boat within target area between barriers. If watergun use is not approved, acoustic stimulus (boat pounding) and electrofishing from three boats to drive fish from target area.
- Barrier 2A energized after drawdown and watergun or boat pounding and electrofishing operation. Barrier 2A and 2B run simultaneously for up to 2.0 hours minutes while 1-2 boats conduct sonar surveys to evaluate success of fish clearing effort.
- Either Barrier 2A or 2B will operate individually pending results of clearing and evaluation. Barrier 2A will be returned to warm standby if clearing is determined to be unsuccessful, whereas Barrier 2B will be brought down for maintenance if clearing is successful.


Lockport Pool Rotenone Site Map
Arched pipe
Barrier 1
Barrier 2B
Barrier 2A
E Romeoville Rd
Renwick Rd
S Independence Blvd
New Ave
S State St
Lockport
53
Command Post
• USCG Trailer
Hanson Materials
• Chemical staging and loading
Media Post
Cargill Site
• Boat launch and staging area
• Trailer parking
• Lined dumpster for dead fish disposal
Application Area
• Five boats and pumps
Detoxification Area
• Five boats and pumps
Regulated Nav. Area

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

ATTACHMENT 6

Asian Carp Regional Coordinating Committee, "FY2012 Asian Carp Control Strategy Framework".

February 2012

FY 2012 ASIAN CARP
Control Strategy Framework

Water gun field testing

Electronic Filing - Received, Clerk's Office, 03/19/2012
PC# 1293 (Attachments 1-7)

THE ASIAN CARP REGIONAL COORDINATING COMMITTEE

FY 2012 Asian Carp Control Strategy Framework

February 2012

Contributing Members:

City of Chicago
Great Lakes Fishery Commission
Illinois Department of Natural Resources
Illinois Environmental Protection Agency
Indiana Department of Natural Resources
Michigan Department of Natural Resources
Michigan Office of the Great Lakes
Minnesota Department of Natural Resources
New York Department of Environmental Conservation
Ohio Department of Natural Resources
Pennsylvania Department of Environmental Protection
Pennsylvania Fish and Boat Commission
Wisconsin Department of Natural Resources
Metropolitan Water Reclamation District of Greater Chicago
National Oceanic and Atmospheric Administration
United States Army Corps of Engineers
United States Coast Guard
United States Department of Transportation/Maritime Administration
United States Environmental Protection Agency
United States Fish and Wildlife Service
United States Geological Survey
White House Council on Environmental Quality

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EXECUTIVE SUMMARY

The Great Lakes food web has been significantly degraded in recent decades by aquatic invasive species (AIS). The most acute AIS threat facing the Great Lakes today is movement of carp not native to the United Sates (bighead and silver)—collectively known as Asian carp—through the Chicago Area Waterway System (CAWS), Wabash River, Grand Calumet River, and possibly other pathways that can connect the Great Lakes to the outside Mississippi River Basin.

The Asian Carp Regional Coordinating Committee (ACRCC), with support from federal, state, and local agencies, and other private stakeholder entities, is working to create a sustainable Asian carp control program and to implement actions for protecting and maintaining the integrity and safety of the Great Lakes ecosystem from an Asian carp invasion via all viable pathways. This Framework lays out the strategy and presents the proposed action items to achieve this goal.

The Obama Administration is implementing an unprecedented and comprehensive set of actions to prevent Asian carp introduction into the Great Lakes, and to ensure sustainable Asian carp populations do not exist within the Great Lakes. The Administration's actions include studying options or controls that could be utilized to implement ecological separation, which could include hydrological separation, of the Mississippi River and Great Lakes Basins to permanently solve the potential Asian carp problem at the connection points, as well as to address other AIS. Engineering controls, biological controls, and rapid responses to achieve eradication throughout the two basins are also under development in order to deal with possible Asian carp introductions to the Great Lakes via other vectors such as human transport or error.

The ACRCC has specified the following goals/actions within the 2012 Framework:

- Provide a sound strategy for addressing the threat of an Asian carp invasion in the Great Lakes such that the Framework continues to provide direction to participating agencies and actions, and identify areas for future action.
- Identify efforts that supplement direct management action, such as education and outreach, or increased regulatory structure.
- Increase program sustainability through Framework action items. Action items such as rotenone stockpiling, net development, and the use of DIDSON technology will build the program base and can implemented if an emergency arises. Further development of biological control agents will assist with the eradication of populations below the electric barrier system.
- Identify ongoing or potential collaboration between ACRCC entities, and specify partner roles.
- Document, track, and communicate the monumental actions of ACRCC partners in applying full authorities, capabilities, and resources to prevent introduction and establishment of Asian carp in the Great Lakes.
- Further engage with governmental, industry, environmental, and other stakeholders.

- Apply technologies and lessons learned to below the electric dispersal barriers and concurrent national Asian carp efforts where applicable.

The best science available underscores this Framework. Widespread agreement exists among scientists and stakeholders that preventing movement of Asian carp into Lake Michigan is critical to reducing the probability of Asian carp establishment in the Great Lakes.

This document describes ACRCC management strategy and its current and future actions. This Framework is designed to be inclusive, allowing government agencies and outside stakeholders to engage in developing and implementing all plausible control actions.

Management actions that comprise the Framework's strategy are based upon the three typical stages of invasive species invasion. Each Framework action item is categorized within one of the following stages of invasion and management action it would impact the most:

- Prevention and Development of Prevention Technologies
- Monitoring and Development of Monitoring Technologies
- Development of Control Technology and Impact Mitigation
- Other Supporting Actions (Education, Outreach, Regulatory Support).

In addition to the many efforts described in this document as part of the ACRCC strategy, the Great Lakes' States continue to undertake efforts against Asian carp and other invasive species. Through a cost-share grant program, the U.S. Fish and Wildlife Service have been able to provide assistance to states for creating and implementing AIS management plans and activities. In 2009 and 2010, the Great Lakes States invested over $26.7 million in prevention and control of aquatic invasive species—of which almost $900,000 was committed to Asian carp control efforts. The following are previous or current efforts by the Great Lakes states as part of their AIS prevention, management, and control programs:

- New rapid response plans developed by Great Lakes states and approved by the AIS Task Force
- State-led rapid response actions and other control efforts
- AIS education and outreach, including increased signage to inform the public about various AIS
- Inspections and enforcement of laws regarding AIS
- AIS barrier studies and design
- AIS monitoring and surveillance.

The ACRCC seeks development of an effective and fiscally sustainable Asian carp biological control program throughout the Great Lakes Basin, as well as throughout the Mississippi River Basin. The near term goal is to prevent entry of Asian carp to the Great Lakes, which will give the ACRCC time to do the research and development necessary to meet the long term goal of eradication/management through biological controls or other ecological separation measures. Because Asian carp are already well established throughout the Mississippi River Basin, this program will be essential to decrease spread of Asian carp and prevent establishment of Asian carp in new waterway systems.

This Framework is a living document and is a continuation of the efforts of previous Asian Carp Framework iterations. It recognizes potential hurdles while providing a baseline reference for collaboration among agencies and the interested communities through which a compelling plan of action can be initiated. Preventing establishment of a self-sustaining Asian carp population requires an understanding of ecological, economic, and hydrological complexities—leading to the conclusion that a comprehensive approach, which cannot rely on only a single strategy, is necessary to reduce the risk of Asian carp invasion.

1.0 INTRODUCTION

The Great Lakes food web has been significantly degraded in recent decades by aquatic invasive species (AIS). The most acute AIS threat facing the Great Lakes today is movement of carp not native to the United Sates (bighead and silver)—collectively known as Asian carp—through the Chicago Area Waterway System (CAWS), Wabash River, Grand Calumet River, and possibly other pathways that can connect the Great Lakes to the Mississippi River Basin. For purposes of this report, Asian carp is limited to bighead and silver carp. However, efforts to contain black and grass carp, species of increasing concern, would benefit from some actions specified in the Framework.

The Asian Carp Control Strategy Framework (Framework) has been prepared by the Asian Carp Regional Coordinating Committee's (ACRCC) participating agencies, states, and stakeholders to specify actions for controlling Asian carp movement.

This section briefly presents the problem of the Asian carp movement toward the Great Lakes ecosystem, reviews the purpose of the Framework, reviews Asian carp ecology and potential impact to the Great Lakes, and cites additional work proceeding outside of this Framework. Section 2.0 presents the ACRCC Fiscal Year (FY) 2012 plan for strategic management of Asian carp throughout the Great Lakes Basin. Strategic management of Asian carp was divided into the following categories:

- Prevention and Development of Prevention Technology
- Monitoring and Development of Monitoring Technology
- Development of Control Technology and Impact Mitigation
- Other Supporting Actions (Education, Outreach, Regulatory Support).

Section 3.0 discusses the critical efforts underway as part of the overall Framework in the following areas:

- Electric Dispersal Barriers in the CAWS
- Great Lakes and Mississippi River Inter-Basin Study (GLMRIS)
- Monitoring and Removal
- Environmental Deoxyribonucleic Acid (eDNA) Calibration Studies
- Risk Assessment
- Scientific Research and Technology
- Enforcement Activities
- Federal and State AIS Management.

The agencies and stakeholders that participate in development of the Framework and coordinate activities of participating agencies and organizations are presented in Section 4.0. Section 5.0 describes stakeholder actions likely to supplement the Framework involving the public and providing for communication and outreach to parties outside the immediate circle of participating intergovernmental agencies.

1.1 Mission Statement

The ACRCC, with support from federal, state, and local agencies, and other private stakeholder entities, will create a sustainable Asian carp control program for protecting and maintaining the integrity and safety of the Great Lakes ecosystem by preventing establishment of a sustainable Asian Carp population into that ecosystem via all viable pathways. This Framework lays out the strategy and presents the proposed action items to carry out this goal.

1.2 Situation

The introduction of AIS into the Great Lakes is occurring at an alarming rate. Since the beginning of the 19th century, more than 180 non-native species have been introduced into the Great Lakes. Some of these species have become 'invasive' (causing ecological or economic damage or threatening human health). These invasive fish, invertebrates, viruses, bacteria, and parasites can devastate native communities, as well as cause great economic damage to the Great Lakes commercial, sport, and tribal fisheries. The geographic range of Asian carp species is expanding in the Mississippi River Basin and threatening invasion of the Great Lakes. The potential invasion of Asian carp is one of the most serious invasive species threats facing the Great Lakes today.

The ecological and economic damage in the Mississippi River watershed that followed Asian carp invasion was an early warning of potential impacts of Asian carp on the Great Lakes. This warning has resulted in extensive mobilization of local, state, and federal entities, and creation of the ACRCC—an organization responsible for coordinating and conducting actions to prevent an Asian carp invasion into the Great Lakes.

The ACRCC works daily to execute an aggressive, multi-tiered strategy to prevent establishment of self-sustaining populations of Asian carp in the Great Lakes, and to ensure vigilant monitoring in order to assess needs for response actions.

1.3 Framework Purpose and Proposed Outcomes

The Obama Administration is implementing an unprecedented and comprehensive set of actions to prevent Asian carp introduction into the Great Lakes and to ensure establishment of Asian carp within the Great Lakes does not occur. The Administration's actions include studying options or controls that could be utilized to implement ecological separation, which could include hydrological separation, of the Mississippi River and Great Lakes Basins to permanently solve the potential Asian carp problem at the connection points, as well as to address other AIS. Engineering controls, biological controls, and rapid response to achieve eradication or separation between the two basins are also under development to deal with possible Asian carp introduction to the Great Lakes via other vectors such as human transport or error.

Implementation of the Framework actions documented herein have brought together experts and resources across federal agencies, Great Lakes states, and local agencies to implement a coordinated plan of immediate actions that would allow time to complete the longer term strategy action items. This Framework highlights the ongoing efforts of the ACRCC and its member agencies; it also provides strategic guidance regarding current and proposed actions to combat Asian carp within the Great Lakes Basin.

To coordinate management and prevention of Asian carp among the ACRCC entities, the first Framework was released in early 2010. Previous Framework editions had listed respective goals, milestones completed, funding sources, and responsible agencies for each management action underway by ACRCC entities or collaborative partners. Increasing knowledge of Asian carp and expansion of ACRCC membership since publication of the 2010 Framework has exposed the need to describe how, together, projects strategically address the invasion problem. The 2012 version of the Framework is a product of recent actions, lessons learned, and a desire to create a more sustainable and long-term approach to both controlling and eradicating existing Asian carp populations.

In sum, the near term efforts are focused on preventing entry of Asian carp to the Great Lakes, which will give the ACRCC time to do the research and development necessary to meet the long term goal of eradication/management through biological controls or ecological separation.

The ACRCC has specified the following goals/actions within the 2012 Framework:

- Provide a sound strategy for addressing the threat of an Asian carp invasion in the Great Lakes such that the Framework continues to provide direction to participating agencies and actions, and identify areas for future action.
- Identify efforts that supplement direct management action, such as education and outreach, or increased regulatory structure.
- Increase program sustainability through Framework action items. Action items such as rotenone stockpiling, net development, and Dual Frequency Identification Sonar (DIDSON) development will build the program base and can be implemented if an emergency arises. Further development of biological control agents will assist with the eradication of populations below the electric barrier system.
- Identify ongoing or potential collaboration between ACRCC entities, and specify partner roles.
- Document, track, and communicate the actions of ACRCC partners in applying full authorities, capabilities, and resources to prevent establishment of a sustainable Asian carp population in the Great Lakes.
- Further engage with governmental, industry, environmental, and other stakeholders.
- Apply technologies and lessons learned to below the electric dispersal barriers and concurrent national Asian carp efforts where applicable.

1.4 Asian Carp Ecology and Potential Impact

Possible invasion of Asian carp into the CAWS and the Great Lakes poses numerous ecological and economic impacts that are under extensive study. Investigations also focus on potential invasion of Asian carp into other pathways between the Mississippi River and Great Lakes Basins. This section provides information about Asian carp and their potential impacts, and why the Obama Administration is committing financial and staff resources to prevent Asian carp establishment within the Great Lakes.

1.4.1 Distribution

In North America, Asian carp usually refers to bighead carp (*Hypophthalmichthys nobilis)*, silver carp (*H. molitrix*), black carp (*Mylopharyngodon piceus*), and grass carp (*Ctenpharyngodon idella*). They all are members of the family *Cyprinidae*. The two species identified for rapid response action under this plan are the silver carp and bighead carp because they pose the greatest threat. This Framework does not address grass carp and black carp. Grass carp are already widely dispersed and have been recorded in 45 states and the Great Lakes. Black carp are not yet widely distributed, but may be a target of future Asian carp efforts[1].

Bighead and silver carp species reportedly were first introduced in the Mississippi River watershed 30 to 40 years ago to keep retention ponds clean and thus improve water quality in aquaculture and wastewater treatment facilities by keeping retention ponds clean, and to serve the food industry[2]. Escape of Asian carp from these facilities could have occurred in many ways, including inadvertent releases, overland flooding events, or intentional releases from bait or aquaria. However they may have escaped, Asian carp have rapidly spread in the Mississippi River watershed, and threaten the ecologic and economic value of the neighboring Great Lakes. For example, silver carp introduced to Arkansas sewage lagoons and aquaculture ponds in the early 1970s have since spread to 23 surrounding states and as far north as South Dakota and Minnesota[2]. During 2002 monitoring efforts, Asian carp were detected in the upper Illinois River just 60 miles from Lake Michigan. In 2010, a single bighead carp was captured in Lake Calumet, just 6 miles from Lake Michigan[3]. Based on currently available information; the ACRCC has concluded that there is no evidence of an established Asian carp population above the Electric Barrier System within the CAWS.

[1] USGS Nonindigenous Aquatic Species Fact Sheet *Ctenopharyngodon idella* (grass carp). http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=514
[2] Kolar, C.S., D.C. Chapman, W.R. Courtenay Jr., S.M Housel, J.D. Williams, D.P. Jennings. 2007. "Bigheaded Carps: A biological synopsis and environmental risk assessment." *American Fisheries Society Special Publication* 33, Bethesda, Maryland.
[3] Conlin, M. 2002. "Asian carp poised to invade the Great Lakes." *News from the Great Lakes Panel on Aquatic Nuisance Species: ANS Update*, 8(3).

1.4.2 Diet and Life History

Asian carp can dominate fisheries in abundance and biomass. Bighead carp can live over 20 years, grow over 5 feet in length, and weigh 100 pounds or more. Bighead and silver carp are planktivorous, eating predominantly phytoplankton and zooplankton, but can be opportunistic and consume a variety of food sources. Bighead carp feed on plankton at the base of the food web. Their dietary patterns may allow them to out-compete both small and large Great Lakes native fish. Maturity is reached between 2 and 7 years of age, depending on the climate and population levels. At maturity, bighead carp generally spawn during the times of flooding when water temperatures are approximately 80 degrees F. Multiple spawning peaks during a given year have been documented.

Silver carp are generally smaller than bighead carp, with similar feeding and spawning habits. Silver carp are often referred to as “flying fish.” When disturbed by boat motors and startled, these fish will jump from the water, posing danger to boaters, anglers, and other recreational users.

1.4.3 Potential Habitat

To successfully complete their life cycle, Asian carp (silver and bighead carp) need access to suitable habitat for spawning of adults, for development and hatching of eggs, recruitment of larvae and early juveniles, as well as habitat for growth and survival of sub-adults and adults. The Great Lakes provide a diverse array of habitat types and would therefore likely provide the necessary physical habitat components for all life stages of Asian carp. For establishment of Asian carp, however, these habitats must be positioned in such a way as to facilitate growth and survival, and sufficient food resources must be available. Given that Asian carp have rather specific requirements for reproduction and recruitment, and that they require concentrations of food resources, areas of the Great Lakes likely are present that would provide these resources and would attract Asian carp.

Although exact spawning cues remain unknown, after a threshold of water temperature has been exceeded, Asian carp find flowing habitats in channels of rivers, with flows over two feet per second to spawn following a rise in water level that is usually accompanied by an increase in turbulence and turbidity. Spawning habitat, therefore, consists of access to areas providing these cues, as well as those providing a sufficient length of flowing water to allow development of eggs and early larvae (see Section 2.1 – Stages of Invasion for more information regarding Great Lakes tributaries that may provide suitable spawning habitat for Asian carp). Early life stages of Asian carp typically inhabit warm, productive, protected, backwater and wetland areas. Wetlands and backwater habitats adjacent to tributaries that can support spawning of Asian carp would be at risk of colonization.

Using a bioenergetics model that considers only plankton as food resources, Cooke and Hill concluded that many open water regions of the Great Lakes could not support growth of juvenile or adult Asian carp due to low concentrations of plankton[4]. But U.S. Geological Society (USGS) scientists have recently documented Asian carp feeding on Cladophora algae and detritis, indicating that Asian carp could grow in productive regions such as Green Bay, western Lake Erie, and some other embayments and wetlands. Guts of Asian carp contain other items in addition to plankton. Whether these foods are nutritious enough to sustain Asian carp is also being tested in the model.

While the results of studies suggest a varied Great Lakes distribution and subsequent impacts from Asian carp infestation, the potential threat to the ecology and economy of the Great Lakes compels immediate precautionary actions to ensure that self-sustaining Asian carp populations do not become established.

1.4.4 Potential Risk to the Great Lakes Basin

An Asian carp invasion can cause significant, permanent damage to the economic and ecological health of a region.[5] Acquisition of an increasing amount of data indicates that an invasion into the Great Lakes by Asian carp could be financially, ecologically, biologically, and socially devastating. These categories of impact are interconnected, all significantly affecting one another. An active, multi-disciplinary approach will be necessary to prevent the negative impacts an invasion could exert on the Great Lakes.

The Great Lakes cover more than 94,000 square miles and host valuable tribal, sport, and commercial fishing industries. Following introduction of Asian carp into the Great Lakes basin, controlling their spread throughout these areas could be nearly impossible. Establishment of Asian carp in the Great Lakes could have lasting and potentially negative effects. Under conditions in the Great Lakes (especially their tributaries and estuaries) such as water temperature, food abundance, slow moving wetland regions, expansive area for migration, and lack of natural predators, Asian carp populations could expand quickly. These species could significantly impact local ecosystems.

However, financial and social costs are associated with actions needed to stop Asian carp from entering the Great Lakes. For instance, permanent closure to the Chicago area locks would greatly affect commerce and recreational use of Lake Michigan and the CAWS. About seven million tons of cargo passes through the O'Brien Lock each year, as do more than 19,000 recreational boats many of which are docked along the Calumet River and reach Lake Michigan through the lock. Additional cargo, ferry, and pleasure boats use the Chicago Lock. In 2010, 11,699 lockages and 36,334 vessels passed through the Chicago Lock—traffic of a size second only to the Hiram M

[4] Cooke S.L. and W.R. Hill. 2010. "Can filter-feeding Asian carp invade the Laurentian Great Lakes? A bioenergetic modeling exercise." *Freshwater Biology* 55: 2138–2152.
[5] Hansen, M. 2010. The Asian Carp Threat to the Great Lakes. Accessed September 18, 2011. On-line address: http://www.glfc.org/fishmgmt/Hansen_testimony_aisancarp.pdf. Great Lakes Fisheries Committee, Ann Arbor, Michigan.

Chittenden Locks in Seattle, Washington. The locks are also used by the Coast Guard stations on the Lake Michigan side of the locks in responding to emergencies on the canal and in patrolling critical infrastructure facilities within the river system.

Financial Risk

As Great Lakes leaders know from experience, it is difficult and expensive to deal with invasive species after their establishment. An example is the Great Lakes Fisheries Commission's (GLFC) expenditure of over $300 million since 1956 to control sea lampreys, an invasive species to the Great Lakes. However, Dr. Michael Hansen, Chair of the Commission during 2010, concluded that this expenditure is a fraction of the billions of dollars in revenue lost because of the sea lamprey's direct role in decline of lake trout, a native keystone species, by a staggering 99 percent.

Fishing in the Great Lakes is an industry estimated to generate billions of dollars of revenue. An invasion of Asian carp to the Great Lakes could be detrimental to the fishing industry and those financial assets. The potential financial risk to fishing alone indicates the significance of an Asian carp invasion to the Great Lakes region.

Social Risk

The social implications of an Asian carp invasion of the Great lakes range from indirect (outcompeting [thus eradicating] native sport populations) to direct (physical harm to people). The Great Lakes Commission (GLC) estimates that nearly 1 million boats and personal watercraft operate on the lakes (GLC 2003) [6], thereby placing more than a million people in potential contact with the silver carp, a projectile fish. The hazards these projectile fish pose to those boating, Jet-skiing, and waterskiing on the Illinois River system would be compounded on the Great Lakes because of a significantly larger boating population, thus posing a larger health and safety issue.[7] The social risk that Asian carp represent to the Great Lakes is directly relevant to the financial risk as well. If Asian carp do make their way into the Great Lakes, recreational activities could be significantly affected, directly impacting revenue based on those activities.

Ecological and Biological Risk

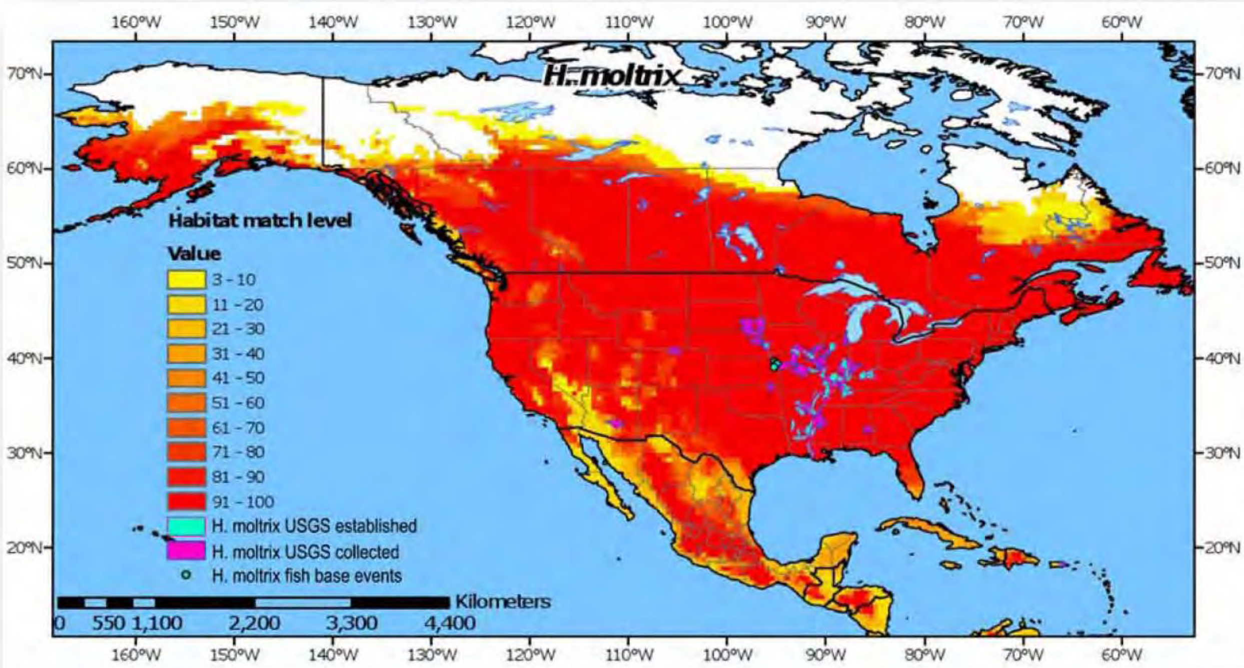
Assessments indicate that the carp are certain to tolerate the Great Lakes Basin's climate, because the basin is well within their native climate range. Mean annual air temperatures that support Asian carp populations range between -2 degrees Celsius (ºC) and 22ºC for bighead carp and -6ºC and 24ºC for silver carp—a temperature span that would support these populations in much of the United States and Canada, including the Great Lakes.[8] An invasive species becomes an issue when it changes the native habitat and populations that inhabit an ecosystem. Biologists reported similar diets were reported by biologists among Asian carp and native fishes in the Mississippi and Illinois Rivers, which suggests the Asian carp would likely outcompete native fish for food.[9] The invasive sea lamprey has changed the Great Lakes ecosystem forever, demonstrating the

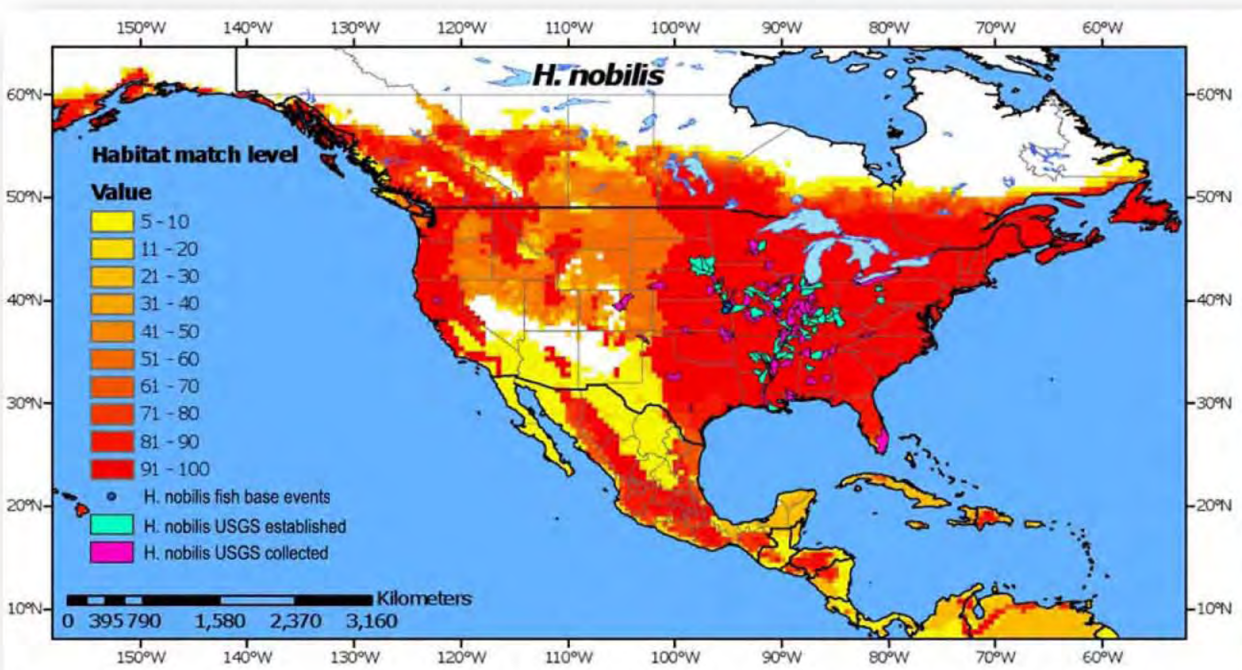
[6] Hanson, above n 5.
[7] Ibid
[8] Ibid
[9] Ibid

impact one invasive species can exert on an ecosystem. Mandrak and Cudmore (2004) [10] concluded that the consequences of establishment of grass and silver carp on the genetics of native species would be certain and profound, and would be reasonably certain and significant from establishment of bighead and black carp. Invasive species are nearly impossible to eradicate, rendering prevention of Asian carp invasion that much more important. Herborg et al.[11] used ecological modeling to predict the suitable environmental habitats for Asian carp in North America. Exhibit 1 represents the suitable environmental habitats—including the Great Lakes—for each of the two Asian carp species central to this Framework: silver and bighead carp.

[10] Mandrak, N. E., and B. Cudmore. 2004. Risk assessment for Asian carps in Canada. Accessed September 18, 2011. On-line address: www.dfo-mpo.gc.ca/csas/Csas/DocREC/2004/RES2004_103_E.pdf. Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Burlington, Ontario.
[11] Herborg, L., Mandrak, N., Cudmore, B., and MacIsaac, H. 2007. Comparative Distribution and Invasion Risk of Snakehead (Channidae) and Asian Carp (Cyrpinidae) Species in North America. *Canadian Journal of Fisheries and Aquatic Sciences* 64: 1723-1735.

Exhibit 1. Predicted Suitable Environment for Asian Carp in North America





Note: Environmental suitability is represented as a number (out of a maximum of 100) of models that predicted a particular location as suitable. From top to bottom, (H. moltrix) silver carp and (H.nobilis) bighead carp.

The Great Lakes are home to many important species of food and sport fish such as whitefish, bloater chubs, and yellow perch, as well as sport fish including trout and walleye. The potential impact of Asian carp on the Great Lakes' sport and commercial fishing industry can be seen now in the Mississippi River Basin where in a few short years following Asian carp introduction, many commercial fishing locations have been abandoned, as native fish have been significantly impacted by Asian carp. The presence of Asian carp is a concern because they are prolific, grow and mature quickly, and feed on plant and animal plankton (phytoplankton and zooplankton). They may alter energy flow in the Great Lakes, which in turn could lead to undesirable consequences for sport and commercial fisheries. A 2002 workshop convened by the Great Lakes Protection Fund, as well as the 2003 Aquatic Invasive Species Summit convened by the City of Chicago and the United States Fish and Wildlife Service (USFWS), determined that introduction of Asian carp into the Great Lakes ecosystem would threaten the sport and commercial fisheries, and could result in ecological and economic damages exceeding those caused by the sea lamprey and zebra mussel invasion.[12]

The Great Lakes are home to nearly 80 federally-listed threatened or endangered fish, mollusks, plants, mammals, insects, and reptiles, and many more species listed as threatened or endangered at the state level. Nationally, about 42 percent — 400 of 958 — of the species listed as threatened or endangered under the Endangered Species Act are considered at risk primarily because of predation or competition with exotic species.[13] Introduction of Asian carp to the region could further stress these organisms through mechanisms that are difficult to predict and perhaps lead to their extirpation. One such fish of concern is the lake sturgeon, which is protected by the State of Michigan because its remaining populations are less than 1 percent of the original population due to overfishing and habitat loss. Many of these fish age to nearly 25 years for females and 12 years for males before reaching maturity, and are bottom feeders with a diet including snails, mussels, and crustaceans. Because Asian carp populations could reach self-sustaining levels near the confluence of the Lake Michigan tributaries and canals in the Chicago vicinity, it is highly likely that range expansion within the lake's watershed could occur over time as a result of density-dependent dispersal. If higher concentrations of Asian carp are realized within an established area, Asian carp would move to new areas seeking suitable habitat and resources. Through this natural dispersal process, populations of Asian carp may become established in embayments, estuaries, lagoons, and river mouths of medium to large rivers and streams proximate to the home range of an established population. These types of water bodies are found within Lake Michigan and throughout the entire Great Lakes Basin.

[12] Chick, J. H. 2002. Establishment of Asian Carp in the Upper Mississippi River and Potential Threats to the Great Lakes. Illinois Waterway Barrier Workshop hosted by the Great Lakes Protection Fund, in Chicago.
[13] Nature Conservancy. 1996. America's Least Wanted: Alien Species Invasions of U.S. Ecosystems. Arlington, Va: The Nature Conservancy; Wilcove D.S., D. Rothstein, J. Bubow, A. Phillips, and E. Losos. 1998. "Quantifying threats to imperiled species in the United States." *BioScience* 48(8): 607- 615.

Isolated Instances of Bighead Carp Found in Ohio River and Western Lake Erie
In addition to the established populations throughout the Mississippi River and other basin waterways, bighead carp have been found in the upper portions of the Ohio River and Lake Erie. The single bighead carp found in the Upper Ohio River is believed to have traversed through the Mississippi River Basin and lock systems of the Ohio River. Five bighead carp have been individually collected between 1995 and 2003 in western Lake Erie. Since 2004, in response to these discoveries, USFWS has monitored western Lake Erie in Sandusky and Toledo, Ohio, using trammel nets. This surveillance sampling has not resulted in any additional collections of bighead or silver carp. These sampling efforts suggest a reproducing population does not exist in Lake Erie. Additional information on collection points can be found in the USGS Nonindigenous Aquatic Species Database at http://nas.er.usgs.gov/.

ACRCC Risk Management

Although further delineation is necessary, the risk of an Asian carp invasion of the Great Lakes and associated basin waters exists. In order to proactively prevent invasion of these Asian carp with potentially damaging impacts on the Great Lakes, a suite of actions have been undertaken or are planned as part of the ACRCC management strategy. The 2012 Framework describes these actions and strategic distribution of these actions to address this problem. Section 3.5 of this document also describes current and future risk assessment activities to further delineate the risk to the Great Lakes Basin.

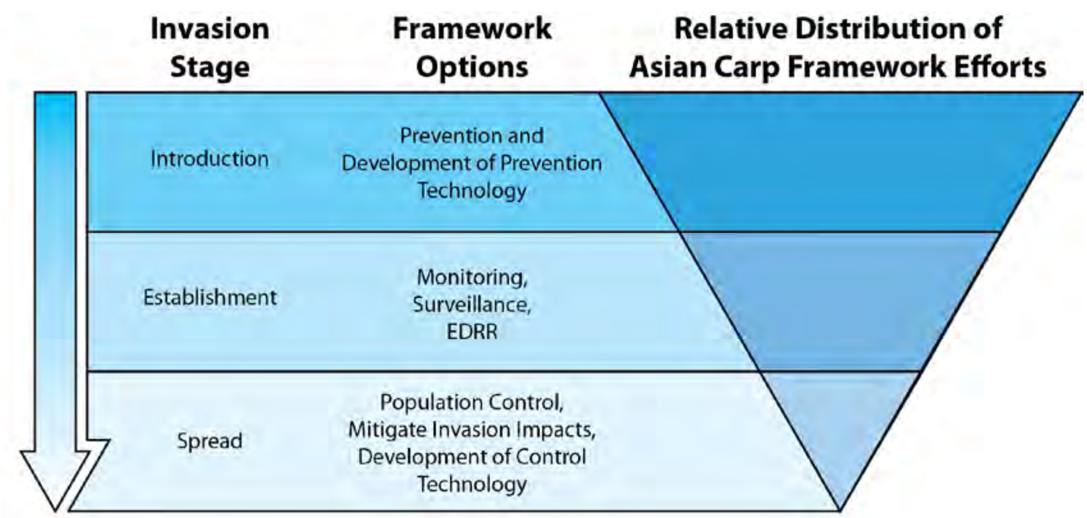
2.0 STRATEGIC MANAGEMENT OF ASIAN CARP

In order to execute the mission to prevent further introduction and establishment of Asian carp, this section of the framework provides strategic guidance for decisions that are made when selecting and executing actions, and how types of actions should be distributed to address the mission. The stages of the invasion process are first introduced to provide insight for the strategic approach and management options at each stage.

2.1 Stages of Invasion Model

This section of the framework provides strategic guidance for decisions regarding selection and implementation/distribution of actions. The stages of the invasion process are first described to reveal the strategic approach and management options at each stage. Common steps in invasion of many species are: (1) arrival and *introduction* to a novel system, (2) successful reproduction and *establishment* within the novel system, and (3) *spread* throughout the system that results from increasing abundance and continued successful reproduction[14]. Exhibit 2 below depicts the common stages of an AIS invasion and the categories of management options that correspond to those stages. The inverted triangle illustrates the relative distribution of Asian carp management actions included in the Framework. That is, the largest number of Framework actions should focus on prevention and development of prevention technologies, followed by those to stop establishment, and then by those developing technologies to minimize spread of Asian carp in the CAWS and Great Lakes (if this proves ultimately possible).

Exhibit 2. Conceptual Illustration of Framework Strategy



[14] Lodge, D.M., S.L. Williams, H. MacIsaac, H. Hayes, B. Leung, S. Reichard, R.N. Mack, P.B. Moyle, M. Smith, D.A. Andow, J.T. Carlton, and A. McMichael. 2006. "Biological Invasions: Recommendations for U.S. policy and management." *Ecological Applications* 16: 2035-2054.

First a species must arrive at and be introduced into the water body. *Introduction* to the Great Lakes waters can occur through various pathways. For Asian carp, purported pathways include: artificial connections to the Great Lakes (Exhibit 3), Great Lakes tributaries (Exhibit 4), organismic movement through the bait or aquarium trade, intermittent hydrologic connections (e.g. Wabash-Maumee area), and organism transport by shipping and ballast water. Once a species has arrived in an ecosystem and can successfully reproduce the stage of invasion advances toward *establishment*. Finally, an invasion advances to the *spread* stage if an established population continues to increase in abundance and spread throughout the novel habitat. Note that Exhibit 4 below also shows the Great Lakes tribuataries in the U.S. likely suitable for Asian carp spawning. These tributaries lack dams and have minimum lengths of 100 kilometers (km) that may be suitable for Asian carp spawning. Other waterways not shown here could still be conducive to spawning and are at least potential corridors for movement to the Great Lakes.[15] Preliminary findings as part of Framework action item 2.5.11 have indicated a shorter river length may suffice for Asian carp to spawn successfully. It has been documented that the CAWS is the primary corridor of concern for Asian carp expansion into the Great Lakes.

[15] Kolar, C.S., D.C. Chapman, W.R. Courtenay Jr., S.M Housel, J.D. Williams, D.P. Jennings. 2007. Bigheaded Carps: A biological synopsis and environmental risk assessment. American Fisheries Society Special Publication 33, Bethesda, MD

Exhibit 3. Artificial Connections to the Great Lakes

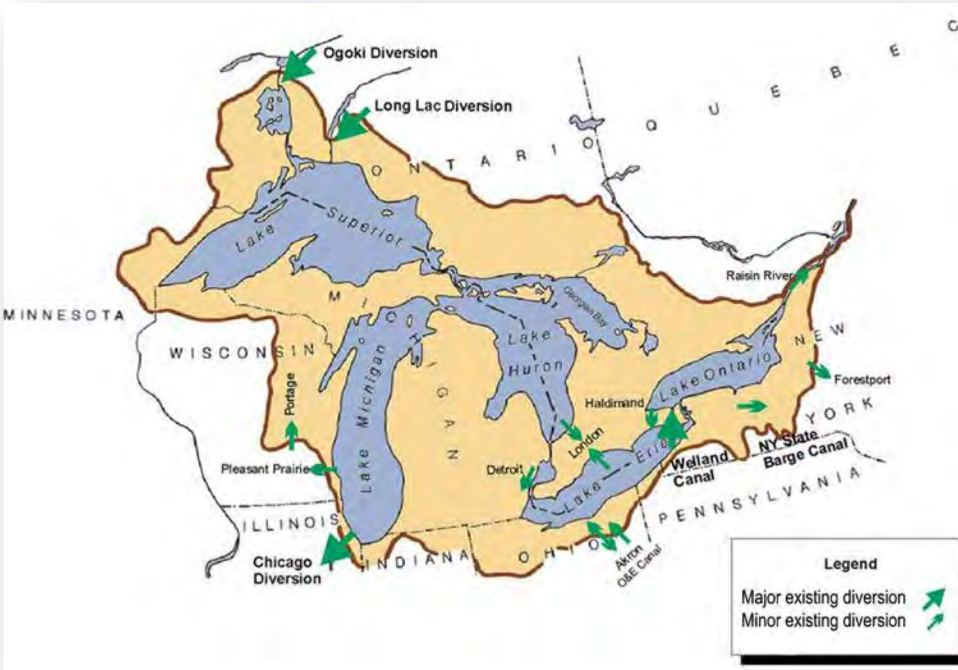


Exhibit 4. Great Lakes Tributaries Likely Suitable for Asian Carp Spawning

2.2 ACRCC Strategic Approach

Early warning of Asian carp introduction allows Great Lakes managers and the ACRCC a unique opportunity to focus on preventing further introduction. Therefore, a majority of efforts underway and documented in this Framework are aimed at direct prevention of Asian carp introduction through its various pathways, and development of prevention technologies. Other Framework actions address the establishment and spread stages of invasion. It is important to understand this does not indicate that Asian carp have advanced to these invasion stages—rather, the actions addressing establishment and spread are proactive and function to help prevent occurrence of these stages. Monitoring for Asian carp presence in the Great Lakes and its tributaries is prudent. Monitoring allows early detection and the onset of rapid response (EDRR) actions that halt advancement to the establishment stage of invasion. Control technologies may also be used to reduce current Asian carp populations in infested waterways, potentially lowering the risk of a Great Lakes invasion. Development of long-term control methodologies is also important; thus, if introduction to the Great Lakes should occur, agencies would be armed with control tools that limit spread, and minimize ecologic and economic impacts. This also enables application of developed methods outside of the CAWS and the Great Lakes Basin. In this way, management would be wholly prepared to minimize effects at each stage of invasion. Yet actions are appropriately focused first and foremost on prevention, as this is the goal of the ACRCC and is likely to be the most cost-effective approach over both the short term and the long term. Representative actions underway or soon to commence as part of the FY 2012 strategy are referenced below; a complete list and descriptions of FY 2012 action items is in Appendix B of this document.

2.3 Management Options for Strategic Direction

Corresponding management actions may prevent occurrence or advancement of each stage of invasion (Exhibit 2). Recognition of these stages and the corresponding management options is likely to improve short- and long-term management planning[16]. The categories of management options are described in more detail below, and are organized according to management actions implemented during each stage of invasion.

2.3.1 Prevention and Development of Prevention Technologies

Management options to prevent *introduction* generally can be categorized as prevention actions and development of prevention technology. Actions that fall under these categories are: (1) investigating likely pathways through risk assessment or other means; (2) reducing the number of invasive species in known pathways (including reducing invasive species in neighboring watersheds to control the source population); (3) enforcing transport regulations (e.g. bait trade, inter and intrastate transport); and (4) deploying or investigating new prevention technology (see Sections 3.1, 3.3, and 3.5 for an explanation of the some prevention and prevention technology efforts currently underway). Thus, to prevent Asian carp introduction, the ACRCC has employed a

[16] Lodge et al, above n 14.

suite of these types of actions. Table 1 lists actions that prevent introduction and thus effectively address all invasion stages. In the short term, prevention of invasion prevents advancement to establishment and spread stages. In the long term, should introductions occur, some actions will reduce the abundance of species that could enter the Great Lakes by first preventing introduction, and over time, reducing the propagule pressure, or number of individuals that normally would cause damage to the Great Lakes. For instance, installation and operation of the electric barrier operation in the CAWS deters movement of Asian carp to the Great Lakes and thus reduces the likelihood of introduction from this pathway.

In the long term, should introductions occur, this management action still functions to deter species and lessen the impacts to the Great Lakes by reducing the number of species that could migrate to the Great Lakes. Risk assessment action for Asian carp will help to target monitoring activities to critical areas, as well as identify follow-on removal efforts that should occur. For example, Framework action item 2.4.5 identifies the likelihood of species introductions from various pathways. A potential use of the results could be to prioritize location and timing of action so that the pathway with larger relative risk can be minimized first. Table 1 below provides examples of current and proposed applications for prevention and development of prevention technology by member agencies in this Framework. Not all preventative actions address all life stages of Asian carp. This point highlights the need for future work and development of long-term solutions to prevent further introduction of young-of-year fish, juveniles, and adult Asian carp to the Great Lakes. Notes: (1) many Framework actions described in this document can be categorized under more than one Management category; (2) each specific action indicates at least one of the dominant types of Framework actions completed as part of that work.

Table 1. Prevention and Prevention Technology Management Options

General Management Categories	Specific Actions	Selected Framework Actions*
Risk assessment	Identify potential pathways for Asian carp to enter Great Lakes	2.4.2, 2.4.6, 2.5.1, 2.5.11, 2.5.17
	Identify and/or assess likelihood of species in pathways	2.4.5
Prevention	Reduce Asian carp abundance/ distribution/ movement in pathways (e.g. bait trade, tributaries, human mediated transport/shipping)	2.1.1, 2.1.2, 2.1.3, 2.2.1, 2.2.2, 2.2.3, 2.3.3, 2.3.5
	Enforce transport regulations	2.7.2
Development of prevention technology	Implement barrier safety and operations testing, defense	2.2.3, 2.3.2, 2.3.4, 2.3.6, 2.3.7, 2.4.1, 2.5.2, 2.5.6, 2.5.19, 2.5.20

***View Appendix A and B for details of individual projects.**

2.3.2 Monitoring and Development of Monitoring Technology

Management options to prevent *establishment* can be categorized generally as monitoring actions and development of monitoring technology that allows managers to rapidly detect early arrivals to the Great Lakes or tributaries. These critical actions allow management to delineate the current distribution of Asian carp in nearby watersheds, and determine where removal and other preventative measures should occur. In addition, rapid response actions such as electrofishing and netting can occur upon detection of individuals to remove the Asian carp from the newly invaded habitats. This helps prevent movement toward the Great Lakes, and would help with rapid removal of any individuals already within the Great Lakes. Actions that fall under these categories are those that: (1) investigate habitats in the Great Lakes likely to harbor Asian carp; (2) develop or refine methods, such as eDNA or bacterial source tracking, that can be used to detect carp presence; (3) track abundance using various forms of monitoring (electrofishing), movement (telemetry), and presence/absence (eDNA) of Asian carp in critical locations within and neighboring the Great Lakes; and (4) employ rapid response actions that remove detected individuals (e.g. rotenone, electrofishing, netting) (see Sections 3.3, 3.4, 3.5, and 3.6 below for more detail regarding some current monitoring and monitoring technology efforts). Selected Framework examples of these actions are listed in Table 2. Note: categories of management actions that prevent introductions of Asian carp also thus inhibit advancement to *establishment* stages of invasion, and selected Framework numbers that execute these actions are shown (i.e. rapid response and removal follows early detection of individuals that have arrived at or near the Great Lakes). Many Framework actions within this document fall into more than one Management category; each specific action indicates at least one of the dominant types of Framework actions completed as part of that work.

Table 2. Monitoring and Monitoring Technology Management Options

General Management Categories	Specific Actions	Selected Framework Actions*
Risk assessment	Great Lakes Habitat Suitability modeling	2.4.5, 2.5.4, 2.5.5
Development of monitoring technology	eDNA refinement	2.5.3, 2.6.1, 2.6.4, 2.6.5
	Development of new detection methodology	2.5.15, 2.5.16
Monitoring for Early Detection	Electrofishing	2.1.1, 2.1.2, 2.3.4
	Telemetry	2.3.4
	eDNA	2.1.1, 2.1.2, 2.6.2, 2.6.3
Rapid Response	Rotenone application	2.1.2, 2.1.3
	Other species removal efforts	2.2.1, 2.2.2
***View Appendix A and B for individual project detail.**		

2.3.3 Development of Control Technology and Impact Mitigation

It is necessary to investigate long-term control methodologies that can effectively eliminate Asian carp species or prevent their movement while minimizing damage to native biota. Actions that fall under these categories are: (1) investigating species-specific control methods, (2) determining efficacy of long-term hydrologic separation, and (3) testing other possible control mechanisms (e.g. application of hydro guns) (see Sections 3.2 and 3.6 below for a more in-depth look at some current control technologies and impact mitigation efforts). Development of these methodologies requires investigation and/or laboratory development and testing before deployment in the field. However, species-specific and permanent control tools are necessary for successful long-term control of source populations. For example, species-specific lampricide was developed to control the harmful sea lamprey in the Great Lakes. The lampricide is applied annually at key tributary locations to mitigate impacts and to control the number of lampreys that arrive at the Great Lakes.

Selected Framework actions are shown in Table 3. Note: Selected Framework actions implemented as components of specific actions are listed. Many Framework actions described in this document fall into more than one Management category; each specific action indicates at least one of the dominant types of Framework actions completed as part of that work.

Table 3. Control Technology and Impact Mitigation Management Options

General Management Categories	Specific Actions	Selected Framework Actions*
Development of population control technology	Investigate species specific control methods	2.5.7, 2.5.8, 2.5.9, 2.5.10, 2.5.12, 2.5.13, 2.5.15, 2.5.20
	Permanent separation efficacy	2.4.2, 2.4.6, 2.4.7
	Other long-term control mechanisms	2.5.6, 2.5.19
***View Appendix A and B for individual project detail.**		

2.3.4 Other Supporting Activities (Education, Outreach, Regulatory Support)

Actions that support Asian carp management include those that increase public awareness of the threat of Asian carp, and the ACRCC continues to inform and engage the public, stakeholder organizations, and governmental organizations in this regard. This is an unprecedented effort to disseminate information about preventing the spread of invasive species—via meetings, press events, and communications. Moreover, education and outreach can lead to behavior changes that may prevent release of the species through bait trade (e.g. 2.7.1). Actions that meet these objectives are listed in Table 4, which shows supporting actions for Asian carp management and selected Framework examples for each type.

Table 4. Other Supporting Activities

General Management Categories	Specific Actions	Selected Framework Examples*
Other Supporting Activity	ACRCC coordination, support, and public relations	2.4.8, 2.5.18, 2.7.4, 2.8.1, 2.9.1
	Education and outreach to raise awareness of Asian carp threat	2.7.1, 2.7.3, 2.7.4, 2.7.5, 2.7.6, 2.7.7
***View Appendix A and B for individual project detail.**		

2.4 Summary

The ACRCC has implemented and will continue to conduct actions to directly prevent Asian carp establishment in the Great Lakes, while monitoring for signs of Asian carp in the Great Lakes. The ACRCC is also investigating critical methods for long-term control of Asian carp. Actions have been conceived and implemented to address all stages of invasion by preventing introduction, utilizing technology to achieve long-term control.

3.0 CRITICAL EFFORTS UNDERWAY

This section provides summaries of efforts underway within the Framework and accomplishments since its inception in 2010. Much of this ongoing work will continue to generate critical knowledge and tools for the efforts against Asian carp.

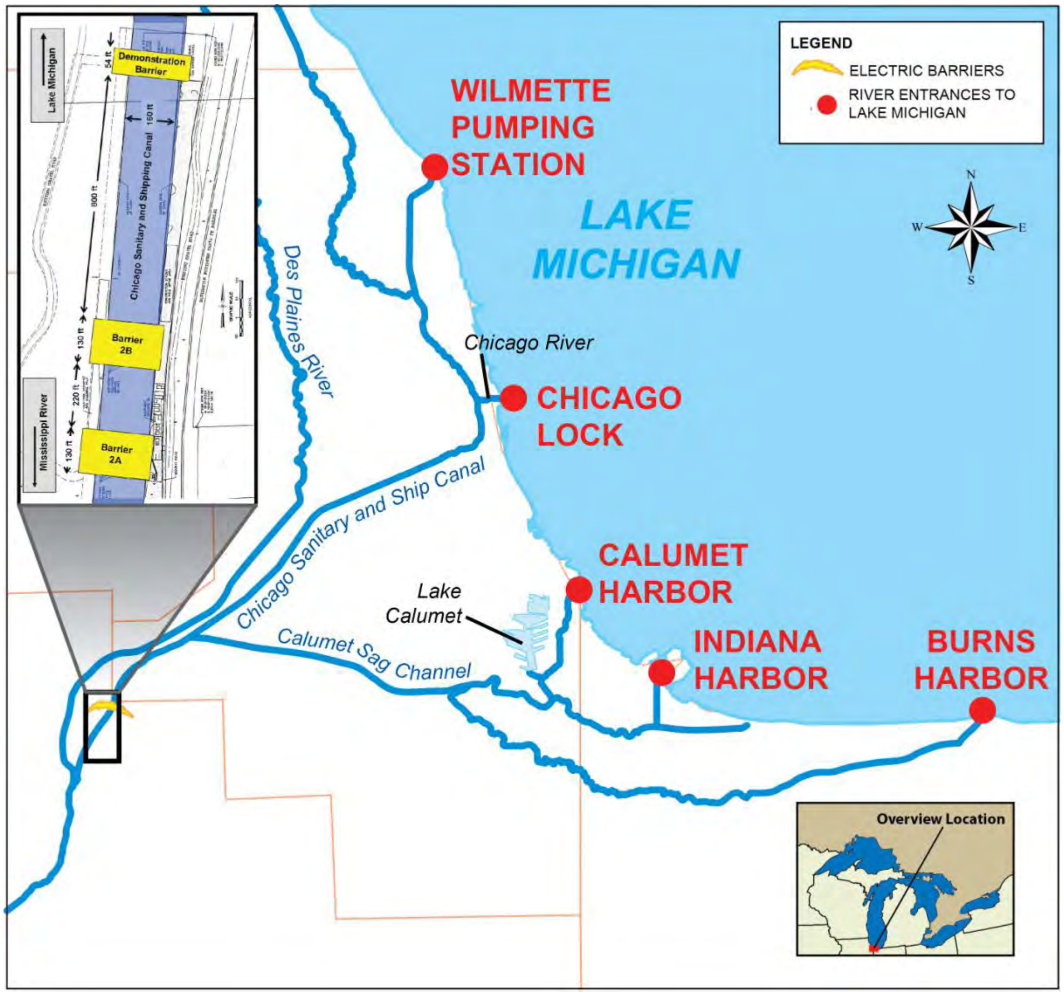
3.1 Electric Dispersal Barriers in the Chicago Area Waterway

The CAWS is the only known continuous connection between the Great Lakes and Mississippi River Basins and, as such, poses the greatest risk for transfer of aquatic nuisance species.

The Electric Dispersal Barriers are located near Romeoville, Illinois in the Chicago Sanitary and Ship Canal (CSSC) within the CAWS (see Exhibit 6). They are designed to prevent the inter-basin transfer of fish between the Mississippi River and Great Lakes Basins via the CSSC. The barriers are formed of steel electrodes secured to the bottom of the CSSC, and connected to a raceway consisting of electrical connections to a control building while not inhibiting waterway vessel traffic (see Exhibit 5). Equipment in the control building generates a direct current (DC) pulse through the electrodes, creating an electric field in the water that discourages fish from crossing, as depicted below.

Exhibit 5. Electric Barrier Design

Exhibit 6. Electric Barrier System Location on the CAWS



Barrier I, also known as the Demonstration Barrier, has been operational since 2002. Due to its original demonstration status, it was designed and built with materials that were not intended for long-term use. The Water Resources Development Act of 2007 authorized the upgrade of Barrier I to a permanent barrier. Construction of the permanent Barrier I is scheduled to begin in 2012.

Barrier IIA was placed into full-time operation in 2009. Barrier IIB was activated in April 2011 with the same operating parameters as Barrier IIA. As of June 2011, Barrier IIA was in warm standby pending a final decision on optimal operating parameters.

The Water Resources Development Act of 2007 also directed the United States Army Corps of Engineers (USACE) to conduct a study of a range of options or technologies for reducing impacts of hazards that may reduce the efficacy of the Electrical Dispersal Barriers through analyzing various technical, environmental, and biological factors. The study was divided into several segments, or interims, as described below.

Interim Report I identified areas of potential bypass and recommended construction of fence and concrete barriers along the Des Plaines River and a stone blockage barrier in the Illinois and Michigan (I&M) Canal. These measures, completed in October 2010, reduce the risk of Asian carp bypassing the barriers during flooding.

Interim Report IIA, completed in September 2011, documents research to determine optimum operating parameters for the dispersal barriers based on safety and operational impacts of altering parameters and the location of very small Asian carp in the upper Illinois River. Although sufficient information was available to serve as a basis for a decision on operating parameters, release of a follow-on report, Interim IIB, is expected after additional tests and evaluation of risk factors have been completed. Interim IIB will be used primarily to improve barrier operations and verify the recommendation in Interim IIA.

Interim Report III, completed in July 2010, evaluates possible risk reduction through changes in operation of structures within the CAWS such as locks, sluice gates, and pumping stations. The report recommends construction and installation of bar screens for two sluice gates at both the O'Brien and Chicago Locks. Implementations of these recommendations were completed in January 2011.

Interim Report IIIA, completed in July 2010, considers how technologies such as bubbles, light, and sound barriers can inhibit Asian carp movement, and recommends construction of an acoustic bubble curtain with strobe lights as a demonstration project. Funding and authority for implementation are required to initiate design of this project.

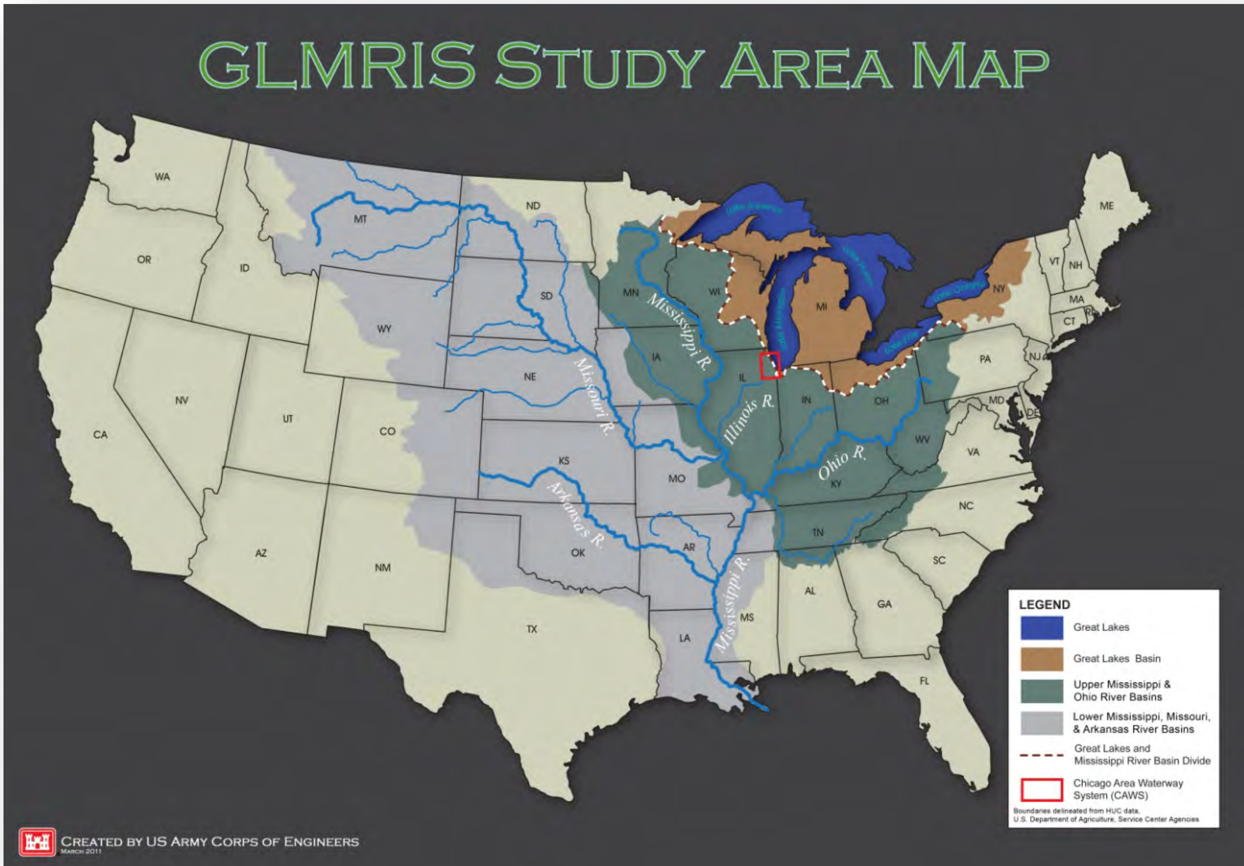
The comprehensive efficacy report will update the status of the aforementioned efforts and recommend risk reduction measures to address pathways not addressed in the interim reports.

3.2 GLMRIS

The Great Lakes and Mississippi River Inter-basin Study (GLMRIS) is a congressionally authorized feasibility study. The authorization directed the USACE to consult with appropriate federal, state, local, and nongovernmental organizations on the range of options and technologies available to prevent spread of AIS between the Great Lakes and the Mississippi River Basins through the CSSC and other aquatic pathways. The study will provide a thorough identification of potential hydraulic connections between the two basins, identify and explore existing and potential aquatic nuisance species, and assess aquatic nuisance species control technologies. These control technologies include but are not limited to physical or hydrologic separation.

The study is proceeding in two focus areas to fix upon a possible solution as soon as possible given the complexity of the task. Focus Area I is the CAWS and Focus Area II encompasses all aquatic pathways outside the CAWS, commonly referred to as the Other Pathways. See Exhibit 7 below for the complete GLMRIS study area.

Exhibit 7. GLMRIS Study Area Map



The main purpose of the GLMRIS is to analyze options for preventing inter-basin transfer of AIS via aquatic pathways. While not directed solely at Asian carp, any solution identified and recommended for implementation would serve to prevent Asian carp movement to the Great Lakes via the CAWS or other aquatic pathways where Asian carp are a threat.

As part of GLMRIS, the USACE is conducting a comprehensive analysis of AIS controls and will analyze the effects each AIS control or combination of controls may have on current uses of: (1) the CAWS, a continuous aquatic pathway between the Great Lakes and Mississippi River basins, and (2) other aquatic pathways between these basins. The USACE will:

- Inventory current and forecast future conditions within the study area.
- Identify aquatic pathways that may exist between the Great Lakes and Mississippi River Basins.

- Inventory current and future potential aquatic nuisance species.
- Analyze possible AIS controls to prevent AIS transfer, to include hydrologic separation of the basins.
- Analyze the impacts each AIS control may have on significant natural resources, and on existing and forecasted uses of the lakes and waterways within the study area.
- Recommend a plan to prevent AIS transfer between the basins. If necessary, the plan will include mitigation measures for impacted waterway uses and significant natural resources.

Significant issues associated with GLMRIS may include, but are not limited to:

- Significant natural resources such as ecosystems and threatened and endangered species
- Commercial and recreational fisheries
- Current recreational uses of the lakes and waterways
- AIS effects on water users
- Effects of potential AIS controls on current waterway uses such as flood risk management, commercial and recreational navigation, recreation, water supply, hydropower, and conveyance of effluent from wastewater treatment plants and other industries
- Statutory and legal responsibilities relative to the lakes and waterways.

3.2.1 Focus Area 1: CAWS

The CAWS is the primary pathway for inter-basin transfer of AIS. It is the only known continuous aquatic connection between the Great Lakes and Mississippi River Basins, and therefore poses the highest risk of potential AIS transfer. Focus Area 1 addresses the goal of preventing transfer of AIS via the CAWS.

3.2.2 Focus Area 2: Other Aquatic Pathways

In addition to the CAWS, in 2010, 36 other potential aquatic pathways were identified along the Great Lakes and Mississippi River Basins divide. An expedited study in fall 2010 eliminated 18 of these pathways, and identified one pathway (Wabash – Maumee) for expedited action. Within Focus Area 2, risk of AIS transfer at the remaining 18 pathways will be evaluated, and, based on this evaluation, the USACE is to develop recommendations to prevent transfer of AIS via these pathways, starting with the highest risk locations.

The aquatic connection that forms across the Wabash – Maumee Pathway (aka Eagle Marsh) in Fort Wayne, Indiana, was identified in 2010 as the highest risk aquatic pathway within Focus Area 2. The risk posed by Asian carp in close proximity to the location resulted in the Indiana Department of Natural Resources (IN DNR), supported by United States Environmental Protection Agency (USEPA), National Resource Conservation Service (NRCS), USGS, USACE, Allen County, and the Little River Wetlands project, cooperating to complete construction of a temporary barrier to adult Asian carp movement across the marsh during flood events. As part of the Focus Area 2 effort, USACE is conducting a feasibility study at this location to determine what action or set of actions could attain a long-term solution that prevents inter-basin transfer of AIS across the Eagle Marsh in Fort Wayne, Indiana. Analyses will include identification of structural and non-structural measures and a systematic evaluation of the completeness, effectiveness, efficiency, and acceptability of each measure in order to formulate a recommended plan.

The USACE welcomes information that will enhance the study and that might shorten the time otherwise required for the necessary review, including results of the Great Lakes Commission and Great Lakes/St. Lawrence River Cities' studies of options for ecological separation.

3.3 Monitoring and Removal in CAWS

The USFWS, USACE, and Illinois Department of Natural Resources (IL DNR) monitor for the presence of Asian carp in the CAWS. Additional state and federal agencies, universities, and consultants are conducting additional monitoring in the CAWS as prescribed by the Monitoring and Rapid Response Workgroup's (MRRWG) annual monitoring and rapid response plan. This plan was created in 2010 by the MRRWG and revised for the 2011 sampling season to incorporate data gathered during the 2010 monitoring season. This section highlights many of the ongoing efforts in conjunction with and independent of the MRRWG's monitoring and rapid response plan.

Fixed site electrofishing samples – IL DNR, USFWS, and USACE have coordinated their efforts and are sampling five fixed sights and additional reaches in the CAWS for the presence of Asian carp and local fish population. In 2011, over 2,100 person-hours were spent electrofishing the waters above the electric dispersal barriers. In addition to monitoring for Asian carp, these data are used to inform a fishery statistical-based model that will ultimately quantify the potential of Asian carp presence/absence and relative abundance. This effort is part of a larger CAWS monitoring program developed by the MRRWG of the ACRCC. In addition, USACE conducts monthly electrofishing surveys at the Barrier, outside of the regular MRRWG monitoring at fixed sites.

Netting and commercial fishing efforts in the CAWS – As part of the MRRWG monitoring program and its monitoring and rapid response plan, the IL DNR extensively monitors the CAWS above the electric dispersal barriers with traditional fishing gears and nets, and contracts with local commercial fishermen. In 2011, 1,590 person-hours were spent netting these waters and 67.4 miles of nets were set.

Rapid response planning in the CAWS – MRRWG members have worked extensively with partner agencies and the ACRCC executive committee to develop a decision matrix to trigger a response action to positive detections of Asian carp results (eDNA and traditional gear monitoring) in the CAWS. Response actions include intensive and focused sampling with traditional gears, commercial netters, and potentially the use of rotenone.

eDNA monitoring and study design – USFWS and IL DNR are sampling eDNA from the CAWS on a regular schedule (weekly basis); USACE and USEPA filter the water samples, and USACE processes the samples at the Engineer Research and Development Center laboratories. This effort began with the USACE in 2009 and will transition to the USFWS in 2013. Additional sampling is planned for fall 2011/spring 2012 during which multiple crews will strategically sample eDNA concurrently across the CAWS for an instantaneous look ("real-time snapshot") of any possible water-borne Asian carp eDNA in the system (amount and location of material). During the 2010 monitoring season, USACE was able to collect over 1200 samples to test for presence of Asian carp DNA.

Des Plaines/CSSC barrier monitoring – LaCrosse and Carterville Fish and Wildlife Conservation Offices (FWCO) have developed a plan and response actions to address threats from overflow from the Des Plaines River into the CSSC, should flooding occur. USFWS and collaborating agencies will attempt to monitor and potentially collect and stop any Asian carp life forms that may cross between the two water bodies. In addition to monitoring of the area, in 2010, the USACE completed a 13-mile barrier above the electric dispersal barrier between the Des Plaines River and the CSSC at the areas deemed most susceptible to flood conditions. This is a steel-reinforced, concrete barrier and reinforced heavy-duty fencing that allows water to flow but prevents transfer of Asian carp into the CSSC.

Des Plaines River sampling – LaCrosse FWCO is sampling the Des Plaines River below Hoffman Dam to monitor for Asian carp adults that may have migrated up to the dam for spawning.

Asian carp gear development – Columbia FWCO is working in the Missouri River to develop various fishery gears more suitable for catching Asian carp where they are known to exist in large numbers. The purpose of this gear development is to transfer the technology to the CAWS to better monitor, collect, and remove Asian carp. Additional work by the IL DNR working with a panel of carp experts and the Illinois Natural History Survey, University of Illinois is proceeding to develop fishery gear to more efficiently capture Asian carp. We have brought together commercial fishers from across the country to gain valuable expertise. Gears for 2012 include extremely deep gill nets, 6-foot hoop nets, and other nets in development. Assessment of gears most effective for collection and sampling of Asian carp juveniles is also underway.

Fish behavior near the electric dispersal barrier as determined through DIDSON and Telemetry studies – The Carterville FWCO of the USFWS, with support from USACE, has a new project that utilizes DIDSON to observe fish behavior in and around the barrier. Both feral and captive fish are viewed. Feral fish are viewed in timed (pre-determined) runs in and through the barrier, and captive fish are being confined and transported through the barrier in a boat-mounted cage to observe their reaction to the electric field. USACE is leading the effort, using ultrasonic telemetry, to directly assess the efficacy of the Barrier by determining if tagged fish are able to challenge and/or penetrate the Barrier. Other purposes of the telemetry project are to determine if Asian carp are able to navigate through lock structures in the Illinois Waterway system, to determine the leading edge of the Asian carp populations, and to directly test the response of smaller sizes of fish to the Barrier. An acoustic array is established in the CAWS and the Illinois Waterway, spanning about 50 miles, which is also supplemented by monthly mobile tracking. USACE implanted 200 fish with transmitters, and their movements are tracked by the series of acoustic receivers throughout the waterway. Above the Barrier and immediately below, fish other than bighead and silver carp are studied (common carp, buffalo, grass carp, freshwater drum); in the lower pools (Dresden Island Pool), bighead and silver carp are tagged and monitored. To date, over 1.2 million detections since 2010 indicate no tagged fish have crossed the Barrier since the operating parameters were increased.

USACE is also using innovative technology to track fish movement at the Barrier. Preliminary analysis shows tagged fish moving upstream toward the Barrier, then turning and moving back downstream. This new technology will give us insight to fish aversion response near the Barrier.

Asian carp removal below the electric dispersal barrier system – As part of the MRRWG program, IL DNR contracts with commercial fishermen to remove Asian carp (both bighead and silver carp) from the waterways below the electric barrier system. The goal of this initiative is to reduce the populations of Asian carp that are able to challenge the barrier. A total of 351.7 tons of Asian carp were caught and removed in 2011. The impacts of harvesting were studied to ensure that this is significant and beneficial. The initial results of the Southern Illinois University study on fish removal will be released in early 2012.

3.4 eDNA

eDNA is a surveillance tool used to indicate the presence of genetic material of bighead carp and silver carp . Fish, including Asian carp, naturally release cells containing DNA into the environment through mucoidal secretions, feces, and urine. DNA degrades in the environment, but the process is not instantaneous, and DNA can be held in suspension and transported. Species can be detected by filtering water samples and then extracting and amplifying short fragments of the shed DNA. Unlike other surveillance methods, eDNA does not rely on direct observation of Asian carp to detect presence.

Currently, eDNA is used by the ACRCC in the Monitoring and Rapid Response Plan (MRRP) developed by its interagency subgroup, the MRRWG. eDNA has been used as an early detection surveillance tool since 2009. It has yielded "presence/absence" eDNA data for the reaches of the waterway sampled. In 2010 and 2011, eDNA has been used as a regular weekly monitoring tool to help inform rapid response decisions as part of the MRRP. Results are posted regularly on the USACE Chicago District website: http://www.lrc.usace.army.mil/AsianCarp/eDNA.htm. In 2012, the eDNA sampling strategy will be set by analyzing the 2011 results, including the large event in December 2011 (the eDNA snapshot), when six sites (720 samples) were sampled over three days.

From 2009 through 2011, over 6000 water samples have been analyzed for bighead and silver carp DNA.

The eDNA method has undergone two review processes. The first was in 2009 when the University of Notre Dame laboratory was audited by an EPA team. That audit concluded that the eDNA method is sufficiently reliable and robust in reporting a pattern of detection that it should be considered actionable in a management context; and the team expressed a high degree of confidence in the basic Polymerase Chain Reaction (PCR) method used to detect bighead and silver carp eDNA. The second was completed in December 2010, when the USACE contracted an independent external peer review of eDNA science and methodology, and findings were presented in the report, *Revised Final Independent External Review Report Environmental DNA (eDNA) Science and Methodology*. The review panel found some clear advantages and disadvantages of the eDNA methodology. In the Panel's opinion, no other single method could provide the suite of advantages offered by the eDNA samples, which included the following: sampling can take place over a large spatial area very rapidly at relatively low cost, and the method is potentially more sensitive for detecting Asian carp in environments typical of the CSSC than are traditional fishery methods. Key limitations of the method, however, are that the locations and condition (live or dead) of fish contributing eDNA to a water sample are not known. Additionally, eDNA detections do not provide information on the size, age, or gender of individuals present. Furthermore, the method cannot distinguish between pure silver or bighead carp and their hybrids, and detection is not immediate because of a time delay between water sample collection and processing for eDNA.

To date, USACE and the MRRWG have acknowledged that a positive eDNA sample indicates presence of Asian carp DNA and possible presence of live fish. Currently, the ACRCC cannot rely solely on eDNA as evidence to verify whether live Asian carp are present, whether the DNA may have come from a dead fish, the number of Asian carp in an area, or whether water containing Asian carp DNA may have been transported from other sources (e.g., translocation by vessels or birds). eDNA cannot presently provide exact, real-time information on locations of Asian carp because of the requisite two-week sample processing time. However, the eDNA method can be used as a basis for precautionary and prudent actions. Moreover, for making critical management decisions, the eDNA method can be a useful complement to traditional fish sampling gears, and can greatly improve the efficiency of the monitoring program for detecting Asian carp.

To help resolve the issues identified above and manage these uncertainties, the USACE is leading an eDNA calibration study (ECALS) with USGS and USFWS. ECALS will be investigating alternate sources of Asian carp DNA, improving existing genetic markers, and determining the relationship between the number and distribution of positive eDNA samples with the density of Asian carp. In addition, ECALS will investigate ways we can make the eDNA process more efficient (decrease processing time and cost). This will allow managers to better interpret what eDNA results mean and obtain results faster.

The following efforts are or will be undertaken as part of ECALS:

eDNA vector assessment – This effort will identify potential vectors for Asian carp DNA to enter the CAWS without originating from a live, free-swimming bighead or silver carp. Potential vectors include introduction of tissue and other cell matter containing Asian carp DNA from both:

- Movement of carp and carp material via fish-eating birds, particularly eDNA deposition via bird excrement, and
- Discharge of carp and carp material via storm sewers that empty into the CAWS (specifically in regions of Chicago where Asian carp are sold in markets on the street).

Additionally, this is to be an effort to determine the rate and duration of eDNA loading from fish carcasses. Fish carcasses could pass barrier via barges, commercial sales and traffic, fish-eating birds, etc.

These are deemed the most likely alternative routes for eDNA to move around the CAWS, and must be investigated to indicate the likelihood of these mechanisms resulting in positive eDNA sample results.

Develop eDNA markers for improved population inference – This effort will develop high-fidelity, sensitive genetic markers for detecting the presence of Asian carp DNA and for making broad estimates of Asian carp abundance. These new markers will provide an increased ability to estimate the minimum number of Asian carp genotypes represented in an eDNA sample, and, along with models of fish movement and population genetic structure, will broadly project Asian carp abundance.

Decreasing analysis time – This effort will develop techniques to decrease the time required for an important step in the analysis process, and develop assays that are expected to be more sensitive to lower concentrations of eDNA. As a result, eDNA processing time may be cut from 10 working days to 5 working days, allowing for much quicker turnaround time for results and more rapid response to new eDNA hits. In addition, this effort will assess whether different water sampling protocols might improve Asian carp detection probabilities (depth integrated sampling, new filtering techniques, and appropriate volume of water to sample).

Determine eDNA assay sensitivity under *no flow* conditions – This effort will determine the relationship between Asian carp size, number of carp, and carp behavior on eDNA loading rates (DNA shedding, sloughing). It will also identify the minimum amounts of eDNA required for detection and time to detection, and the rate at which detectable amounts of eDNA fill a volume of water under non-flowing conditions. This will be important for areas such as Lake Calumet and other embayments where no flow occurs.

Determine eDNA assay sensitivity under *flowing water* conditions – This effort will help determine the rate at which detectable amounts of eDNA fill a volume of water under flowing conditions. This will be important for most of the CAWS, where flow occurs under most conditions.

Quantify relationships between major environmental factors and eDNA degradation under *no flow* conditions – This effort will determine relationships between environmental factors—water temperature, light exposure, zooplankton, and microbial biomass, pH—and eDNA degradation rates in no flow systems.

Develop guidance on using calibration data to broadly estimate Asian carp abundance under *no flow* conditions – This effort will help evaluate likely spread of eDNA from source points in no flow systems so that sampling can be planned such that sample points are reasonably expected to represent independent eDNA conditions (not from same eDNA plume).

Develop a hydrodynamic eDNA transport predictive model to characterize fish occurrence – This effort will develop models based on fish behavior and CAWS water flow dynamics to extrapolate eDNA behavior in the system and to identify likely carp population scenarios associated with an array of eDNA monitoring outcomes. A hydrodynamic model for eDNA transport in the CAWS (down to Lockport Lock) will be developed.

ECALS Products:

Vectors: the vectors investigation will result in a conceptual model with all possible vectors that allow eDNA to persist in the system from a source other than a live fish. Studies will specifically investigate the viability of DNA from dead fish and alternative sources, such as storm sewers and piscivorous birds—these results will be provided in reports to the ACRCC.

Markers: PCR markers (fragments of DNA able to bind only to specific strands of to Asian carp DNA) will be developed and independently tested; results will be reported to the ACRCC and MRRWG to enhance sampling protocols and increase efficiency.

Calibration: several studies will be conducted to refine eDNA sensitivity as to how environmental variables influence detection, degradation, and transport through the CAWS. All study results will be reported to the ACRCC.

The long-term strategy for eDNA monitoring is to transfer this responsibility to the US Fish and Wildlife Service, La Crosse Fish Health Center, in 2013. USFWS will then take on the responsibility of eDNA monitoring as part of the MRRWG's MRRP.

3.5 Risk Assessment

Risk assessment is a process that incorporates existing biological information to assess the risk and potential impacts of an invasive species. Risk is evaluated as the sum of the probability of introduction and the magnitude of consequences should a species successfully invade. The probability of introduction is based on four metrics: the probability an invasive species will arrive in a system, the probability that the species will survive in the system, the probability that the species can establish in the system, and the probability that the species can spread within the system. Coupled with this evaluation of risk is the uncertainty of the conclusion, based on the amount and quality of the information available. An evaluation of the potential ecological impacts of the invader occurs, often using ecosystem modeling. Based on the information derived from the biological assessment of risk, a socio-economic evaluation of risk also may occur. Risk assessment is part of a larger process called risk analysis that includes the risk assessment, risk management or mitigation, and risk communication.

Broad, national-level ecological risk assessments have previously been completed for Asian carp in Canada and the U. S. Both risk assessments categorized the risk of Asian carp as high, with high or fairly high certainty. However, neither risk assessment specifically evaluated the risk of Asian carp to the Great Lakes. Since completion of these risk assessments in 2004 and 2005, substantial new information about Asian carp has become available and more specific management questions have arisen surrounding the probability of Asian carp introduction into the Great Lakes. Fisheries and Oceans Canada (DFO) announced in October 2010 that it would lead, through its Centre for Excellence in Aquatic Risk Assessment, a risk assessment of Asian carp for the Great Lakes. This project is coordinated by the GLFC to facilitate smooth transfer of information among agencies on both sides of the border. Release of the final risk assessment is expected by the end of 2012. A socio-economic analysis of the potential impacts of Asian carp will follow completion of the biological risk assessment in 2012. In combination with ongoing research by USGS, USFWS, NOAA, and others, the DFO-led risk assessment will help inform subsequent risk assessments looking in more detail at the ecological and bio-economic impacts of Asian carp on the Great Lakes.

Several risk assessment activities surrounding Asian carp are also ongoing or planned by U.S. agencies through the 2011 and 2012 Frameworks. Current research activities provide information to be used in risk assessments. Some of these efforts are occurring outside of the ACRCC Framework; however, USGS is communicating and coordinating with the ACRCC to ensure that information is incorporated into the ACRCC's ongoing activities.

In 2010 and 2011, USGS undertook the project titled, *Great Lakes' Tributary Assessment for Asian Carp Habitat Suitability* (2.5.11) focusing on the Milwaukee River in Wisconsin and the St. Joseph River in Michigan. The outcomes of this project included the following:

- Determination of a more exact timeline for Asian carp to achieve required key developmental stages
- Determination of the minimum velocities needed to keep Asian carp in early, non-swimming life stages suspended in the water column
- Doppler current profile data, the mean velocities and longitudinal particle dispersion coefficient of rivers most likely to be used as spawning habitat by Asian carp
- Modeling of the transport of Asian carp eggs and larvae to assess spawning habitat suitability.

The hydraulic and water quality data obtained will be analyzed and documented to finish the ongoing risk assessment within the Milwaukee River in Wisconsin by the end of 2011. Additional testing of the other Asian carp species at the USGS Columbia Environmental Research Center will verify the development series and density data obtained. Spawning suitability models will be developed with the University of Illinois. In 2012, one additional tributary will be assessed.

USGS scientists conducted research in 2011 to examine the suitability of the Maumee River for spawning of bighead carp. Findings indicate that the temperature regime and water flow characteristics of the Maumee River appear to be suitable for spawning of bighead carp. The research manuscript describing these results has been submitted to a scientific journal and publication is expected by June 2012. Additional research is planned for 2012 to identify potential spawning locations or to determine if entire river length is suitable for development of mitigation options. These study methods will be applied to six other major tributaries in Ohio: Sandusky, Portage, Huron, Vermilion, Black, and Grand Rivers.

USFWS and NOAA are collaborating on a project titled, *Ecological/Biological Risk Assessments* (2.4.4). This project will develop biological and/or ecological models for Lake Michigan, Lake Erie, and Lake Huron to more accurately predict the potential for establishment and impacts of Asian carp on each water body.

NOAA is also leading an effort titled, *Forecasting Spread and Bio-economic Impacts of AIS from Multiple Pathways* (2.4.5). This effort will forecast the probability of establishment of non-indigenous species likely to be introduced into the Great Lakes via three major pathways: (1) shipping, (2) organisms in trade, and (3) canals, especially the CSSC. The effort will focus on forecasting:

- Probability of establishment
- Potential habitat of species within the Great Lakes
- Potential spread of invaders within the Great Lakes
- Regional economic impact.

These efforts collectively will provide an important look at the risk of Asian carp introduction to the Great Lakes, and will provide direction for monitoring, response, and mitigation efforts if ever needed.

3.6 Scientific Research and Development

Numerous historical examples demonstrate the difficulty of eradicating or controlling populations of nuisance or invasive aquatic species (e.g., sea lamprey, zebra mussels, and common carp). Extirpation is rarely accomplished, and achieving persistent population control is challenging at best and expensive, requiring a long-term dedicated effort. This reality has oriented the major focus of Framework projects on preventing introductions of Asian carp into the Great Lakes. However, fishery management tools are needed if failures of prevention occur, and would be helpful to further reduce propagule pressure (i.e., lower population densities) of Asian carp in areas closest to Great Lake entry points.

Perhaps the most widely used tool used by fisheries managers to control unwanted populations of fish has been the application of piscicides (i.e., toxins poisonous to fish). Currently, four piscicides are registered for use in the United States; two specifically target sea lamprey (*Petromyzon marinus*), and the remaining two are general use toxins that require treatment of the entire water column, thereby unnecessarily killing all species of fish in the treatment area and driving up control costs. Additionally, rotenone, the most widely used piscicide in North America, is currently under additional scrutiny due to human health implications. Therefore,, development of piscicides that specifically target Asian carp would be of great use to fisheries managers and aid in achieving Framework goals. Several ongoing USGS research projects are aimed at developing these fishery management tools.

Developing a chemical control tool that targets specific species requires identification and development of a targeted toxicant or toxicant delivery system, and assurances that only species intended for control are affected by control measures. Ongoing projects in the Framework address each of these requirements.

USGS is working with private industry and other partners on a project titled *Technologies Using Oral Delivery Platforms for Species-Specific Control* (2.5.12) to develop and synthesize a new form of fishery management chemical control tool: nanoparticles of specific sizes that encapsulate a toxin to be delivered to fish that consume the particle in open waters where the toxicity is released only to Asian carp. Designing such a molecule (micromatrix) requires a thorough understanding of the digestive physiology, as well the toxicity of the chemical to target and non-target fish species. To date, a particle has been developed that Asian carp readily filter from the water column, the toxic dose of rotenone has been determined, and much has been learned about potential target organs of Asian carp. *Developing Targeting Control Systems for Asian Carp Based on Species-Specific Digestive System Characteristics* (2.5.10) conducts parallel research on the digestive system of native planktivorous fish. Results of this project will synthesize understandings of digestive physiologies of native planktivores and compare those to the digestive physiology of Asian carp. In 2012, researchers hope to complete field tests of a toxin embedded in a micromatrix developed to target Asian carp.

To further protect native fishes and avoid use of rotenone, currently under scrutiny for human health concerns, a project titled *Identify Potential Compounds for Inclusion in a Toxicant Screening Program to Identify Potential Selective Toxicants for Control of Asian Carp* (2.5.8) involves a search for a chemical specifically toxic to Asian carp. In 2012, researchers plan to begin cell toxicity assays of native fish, as well as Asian carps, using candidate chemicals. In the future, chemicals identified in this project could be incorporated into a micromatrix or developed for application in water to specifically control Asian carp.

Other methods of controlling fish populations are numerous, and the success of the Integrated Sea Lamprey Control Program, coordinated by the GLFC, demonstrates the benefit of incorporating a variety of control tools into a comprehensive management plan. Several USGS research projects in the Framework use aspects of fish behavior to effect control or containment of Asian carp. *Use of Seismic Technology to Divert or Eradicate Asian Carp* (2.5.6) examines the utility of pulsing sound pressure in the water using water guns to affect distribution of Asian carp. To date, results show that a water gun subjected fish to sound pressure levels over 150 pounds per square inch (PSI) 9 meters from the sound source, and caused significant negative effects in caged fish of several species, including Asian carp. In 2012, research will focus on using water guns to repel and divert Asian carp. In the future, this tool could be used in conjunction with netting to remove fish from targeted areas. The potential impact of deployment of this technology on engineering structures of the CAWS is under examination in *Seismic Monitoring for Asian Carp Water Gun Deployment* (2.5.19). A similar technology, using sound of very specific frequencies to affect the physiology of Asian carp enough to kill those in targeted areas, is under examination in *Deterrence/Destruction of Asian Carp Using Resonant Frequency (Continuous Wave Sonar* [2.5.20]).

Another method of affecting distribution of Asian carp is under study in *Expand Research on the Identification of Asian Carp Attraction/Repulsion Pheromones* (2.5.7). In this project, researchers are investigating whether Asian carp sex pheromones (chemical substances detected through the fish's sense of smell and which trigger reproductive interactions) could be exploited to improve containment and control of Asian carp. To date, olfactory stimulation by presence of pheromones has been verified, and behavioral assays confirm an attraction to the pheromone. Field tests are planned for the future. The intent is to develop this tool to concentrate Asian carp into a specific area for removal by another control method.

Any of the above methods used to concentrate Asian carp into a specified area for targeted removal (such as use of pheromones, sonar, or seismic technology) would be improved by development of traps and nets designed to specifically target Asian carp once fish have been aggregated. Gear improvements are under examination in *Develop Alternate Traps and Net Designs to Enhance Asian Carp Capture Rates* (2.5.15). This project will bring together experts in various fields to develop and test alterative net and trap designs.

3.7 Enforcement Activities

The USFWS has expanded surveillance and enforcement of illegal transportation of federally listed invasive species. Wildlife inspectors have increased their efforts to target and interdict federally listed invasive species at border locations. In addition, the USFWS has acquired an x-ray van that can be deployed at all international ports of entry. This van will improve effectiveness and efficiency of wildlife inspectors' search for invasive species. In addition, the USFWS is working with state partners to control the spread of invasive species, including Asian carp, through investigations here in the United States. These efforts will expand in 2012, and are considered law enforcement-sensitive due to ongoing operations.

3.8 Federal and State AIS Management

The Non-indigenous Aquatic Nuisance Prevention and Control Act (NANPACA) of 1990, as amended and expanded by the National Invasive Species Act (NISA) of 1996, calls for development of state and regional AIS Management Plans. Through a cost-share grant program, the USFWS with the concurrence of NOAA has been able to provide assistance to states for creation and implementation of AIS management plans and activities. This has included development of state-led rapid response actions conducted under new rapid response plans developed by Great Lakes states and approved by the ANS Task Force. In 2009 and 2010, the Great Lakes states invested over $26.7 million toward prevention and control of aquatic invasive species, of which almost $900,000 was committed to Asian carp control efforts. This section highlights some of the Great Lakes' state actions planned or underway.

Illinois: Illinois completed extensive monitoring and removal efforts in support of collaborative Asian carp work in the CAWS. These efforts included sampling with traditional fishery gears, contracted commercial fishermen for targeted removal, sampling for larval Asian carp, support of eDNA monitoring, alternative barrier studies and fishery gear assessments, collaborative work on the Asian Carp MRRP, and outreach to the public and bait shops in the Chicago area. A continued collaborative Asian carp monitoring and removal effort in the Illinois River and CAWS is expected for FY 2012 and beyond. Additional plans for 2012 include (1) updating the State's AIS Management Plan; (2) conducting priority research into potential resource implications and environmental impacts of AIS introductions; (3) continuing to develop, assess, and improve AIS information and education programs; (4) continuing to facilitate development of collaborative AIS Rapid Response Plan; (5) developing a submersed aquatic vegetation management plan; and (6) developing a pilot program to target and control AIS in near-shore Lake Michigan habitats.

Indiana: Indiana developed contracts for plant control and eradication, constructed fences at Eagle Marsh to prevent the spread of Asian carp into the Maumee drainage, worked with the University of Notre Dame to conduct eDNA sampling in the Wabash-Maumee Basin and in Northwest Indiana waters that have connections with the CAWS. The state worked with Indiana Sea Grant to create signage for AIS education and public outreach. Additionally, IN DNR is working with Purdue University on a two-year study to track the movement and spawning behavior of Asian carp in the upper Wabash River. Although still early in the planned two-year study, abundant information has already been gained.

Asian Carp Movement in the Upper Wabash River
Work to study the movement of Asian carp has begun in the upper Wabash River. Efforts to implant transmitters into Asian carp proved difficult in the extreme upper Wabash River, as very few fish were observed or collected. It was not until approximately 80 miles downstream of the fence across Eagle Marsh that substantial numbers of fish were collected for implanting tracking devices. Receivers in the river have detected little interest among the Asian carp to move into the extreme upper Wabash, and to date, no fish have been recorded at a receiver in Little River. The fish seem to show no interest in running up Little River toward Eagle Marsh despite the abundance of spring high-water events

Asian Carp Spawning Behavior in Indiana
Purdue is studying the spawning limits in the upper Wabash River and the East Fork White River. Asian carp eggs were relatively abundant in late May and early June following a high water event from Lafayette and upstream to Logansport which are approximately 120 and 80 miles respectively from the fence at Eagle Marsh. The upstream extent of Asian carp eggs observed was at Peru which is nearly 60 miles downstream of Eagle Marsh. The low numbers of eggs observed at Peru were early term eggs and would have drifted a substantial distance downstream before hatching. Spawning was also evaluated in the East Fork of White River although this river has no bearing on a connection with the Great Lakes watershed. A substantial numbers of eggs were observed in a part of the East Fork White River that is approximately 25 percent smaller than the uppermost area of the Wabash where a considerable number of eggs were found. All of this information should be beneficial to assist in predicting which streams that feed the Great Lakes might be conducive to Asian carp spawning.

Michigan: Michigan began updating the Michigan ANS State Management Plan (SMP), which includes a statewide strategy for Asian carp prevention and Phragmites control. Michigan Department of Natural Resources (MI DNR) Law Enforcement conducted a statewide inspection of all wholesale fish dealers in an effort to prevent importation of live invasive fish species. Michigan also continued to build staff capacity for the AIS program, and implemented priority activities identified in the SMP with a focus on preventing entry and spread of AIS within the State.

Minnesota: Minnesota plans to develop AIS Rapid Response Plans, conduct watercraft inspections, and purchase pressure washing equipment to prevent spread of AIS from infested areas, increase AIS outreach and enforcement efforts, conduct AIS management and early detection monitoring actions, and provide grants for Tribal and local AIS prevention.

Ohio: Ohio plans to identify species of greatest concern and manage invasion pathways for those species, monitor AIS already established in Ohio through existing efforts, initiate AIS control efforts at selected locations in Ohio, develop an AIS Rapid Response Plan, and provide targeted AIS outreach efforts.

Wisconsin: Wisconsin began outreach to targeted areas with bait dealers and anglers, focusing on best practices and bait hygiene. The State has increased AIS monitoring and tracking; created websites for responsive reporting of findings; hired a Watercraft Inspection Coordinator in cooperation with University of Wisconsin Sea Grant to enhance watercraft inspection and compliance with laws. It has created educational media and signage at boat ramps to continue public outreach and education and provided counties within the Great Lakes Basin with funds to implement local AIS prevention, control, and education programs. Similar to the program established in Illinois, Wisconsin will soon begin work with bait dealers, anglers, and boaters to prevent introduction and spread of AIS within the waters of the State; increase AIS monitoring efforts to include 500 water bodies annually; and enhance watercraft inspection and regulatory compliance. To increase monitoring efforts on Lake Michigan and its Wisconsin tributaries, the State is coordinating with The Nature Conservancy and the University of Notre Dame to begin collecting and analyzing samples for eDNA presence.

With ongoing Great Lakes Restoration Initiative (GLRI) funds, the Great Lakes states will have fully developed, revised, and implemented AIS management plans. Additionally, these plans will include rapid response capabilities, mock exercises, and possibly actual rapid response actions. The plans will promote coordinated education and outreach that will prevent introduction and spread of invasive species through recreational uses such as hunting, fishing, and boating. These activities will also support implementation of on-the-ground AIS management actions for each of the Great Lakes states.

3.9 Asian Carp Efforts Downstream of the Electric Barrier System

A great deal of effort has focused on the areas downstream of the Electric Barrier System within the Illinois River to reduce the pressure of Asian carp populations near the electric barriers. Beginning with this Framework, in addition to the monitoring and commercial fishing endeavors discussed in previous sections, strategy will shift toward a biological control program for Asian carp within this area. A goal of the ACRCC is to expand a sustainable Asian carp biological control program throughout the Great Lakes and Mississippi River Basins. Given that Asian carp are already well established throughout the Mississippi River Basin, this type of control program will be essential to slow their spread and prevent their establishment within waterway systems where they have not been present. The areas downstream of the electric barrier systems will be at the forefront of this control program as efforts expand. The following examples highlight current and future efforts:

Asian carp removal below the electric dispersal barrier system – This program was started in 2010, and through 2011 over 420 tons of bighead and silver carp had been removed from the Illinois River. The majority of the fish caught were more than 65 miles south of Lake Michigan and over 30 miles south of the electric barrier system. This program will continue.

Future research applications – The waterway areas below the electric barrier system where Asian carp are well established and plentiful could serve in tests of applications that have been researched and developed as part of the Asian carp control program.

The USGS "Oral Delivery System" One Potential Component for the Asian Carp Biological Control Program

The USGS is working to develop a species-specific oral delivery system. As discussed in Section 3.6, this technology possibly could deliver bioactive agents (like a toxin) that are encapsulated within engineered particles sized for Asian carp ingestion and designed to release their bioactive payload only under certain conditions (such as presence of specific enzymes present in the target species). This technology is currently used commercially for salmon to deliver a coloring agent and a vaccine in feeds; the oral delivery system stabilizes the colorant and the vaccine as these pass through the salmon stomach, and then release them for absorption in the intestine where the enzymes required to break apart the particle are present. Research thus far with bighead carp and silver carp has indicated that the fish are actively eating the particles. Research is also in progress to confirm the particle size at which they most efficiently filter the particle for consumption, as well as to identify the enzymes that would trigger the bioactive agent release. USGS and the ACRCC believe this will play an important role in Asian carp biological control efforts.

Once refined, this type of species-specific delivery system may also play a key role in management of other invasive species. Species such as the zebra and quagga mussels, of great concern in and around the Great Lakes, are also filter feeders similar to Asian carp. As this technology is further refined, these species may be targeted for removal or control.

4.0 AGENCY COORDINATION AND ROLES AGAINST ASIAN CARP

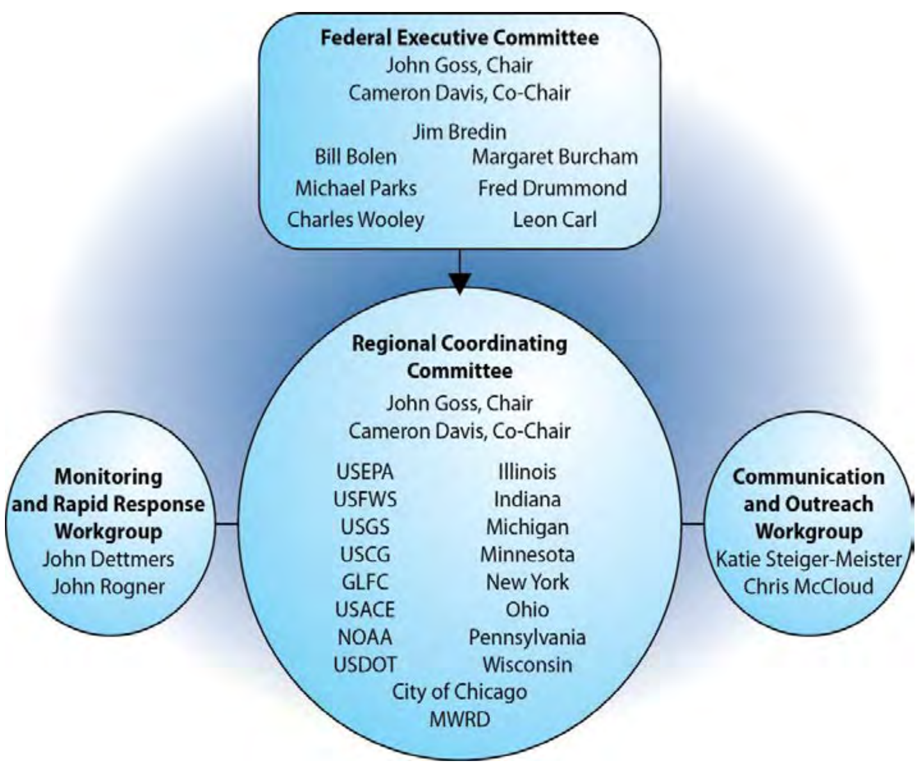
Federal, state, and local agencies with jurisdictional authority and/or vested interest in defending the Great Lakes against the potential establishment of Asian carp came together to form the ACRCC and present a unified front in the ongoing efforts.

4.1 ACRCC Coordination

The ACRCC, with support from federal, state, and local agencies and other private stakeholder entities, will implement actions to protect and maintain the integrity and safety of the Great Lakes ecosystem from an Asian carp invasion via all incoming pathways. This Framework will lay out the strategy and present the proposed action items to carry out this goal.

Exhibits 8 and 9 below depict the relationship of the primary agencies or governmental groups involved in implementation of the Framework. The relationship is non-linear because of the need for harmonized input from each group in all facets of the Framework. The Executive Committee consists of senior managers from key federal agencies. The ACRCC is comprised of agencies with operational and coordinating authority over work relevant to the CAWS and the Great Lakes. The two workgroups bracketing the ACRCC are tasked with the specific responsibilities laid out in the Framework.

Exhibit 8. The ACRCC Organization



The third group, Non-Federal Technical and Policy Group, is a stand-alone entity providing input to the ACRCC workgroups. The stakeholder groups identified in Exhibit 9 below, led by representatives from their respective communities/agencies/organizations, compose and advise the Non-Federal Technical and Policy Group.

Exhibit 9. Non-Federal Technical and Policy Group

4.1.1 Monitoring and Rapid Response Workgroup

This workgroup of the ACRCC is tasked with monitoring and response efforts within the CAWS and at the leading edge of the present Asian carp boundaries. This workgroup is generally composed of fisheries biologists and scientific experts from the GLFC, IL DNR, IEPA, IN DNR, USFWS, and USACE. In 2010, the MRRWG created a MRRP for the CAWS and revised this plan in 2011 with the overall goal of preventing Asian carp from establishing self-sustaining populations in the CAWS and subsequently Lake Michigan. Five strategic objectives are identified in the plan to accomplish the overall goal. These objectives are:

1. Determine the distribution and abundance of any Asian carp in the CAWS, and use this information to inform rapid response removal actions.
2. Remove any Asian carp in the CAWS to the maximum extent practicable.
3. Identify, assess, and react to any vulnerability in the current system of barriers to exclude Asian carp from moving into the CAWS.

4. Determine the leading edge of major Asian carp populations and reproductive success of those populations.
5. Improve understanding of the likelihood that Asian carp could become established in the Great Lakes.

The MRRWG carries out these objectives through collective efforts by member agencies. The workgroup oversees eDNA collection, commercial fishing, netting, electrofishing, and other collection operations, and then interprets the data obtained to offer informed recommendations to the ACRCC.

4.1.2 Communications and Outreach Workgroup (CWG)

The purpose of the CWG is to facilitate internal and external communication on Asian carp control efforts of the ACRCC. Communication audiences include (1) elected officials, (2) the public with special attention to key constituents, (3) media (4) internal ACRCC members, and (5) ACRCC Work Groups, Framework Science Coordination groups, and other relevant groups outside the ACRCC.

Communication efforts support the ACRCC as it develops and executes short- and long-term strategies for preventing Asian carp movement above the electric barrier system in the CAWS, and other monitoring and control activities in other areas of the Great Lakes Basin. The CWG does not intend to supplant or supersede actions of the ACRCC members.

The CWG has communication representatives from the Council on Environmental Quality (CEQ), USFWS, USEPA, USACE, U.S. Coast Guard, USGS, the Great Lakes states, GLFC, and Metropolitan Water Reclamation District. All members of the ACRCC are invited to establish representation on the CWG.

The CWG is currently co-chaired by a representative of the USFWS and IL DNR. The chair has primary responsibility for the group's management, organization, and operation, but the work is shared among the CWG members. One or both co-chair positions may be filled by a CWG member from another agency deemed appropriate by the CWG.

The CWG is divided into sub-committees consisting of appropriate agency communication representatives. Subcommittees include agency representatives from legislative affairs, media relations, and public/stakeholder outreach. At this time, the CWG has two standing sub-committees: the Key Constituents Sub-committee and the Media Sub-committee.

Specific efforts of the CWG include, but are not limited to the following:

- Work in collaboration with ACRCC members to foster internal communications among ACRCC members.
- Update and maintain www.asiancarp.us web site and other social media to reach the general public.
- Distribute comments, concerns, and questions received by external audiences to appropriate response agency.
- Respond to media requests or filter to appropriate response agency.
- Coordinate on-site or telephonic media events, including press announcements, regarding new Asian carp control efforts.
- Coordinate public forums/meetings.
- Provide outreach to municipal leaders, Tribal leaders, and other interested parties.
- Serve in advisory capacity to the ACRCC on communication needs.
- Develop other outreach products for public use.

4.2 Agency Roles, Responsibilities, and/or Authorities

This section generally describes the jurisdictions, authorities, and roles of the agencies and governmental units participating in this Framework. This is meant to be an informal description of these agencies with respect to the actions discussed in this Framework, and is not meant to restrict or assign responsibilities and authorities belonging to the agencies under their implementing statutes and regulations.

- **City of Chicago**

  Jurisdiction: Exercises home rule authority within municipal limits.

  Authority: Municipal.

  Role: Supports the work of other agencies, particularly those actions within the City of Chicago, and performs law enforcement, patrol, and emergency response duties along the lakefront and inland waterways within the City's jurisdiction.

- **Great Lakes Fishery Commission (GLFC)**

  Jurisdiction: Great Lakes Fishery Convention Act allowing implementation of a convention of Great Lakes Fisheries between Canada and the United States.

  Authority: Bilateral treaty.

  Role: Coordinate, communicate, and conduct fishery resource management actions on the Great Lakes.

- **Illinois Department of Natural Resources (IL DNR)**

  Jurisdiction: Investigations pertaining to the natural history, entomology, zoology, and botany of the State; the geology and natural resources of the State; the water and atmospheric resources of the State; and the archeological and cultural history of the State of Illinois.

  Authority: State.

  Role: Lead agency for work relating to monitoring, sampling, fish removal actions, and rapid response activities within the State.

- **Illinois Environmental Protection Agency (IEPA)**

  Jurisdiction: IEPA's mission is to safeguard environmental quality, consistent with the social and economic needs of the State, so as to protect health, welfare, property and the quality of life.

  Authority: State.

  Role: Ensure that Illinois' rivers, streams, and lakes support all uses for which they are designated, including protection of aquatic life, recreation, and drinking water supplies.

- **Indiana Department of Natural Resources (IN DNR)**

  Jurisdiction: May investigate, compile, and disseminate information and make recommendations concerning the natural resources of Indiana and their conservation; and may cooperate with other governmental entities and public and private institutions in carrying out these powers.

  Authority: State.

  Role: Lead agency for work relating to monitoring, sampling, fish removal actions, and rapid response activities within the State of Indiana.

- **Office of the Great Lakes (OGL); Michigan Department of Environmental Quality (MI DEQ),**

  Jurisdiction: Within Michigan's waters of the Great Lakes, the OGL collaborates with partners to support sustainable use of coastal resources, coordinate restoration of severely degraded areas, manage water quality and quantity, prevent aquatic invasive species, and engage in emerging issues.

  Authority: State.

  Role: The Office of the Great Lakes leads policy development and implements programs to protect, restore, and sustain the world's premier freshwater lakes.

- **Michigan Department of Natural Resources (MI DNR)**

  Jurisdiction: In the State's waters, the Department is responsible for management and protection of the Great Lakes fishery resources in regards to recreational, commercial, and tribal fisheries interests, and for the conservation and protection of biodiversity and aquatic habitats.

  Authority: State.

  Role: Provide leadership for strategic monitoring assessment, response, and public communication in Michigan as they pertain to Asian carp. Assist other states as requested in these activities.

- **Minnesota Department of Natural Resources (MN DNR)**

  Jurisdiction: Mission is to work with citizens to conserve and manage the State's natural resources, to provide recreational opportunities, and to provide for commercial uses of natural resources in a way that creates a sustainable quality of life.

  Authority: State.

  Role: Managing, protecting, and regulating the State's fish and wildlife resources.

- **New York Department of Environmental Conservation (NY DEC)**

  Jurisdiction: Mission is to conserve, improve and protect New York's natural resources and environment, and to prevent, abate, and control water, land, and air pollution, in order to enhance the health, safety, and welfare of the people of the State and their overall economic and social well-being.

  Authority: State.

  Role: Responsible for the conservation and enhancement of New York State's abundant and diverse populations of freshwater fishes while providing the public with quality recreational angling opportunities. Serves as the lead agency for work involving the prevention and control of invasive species in New York's waters. Cooperation and coordination with other jurisdictions in the Great Lakes fisheries arena is routinely pursued through the GLFC.

- **Ohio Department of Natural Resources (OH DNR)**

  Jurisdiction: Responsible for the protection, development, conservation, and management of Ohio's natural resources, including: managing the State's natural resources for sustainable productivity; protecting Ohio's native plant and animal species; developing industry and tourism opportunities and supporting the present and future economic health of the State; providing recreational opportunities for the public at all levels; and protecting health, safety, and biodiversity through fair and consistent law enforcement.

  Authority: State.

  Role: Lead agency in Ohio for fish research, fish sampling and monitoring, rapid response actions, as well as operation and maintenance of certain canal lands within the State.

- **Pennsylvania Department of Environmental Protection (PA DEP)**

  Jurisdiction: Lead agency for enforcement of the Pennsylvania Clean Streams Law, Pennsylvania Water Quality Standards (25 PA Code Chapter 93) and delegated portions of the federal Clean Water Act. Water Quality Standards consist of Protected Water Uses (including Aquatic Life Uses), as well as the Water Quality Criteria necessary to protect them. PA DEP's Coastal Resources Management Program has various policies to prevent the introduction and spread of AIS.

  Authority: State.

  Role: Permitting of pesticide applications needed for Asian carp response; monitoring and surveillance for Asian carp; supporting Asian carp rapid assessment and response; general scientific support as needed.

- **Pennsylvania Fish and Boat Commission (PA FBC)**

  Jurisdiction: Responsible for all aquatic organisms in the Commonwealth of Pennsylvania and shares enforcement responsibilities regarding aquatic resource issues with the PA DEP.

  Authority: State.

  Role: Primary responsibility for threat assessment and monitoring of all Pennsylvania AIS occurrences, including Asian carp, and has lead responsibility for initiating the State's AIS rapid response plan when deemed necessary.

- **Wisconsin Department of Natural Resources (WI DNR)**

  Jurisdiction: Natural resources, conservation, outdoor recreation, and environmental quality in the State of Wisconsin.

  Authority: State.

  Role: Cooperate and support any activities which lead to the immediate and complete ecological separation of the Mississippi River and Great Lakes Basins in the Chicago area. Cooperate and support any activities which evaluate and eliminate other potential ecological pathways between the Mississippi River and Great Lakes Basins in Wisconsin.

- **Metropolitan Water Reclamation District of Greater Chicago (MWRD)**

  Jurisdiction: Surface water, municipal wastewater treatment for the metropolitan Chicago area (including almost all of Cook County), control of combined sewer overflows, dry and wet weather operation of the CAWS.

  Authority: Regional.

  Role: Supports the work of other agencies and implements designated action items to the extent allowed by its statutory wastewater and stormwater authority.

- **National Oceanic and Atmospheric Administration (NOAA)**

  Jurisdiction: Implementation of technical assistance and management-oriented research programs that support coastal zone management.

  Authority: Coastal Zone Management Act of 1972 (16 U.S.C. § 1456c) and the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (P.L. 101-636).

  Role: Funding of research studies and activities. Additionally, the Great Lakes Environmental Research Laboratory of the National Oceanic and Atmospheric Administration shall provide technical assistance to appropriate entities to assist in the research conducted pursuant to this subsection.

- **United States Army Corps of Engineers (USACE)**

  Jurisdiction: Planning, construction, and operation of navigation and flood damage reduction projects; hydropower operations; environmental protection and restoration; water conservation, recreation, and disaster assistance.

  Authority: Federal.

  Role: Operation of the CAWS Lock and Dam System and the Electric Barrier System.

- **United States Coast Guard (USCG)**

  Jurisdiction: Navigable waterways.

  Authority: Federal Authority; Port and Waterways Safety Act of 1972 and other legislation.

  Role: Ensure the safety, security, and environmental protection of the Great Lakes and the Western Rivers. The Coast Guard manages waterways through Regulated Navigation Areas, and safety and security zones. Regulates the marine industry and supports the marine transportation system.

- **United States Department of Transportation (US DOT)/Maritime Administration (MARAD)**

  Authority: Federal

  Role: Supports the maritime transportation system and coordinates with marine transportation stakeholders.

- **United States Environmental Protection Agency (USEPA)**

  Jurisdiction: Coordination of federal Great Lakes policy and activities.

  Authority: Federal Great Lakes protection and restoration policy and efforts provided in Clean Water Act (CWA) 118, Executive Order 13340 and other legislation.

  Role: Coordination and funding.

- **United States Fish and Wildlife Service (USFWS)**

  Jurisdiction: Implementation of activities in support and enforcement of the Lacey Act, Endangered Species Act, Fish and Wildlife Coordination Act, Great Lakes

Fish and Wildlife Restoration Act, and the Non-indigenous Aquatic Nuisance Prevention and Control Act as amended; and supporting activities to include fish and AIS monitoring, risk assessment, and law enforcement.

Authority: Federal.

Role: Coordination with federal, state, tribal, and non-governmental partners on actions to prevent the introduction and establishment of AIS or to mitigate resource impacts from introduced species.

- **United States Geological Survey (USGS)**

Jurisdiction: Performance of surveys, investigations and research covering topography, geology, hydrology, biology, and the mineral and water resources of the United States, its territories, and possessions.

Authority: Federal.

Role: Provide leadership, technical expertise, and information needed to develop management tools to better predict ranges and effects of AIS; and to contain, reduce, or eradicate their populations.

- **White House Council on Environmental Quality (CEQ)**

Authority: Federal – CEQ coordinates federal environmental efforts and works closely with agencies and other White House offices in the development of environmental policies and initiatives.

Role: CEQ is closely monitoring the development and execution of the Asian Carp Control Strategy Framework.

- **International Involvement**

Canada has followed the Asian carp issue closely, and has offered its assistance to U.S. efforts to keep the species from establishing a presence in the Great Lakes. In October, the Canadian Minister of Fisheries and Oceans launched a bi-national initiative to assess the risk that Asian carp pose to the Great Lakes. The risk assessment will be the first such joint effort. The bi-national GLFC will facilitate the project, which should take about 18 months to complete. The Canadian government has committed over $400,000 to the risk assessment effort.

5.0 STAKEHOLDER PARTICIPATION

The effectiveness of the actions summarized in the Framework can be significantly enhanced through effective communication and increased participation by other agencies and stakeholders. To facilitate this, the ACRCC has developed a strategic communication plan that provides opportunities to inform the public and other stakeholders about key Asian carp control activities including implementation of control actions, development of new control technologies, and progress toward Framework goals.

One of the primary efforts to garner public participation and involvement was the recent institution of regularly scheduled public forums across the Great Lakes Basin. At these meetings, the ACRCC invites stakeholders and user groups to provide input and comments on the Framework. Ongoing stakeholder input is necessary in both individual actions within this Framework and in further development of the Framework itself.

The revamped ACRCC Asian carp website at **www.asiancarp.us** also provides opportunities for stakeholder involvement. This new website offers extensive information regarding all aspects of the ACRCC actions, and includes links to other important federal, state, and other relevant actions.

Specific communication outreach actions are targeted in the 2012 Framework and are being implemented concurrently with the programs in the Framework, including:

- Implementation of a Strategic Communication Plan as part of this Framework. The plan outlines communication tools, methods, and protocols that will provide timely and transparent information to multiple target audience groups including elected officials, states, tribes, key constituents, and the media
- Development of opportunities for public comment including the regularly scheduled public forums occurring across the Great Lakes Basin
- Maintenance of the primary online communication tool **www.asiancarp.us** to disseminate announcements and provide information on ACRCC activities; a new "How to Help" section is being established on the website
- Release of both interim and final reports, findings, and studies as information becomes available
- Coordination of on-site or telephonic media events, including press announcements regarding new Asian carp control efforts or other important related actions or findings
- Outreach to municipal leaders, tribal leaders, and other interested parties.

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Appendix A
2012 Asian Carp Control Strategy Matrix – Funding by Agency

Action Item*	Title	NOAA		USACE		USCG		USEPA		USFWS		USGS		USFWS-IL DNR		USFWS-IN DNR		GLFC	
		GLRI	Base	GLRI	Base	GLRI	Base	GLRI	Base	GLRI	Base	GLRI	Base	GLRI	Base	GLRI	Base	GLRI	Base
2.1.1	Enhanced Monitoring Efforts Above and Below the Electric Barrier System													$2,257,417	$0				
2.1.2	Monitoring (Electrofishing) and Rapid Response Team Support									$650,000	$0								
2.1.3	Support for Asian Carp Rapid Response in the Great Lakes Basin									$700,000	$0								
2.2.1	Commercial Fishing for Removal Below Lockport Pool													$1,200,000	$0				
2.2.2	Illinois River Stock Assessment/Management Alternatives													$1,300,000	$0				
2.2.3	Investigation of Certification Requirements for Asian Carp Usage													$0	$0				
2.3.1	By-Pass Barrier Operations			$0	$1,000,000														
2.3.2	Electric Barriers Operation and Improvement (formerly Expedited Contruction of Barrier IIB)			$0	$21,500,000							$75,000	$0						
2.3.3	Modified Structures and Operations			$0	$65,000														
2.3.4	Electric Barrier Effectiveness (formerly Tagged Fish)			$1,100,000	$1,000,000														
2.3.5	Eagle Marsh Temporary Barrier Fence Maintenance															$50,000	$0		
2.3.6	Wabash-Maumee ANS Controls Report			$0	$0														
2.3.7	CSSC Electric Fish Barrier Marine Safety Risk Assessment and Risk Mitigation Measures					$150,000	$98,000												
2.3.8	Waterway Traffic Management in Support of Asian Carp Control Activities					$210,000	$0												
2.4.1	Efficacy Study			$0	$500,000														
2.4.2	GLMRIS Focus Area I: CAWS			$0	$3,000,000														
2.4.3	Feasibility Assessment of Inter-Basin Transfer of Aquatic Invasive Species Between the Des Plaines River and CAWS											$0	$0						
2.4.4	Ecological/Biological Risk Assessments									$500,000	$0								
2.4.5	Forecasting Spread and Bio-economic Impacts of AIS from Multiple Pathways	$687,617	$60,000																
2.4.6	GLMRIS II: Other Area Pathways			$300,000	$0														
2.4.7	Wabash-Maumee Hydrologic Support to Prevent Interbasin Transfer of Asian Carp											$85,000	$0						
2.4.8	Risk Assessment Coordination																	$0	$0
2.4.9	Assessment of Silver and Bighead Carp Movement and Spawning Activities in the Wabash River Watershed, Indiana															$0	$0		
2.4.10	Enhanced GLMRIS Stakeholder Engagement			$200,000	$0														
2.5.1	Investigate Tow Boats and Barges as Potential Vectors					$0	$0												
2.5.2	Assessment Study of Potential Impacts of Steel-hulled Barges on Fish Movement Across Electric Barrier II			$500,000	$0														
2.5.3	Research on the Impacts of Potential Asian Carp Vectors Being a Source of Fish or eDNA Movement in the CAWS			$650,000	$0					$50,000	$0	$200,000	$0						
2.5.4	Assessing Risks of Great Lakes Invasion by Understanding Asian Carp and Bluegreen Algae Dynamics											$0	$0						
2.5.5	Risk Assessment of Asian Carp Establishment in the Great Lakes Based on Available Food Sources											$0	$0						
2.5.6	Use of Seismic Technology to Divert or Eradicate Invasive Asian Carp			$50,000								$500,000	$675,000						

2.5.7	Expand Research on the Identification of Asian Carp Attraction/Repulsion Pheromones											$0	$240,000						
2.5.8	Identify Potential Compounds for Inclusion in a Toxicant Screening Program											$0	$250,000						
2.5.10	Developing Targeting Control Systems for Asian Carp Based on Species-Specific Digestive System Characteristics											$0	$80,000						
2.5.11	Great Lakes' Tributary Assessment for Asian Carp Habitat Suitability											$0	$225,000						
2.5.12	Technologies Using Oral Delivery Platforms for Species-Specific Control											$0	$1,025,117						
2.5.15	Develop Alternate Traps and Net Designs to Enhance Asian Carp Capture Rates													$600,000	$0				
2.5.16	Development of a Rapid and Quantitative Genetic-Based Asian Carp Detection Method											$0	$0						
2.5.17	Chicago Area Waterway System Monitoring Network Evaluation											$190,000	$0						
2.5.18	Asian Carp Control Methods Coordination											$0	$0						
2.5.19	Seismic Monitoring for Asian Carp Water Gun Deployment											$213,700	$0						
2.5.20	Deterrence/Destruction of Asian Carp using Resonant Frequency											$0	$0						
2.5.21	Other Science Contributing to Asian Carp Control Efforts											$100,000	$556,883						
2.6.1	eDNA Monitoring of the CAWS			$650,000	$0														
2.6.2	USFWS Capacity for eDNA Sampling for Early Detection									$0	$300,000								
2.6.3	eDNA Calibration and Increased Efficiency			$1,925,000	$0							$225,000	$0						
2.6.4	USFWS Region 3 Fisheries Capacity for eDNA Processing									$460,000	$700,000								
2.6.5	eDNA Genetic Marker Development			$70,000	$0					$100,000	$0	$50,000	$0						
2.6.6	Environmental DNA Surveillance - Applied Early Detection									$0	$0								
2.7.1	Investigation of Northeast Illinois' Bait Shops													$30,000	$0				
2.7.2	Increased Lacey Act Enforcement of Illegal Transport of Injurious Wildlife									$400,000	$0								
2.7.3	Community Action Initiatives to Increase Awareness, Surveillance, and Enforcement of Unlawful Live Asian Carp													$400,000	$0				
2.7.4	Public Outreach through Website Development									$50,000	$0								
2.7.5	Asian Carp Education and Outreach	$98,000	$0																
2.7.6	Asian Carp Video Footage																	$0	$0
2.7.7	Communications, Outreach, and Education Displays for Public Consumption																	$0	$0
2.7.8	USFWS Early Detection Workshop									$30,000	$0								
2.8.1	State and Interstate AIS Management Plans									$0	$0								
2.8.4	USFWS Great Lakes Asian Carp Monitoring Program									$150,000	$1,000,000								
2.9.1	USEPA Support for Asian Carp Activities							$2,232,983	$0										
Agency Total: GLRI and Base Funding		$785,617	$60,000	$5,445,000	$27,065,000	$360,000	$98,000	$2,232,983	$0	$3,090,000	$2,000,000	$1,638,700	$3,052,000	$5,787,417	$0	$50,000	$0	$0	$0

Total FY 2012 Agency Base funding planned	$32,275,000
Total Fy 2012 GLRI funding requested	**$19,389,717**
Total Planned FY 2012 Funding: GLRI and Base	**$51,664,717**

Notes:

* Each Action Item reflects the 2011 Framework number assigned to it. New 2012 action items were numbered following the categorization used in the 2011 framework.

Appendix B
2012 Asian Carp Control Strategy Framework
Action Items

Asian Carp Regional Coordinating Committee

2012 Asian Carp Control Strategy Framework

: Appendix B: Action Items

February 2012

Table of Contents

Note: The template numbers in this document reflect the action item numbers assigned to them in the 2011 Asian Carp Control Strategy Framework. Newly proposed action items submitted for inclusion in the 2012 Asian Carp Control Strategy Framework have been categorized according to the 2011 Framework and were assigned the next number in the series.

2.1 Targeted Monitoring Assessment Activities Above and Below the Electric Barrier System

2.1.1 Enhanced Monitoring Above and Below Electric Barriers

Lead Agency: Illinois Department of Natural Resources (IL DNR)

Agency Collaboration: IL DNR, U.S. Army Corps of Engineers (USACE), and U.S. Fish and Wildlife Service (USFWS) worked continually and extensively on the creation of the Monitoring and Rapid Response Plan (MRRP) and monitoring efforts and plans.

Fiscal Year (FY) 2012 Funding: $2,257,417 Great Lakes Restoration Initiative (GLRI) funds.

Project Explanation: Work will include a continuation of extensive monitoring efforts in elevated risk areas to detect the presence of Asian carp and remove them, as necessary. Elevated areas are those previously identified through waterway characterization as preferable Asian carp habitat or where previous environmental deoxyribonucleic acid (eDNA) sampling indicated the presence of Asian carp deoxyribonucleic acid (DNA) in the area at the time of sample collection.

FY 2010 Actions Undertaken

- February - March 2010: Sampling with traditional electrofishing and netting gear and with use of commercial fishermen was carried out in the Chicago Area Waterway System (CAWS) above the Electric Barrier System. Sampling targeted warm water discharges, backwater habitats, established fixed reaches, and other selected areas to maximize chances of encountering Asian carp, and included reach-wide electrofishing runs along the entire waterway above the barrier. No Asian carp were collected during these efforts.
    - 100 person-days expended.
    - 132 electrofishing runs (effort = 72 hours).
    - 124 trammel/gill net sets (effort = 10,600 yards of net).
- March – June 2010: A comprehensive MRRP for the CAWS and Upper Illinois River was developed. This plan was designed to systematically determine the distribution and abundance of Asian carp in the waterways, remove any Asian carp in the CAWS, and identify the location of the leading edge and reproduction of those populations.
- May-June 2010: Completed were one large-scale rotenone rapid response action on the Little Calumet River and two conventional gear rapid response actions (North Shore Channel and South Branch Chicago River near Bubbly Creek) in response to consecutive positive eDNA results at these locations.
    - 721 person-days expended.
    - 2.6 miles of river treated with rotenone (173 acres).
    - 26 electrofishing runs (effort = 32 hours).

  - 61 trammel/gill net sets (effort = 9,533 yards of net).
  - More than 70,000 fish from 44 species and two hybrid groups sampled, none of which was bighead or silver carp.
- June 22, 2010: Commercial fishing crews working as part of the MRRP recovered one bighead carp at the Northwest corner of Lake Calumet. This capture confirmed the presence of live Asian carp in the CAWS above the barrier and resulted in 11 days of sampling in Lake Calumet, the Calumet River, and Calumet Harbor.
- An additional 334 water samples from Lake Calumet (114), Calumet River and Harbor (95), and Indiana ports and harbors (125) were collected during July and August, and analyzed for Asian carp DNA. None of the DNA testing indicated the presence of bighead or silver carp DNA in any of the regions surveyed. Electrofishing and commercial netting efforts in both Lake Calumet and the Calumet River were increased. No additional Asian carp were found above the electric barrier.
- Fixed site sampling (electrofishing and netting) continued on a twice-monthly schedule throughout the summer and fall. These efforts expended 264 person-days of labor, and no Asian carp were caught or observed.
  - 559 electrofishing runs (139.8 hours).
  - 208 net sets (41,600 yards of net).
  - Over 36,000 fish (64 species and four hybrid groups) caught.
- Three reach electrofishing samplings of the entire 70+ miles of the CAWS upstream of the Electric Barrier System were completed in 2010 to expand sample coverage in the CAWS. This work was completed by the Illinois Natural History Survey (INHS) in collaboration with IL DNR and USACE.
  - 69 person-days of effort.
  - 292 electrofishing runs (73.0 hours).
  - No Asian carp captured in a combined catch of over 2,700 fish from 33 species and three hybrid groups.
- Intense monitoring events in October and November 2010 in Lockport Pool downstream of the Electric Barrier System utilized conventional gear and hydroacoustic sonar for small and large fish capture, with no Asian carp collected.

FY 2011 Actions Undertaken

- 2011 MRRP was drafted in cooperation with action agencies and Monitoring and Rapid Response Workgroup (MRRWG).
- Agency sampling crews and contract commercial fishermen deployed in support of plan implementation:

- Five fixed sites upstream of the Dispersal Barrier each sampled with electrofishing gear and trammel/gill nets 18 times between 23 March and 9 December.
  - Over 3,700 person-hours of effort.
  - Over 200 hours of electrofishing completed and 65 miles of nets fished.
  - No bighead or silver carp captured or observed in a combined catch of over 57,000 fish representing over 60 species.
- Three reach-long electrofishing samplings of the entire 70+ miles of the CAWS upstream of the Electric Barrier System completed in 2011 to expand sample coverage in the CAWS (300 person-hours). This work completed by INHS. No Asian carp captured or seen during reach electrofishing.
- Sixteen fixed sites below the Dispersal Barrier sampled with electrofishing gear and trammel/gill nets nine times from 29 March through 5 December.
  - Over 1,500 person-hours of effort.
  - 36 hours of electrofishing completed and nearly 47 miles of nets fished.
  - No bighead or silver carp captured in Lockport Pool. One bighead carp observed in Brandon Road Pool but not captured. Total combined catch below the barrier of over 10,000 fish. No silver carp and 20 bighead carp captured in Dresden Island Pool, and 251 silver carp and 429 bighead carp taken from Marseilles Pool.
  - Patterns in captures of Asian carp among pools in 2011 similar to those observed during 2010 sampling.
- Monitoring for Asian carp eggs and larvae at 16 stations throughout the Illinois and Chicago Area waterways from April through September.
  - Over 600 samples collected
- No Asian carp eggs or larvae sampled upstream of Brandon Road Lock and Dam; downstream sample processing ongoing. Fourteen items of gear evaluated to assess effectiveness at capturing adult and juvenile Asian carp. Sampling over a range of Asian carp densities at nine stations located throughout the Illinois and Chicago Area waterways during spring, summer, and fall 2011.
  - Preliminary analysis of the data suggests electrofishing effective for sampling adult silver carp, and large mesh hoop nets and trap nets effective for sampling bighead carp.
  - No bighead or silver carp sampled above Treats Island (near I-55 Bridge) in the Dresden Island Pool.
  - Few Asian carp juveniles captured in any gear, and the most upstream capture near Henry, Illinois, about 100 river miles downstream from the Dispersal Barrier.

- Rapid response occurred to three consecutive eDNA-positive sampling events in August 2011—slightly larger than a level one response as outlined in the MRRP.
  - 1,066 person-hours of effort.
  - Over 22 hours of electrofishing, 11 miles of trammel/gill net set, and two 880-yard commercial seine hauls.
  - No bighead or silver carp captured in a combined catch of over 8,600 fish representing 39 species.
  - Additional summary information available on www.Asiancarp.us
- In support of barrier maintenance, an Incident Management Team organized by IL DNR oversaw fish clearing operations to support the USACE. Increased water velocity, water gun technology, and remote sensing techniques (side scanning sonar, hydro-acoustics, and DIDSON cameras) were applied. The operation successfully cleared the barrier area of fish > 12 inches (deemed the only Asian carp threat at the time within the area). Success of this event allowed for barrier maintenance without use of a non-discriminate fish piscicide (rotenone) to clear the barriers.
- Coordination with MRRWG occurred.
- An Asian carp database was developed and maintained.
- Bighead carp within two urban ponds near Chicago (neither pond connected to other water bodies) were assessed and removed; details are in a report entitled "Bighead Carp in Illinois Urban Fishing Ponds" (December 2011) http://asiancarp.us/news/bigheadponds.htm
- eDNA surveillance was supported.

FY 2012 Actions Proposed

IL DNR in collaboration with USACE and USFWS will continue support of MRRP through enhanced monitoring above and below the Electric Barrier System, as in prior years. Monitoring of these elevated areas will include the following:

- A Barrier efficacy study of in-situ effects of barrier on small fish .
- Continuation and support of conventional monitoring, evaluation, coordination, and reporting for areas above and below the electric barrier.
  - Electrofishing and netting at MRRP-designated areas and others requiring evaluation.
  - Rapid response development, barrier maintenance coordination.
  - Continuation of contracts with commercial fishing crews to extensively sample within CAWS.
  - Development of increased protocols for and implementation of detecting small fish (less than 6 inches) in the CAWS and near-shore Lake Michigan areas (according to

the Holliman report, these fish are less prone to repulsion at the electric barrier system when that operates at 2.0 volts/inch). Modified operation can deter smaller fish, but increased knowledge of these fish will inform managers of the risk for breaching the barrier, as well as biology of the fish in nearby river segments—valuable for sustained management.

  - Enhanced eDNA data collection (IL DNR will continue to assist in acquisition of these data, minimizing travel, and providing consistency).
  - Deployment and support of gear developed under the FY2011 Alternate Traps and Net Design Project within the CAWS to increase detection ability.
  - Monitoring and management of commercial gear deployment within the CAWS.

- Initial development of increased surveillance farther into CAWS and Lake Michigan near-shore waters using commercial and/or conventional fisheries gear already deployed in the CAWS. Additional sampling would enable acquisition of baseline data in these areas, and possibly additional grass carp capture and removal to gather information for ploidy, environmental history, and growth in novel environments.
- Sampling in CAWS and Upper Illinois Waterway of larval, egg, and small young-of-year (YOY) fish (less than approximately 6 inches that are 0 years old). Currently YOY fish exist well below the CAWS, approximately 150 miles downstream near Chillicothe, Illinois. As the leading edge of the reproductive front, close monitoring is critical to understanding of risk to the CAWS by encroaching reproducing fish. Although no reproduction has been documented above Starved Rock, any change in this could greatly increase numbers of fish challenging the electric barriers.
- Building upon the actions undertaken in FY 2011, continuous evaluation of the monitoring data obtained, and scientific review of strengths and weaknesses of the MRRP; ensuing symposium expected in order to identify any improvements or needed information.
- Lead role in developing 2012 MRRP based on 2011 results, as well as coordinating and reporting all action under the plans.
- Complete surveys of Chicago urban fishing ponds to ensure that these do not contain Asian carp.

Expected Milestones

- Throughout 2012: Evaluation of threat in CAWS.
- Throughout 2012: Continuing high level of surveillance.
- Throughout 2012: Contract commercial fishing surveillance in the CAWS and possibly near-shore Lake Michigan.
- Throughout 2012: Application of new gear as developed.

- Throughout 2012: Weekly reports of monitoring results to Asiancarp.us, and updates to Asian Carp Regional Coordinating Committee (ACRCC) partners.
- September 2012: MRRP findings symposium.

Outcomes/Output

- Prevention of Asian carp establishment in CAWS threatening the Great Lakes through an active and adaptive monitoring and management program.
- Summary of sampling and response efforts.
- Additional tools available to detect and/or remove Asian carp from deep water channels.
- From working with USFWS and others, a scientific evaluation of efforts at population level analysis based upon 2 years of intense effort (draft report to be available in spring 2012).

Potential Hurdles

- Unidentified pathways for expansion of Asian carp.
- Timeline of funding and prevention of timely allocation of resources.
- Very large system to find very rare fish.

2.1.2 USFWS Monitoring and Rapid Response Team Support in CAWS

Lead Agency: USFWS

Agency Collaboration: IL DNR, USACE

FY 2012 Funding: $650,000 GLRI funds.

Project Explanation: This task encompasses long-term monitoring and rapid response activities for Asian carp throughout the CAWS, both above and below the Electric Barrier System. The enhanced sampling with both conventional (rotenone, electrofishing, netting) and novel gear (eDNA, DIDSON) will be used to document Asian carp population dynamics within the canal system and connecting waterways, provide data for modeling potential population movements (range expansion), and determine life stages of Asian carp potentially present. Rapid response activities may be implemented where specific evidence indicates presence of Asian carp above the electric barriers, or if a catastrophic event necessitates immediate action.

FY 2010 Actions Undertaken: Following the 2010 MRRP, IL DNR, USFWS, and USACE increased eDNA sample collection and extensive netting and electroshocking efforts in search of Asian carp above the barriers. From June through September 2010, USFWS electrofished twice per month and completed 399 runs for a total of 100 hours. Through this effort, over 25,000 fish from 46 species and two hybrids were observed or handled. No Asian carp were observed through electrofishing.

FY 2011 Actions Undertaken: USFWS teams will support Asian carp monitoring and rapid response activities throughout the region as necessary. All monitoring techniques available may be used at designated areas in accordance with the February 2011 DRAFT "Monitoring and Rapid Response Plan for Asian Carp in the Upper Illinois River and Chicago Area Waterway System" developed by the ACRCC's MRRWG. Service personnel served on this workgroup and helped author this Plan, along with staff from the USACE, IL DNR, U.S. Environmental Protection Agency (USEPA), and U.S. Coast Guard (USCG). The goal of the Plan is to prevent Asian carp from establishing self-sustaining populations in the Great Lakes, and its objectives are to:

1. Determine the distribution and abundance of any Asian carp in the CAWS, and use this information to inform rapid response removal actions.
2. Remove any Asian carp in the CAWS to the maximum extent practicable.
3. Identify, assess, and react to any vulnerability in the current system of barriers that are to exclude Asian carp from moving into the CAWS.
4. Determine the leading edge of major Asian carp populations and reproductive success of those populations.
5. Improve understanding of the likelihood of Asian carp establishment in the Great Lakes.

USFWS will help its partners work to achieve the goals and objectives of the Plan.

FY 2012 Actions Proposed: A USFWS team(s) will support Asian carp monitoring and rapid response activities throughout the region as necessary, and help implement actions called for under the MRRP.

Expected Milestones:

- Development of ACRCC's MRRP.
- Support of Incident Command System (ICS) as needed.
- Provision of staff, equipment, supplies, and ICS team members as needed.

Outcomes/Output:

- Attainment of goals and objectives of the MRRP.

Potential Hurdles:

- Weather conditions.
- Staff availability.
- Possible negative impacts to commercial vessel traffic movement, recreational uses, and resident aquatic life (other than Asian carp) from activities associated with this template.
- Possible public resistance to continuing monitoring and rapid response efforts.

2.1.3 Support for Asian Carp Rapid Response in the Great Lakes Basin

Lead Agency: USFWS

Agency Collaboration: Great Lakes States.

FY 2012 Funding: $700,000 GLRI funds.

Project Explanation: Current USFWS capacity for rapid response actions is largely restricted to the CAWS (via Task 2.1.2) or is limited in scope (Task 2.8.4). However, planned or ongoing early work to detect Asian carp will occur throughout the Great Lakes Basin (via Task 2.8.4) and near interbasin connection points specified in the Great Lakes Mississippi River Interbasin Study. Given possible need for multiple, high-cost, rapid response actions, additional response capacity is required. Rapid response activities may be implemented where specific evidence indicates presence of Asian carp within the Great Lakes basin or near interbasin connections.

FY 2010 Actions Undertaken: USFWS participated in two rotenone-based rapid response actions led by the Illinois DNR in the CAWS.

FY 2011 Actions Undertaken: USFWS used funds provided by GLRI to purchase and store 2,000 gallons of 5% rotenone liquid to retain on hand for Asian carp rapid response. The December 2009 and May 2010 rotenone actions led by the Illinois DNR used 2,000 and 2,200 gallons of rotenone, respectively. The quantity purchased will provide rotenone for a rapid response event similar in scale to those. USFWS is also prepared to purchase other chemicals and materials associated with rotenone use. In addition, USFWS assisted the Illinois DNR in a standard fishery gear-based rapid response event triggered by positive silver carp eDNA results in Lake Calumet of the CAWS.

FY 2012 Actions Proposed: USFWS will support rapid response actions led by states or other jurisdictions around the Great Lakes basin. To supplement these efforts, USFWS will continue to store rotenone and be prepared to purchase other associated chemicals and materials. Additional staff will be trained in ICS.

Expected Milestones:

- February 2012: A process in place to determine how rotenone and resources provided under this template may be used.
- Throughout FY 2012: Provision by USFWS of support for any rapid response actions in the Great Lakes basin or associated with interbasin connection points.

Outcomes/Output:

- Satisfaction of needs of USFWS partners in addressing rapid response actions around the Great Lakes basin.

Potential Hurdles:

- Local coordination, staffing, and logistics of rapid response actions.

2.2 Commercial Harvesting and Removal Actions below the Electric Barrier System

2.2.1 Contract Fishing for Asian Carp Removal

Lead Agency: IL DNR

FY 2012 Funding: $1,200,000 GLRI funds.

Project Explanation: This program was established to reduce the numbers of Asian carp below the Electric Barrier System through controlled and contracted fishing efforts. Reducing the number of Asian carp below the Electric Barrier System will reduce the opportunity for carp to test the barrier and therefore decrease the possibility of Asian carp moving across the barrier and gaining access to waters upstream of the Barrier. This program has removed over 60 tons of Asian carp in 2010, and over 300 tons in 2011. This program also allows for monitoring population densities of Asian carp over time in the four pools immediately below the Electric Barrier System.

FY 2010 Actions Undertaken

Contract commercial fishermen harvested 5,633 Asian carp (122,428 pounds) from Marseilles Pool and 110 (2,358 pounds) from Dresden Pool during 30 days of fishing.

FY 2011 Actions Undertaken:

Contracted commercial fishers and IL DNR biologists caught and removed over 23,000 bighead carp and 17,000 silver carp from Starved Rock, Marseilles, and Dresden Island pools of the Illinois River in 61 days of fishing. Combined, over 351.7 tons of Asian carp was removed from the river in 2011. Marked/recapture and remote sensing studies took place to estimate populations. Seasonal fluctuations are noted in population estimates, as well as catch rates. These will be considered for future efforts, allowing for possibly more fish removal in the future. The catchable leading edge of carp does not appear to have moved farther upstream toward the CAWS and Lake Michigan.

FY 2012 Actions Proposed:

Ten commercial fishing crews are employed to continue to harvest and reduce population of Asian carp in the area between the Starved Rock Lock and Dam and the Electric Barrier System, approximately bi-weekly. Harvested fish will be picked up and utilized by private industry under contract to IL DNR. The harvest will indicate to managers changes in population/harvest rates and fish condition, further informing us of Asian carp population changes, important to the control of these species. Length/weight and catch rates will be reported bi-weekly and monitored continuously. Scheduling of fishing effort will be targeted when fish are in high access areas, based on prior years' experience, allowing for similar effort to remove more fish.

Other monitoring will take advantage of removal efforts to gain valuable insight on movement of Asian carp responding to the density changes due to harvest up and down the waterway, as a supplement to fixed site monitoring. Efficacy of reduction efforts will be gaged by monitoring by other components and Framework responses. The removal efforts will support the MRRP and coordinate with results of peer review and recommendations upon conclusion of 2011 analyses.

Expected Milestones:

- September 30, 2012: Overall reduction of biomass of Asian carp in river reaches below the Electric Barrier System, thus reducing the threat of challenges to Electric Barrier System and lowering the threat to the Great Lakes.

Outcomes/Output:

- Ability to assess these populations by spring 2012 and adjust efforts to optimize impacts.
- Population reduction.
- Assessment of efficacy of removal efforts by reference to added telemetry data (other projects) is expected to indicate success of removal efforts on a pool by pool basis and thus success in prohibiting upstream movement of Asian carp.

Potential Hurdles:

- Increased immigration from out-populations.

2.2.2 Illinois River Stock Assessment/Management Alternatives

Lead Agency: IL DNR

Agency Collaboration: Southern Illinois University, Feeding Illinois

FY 2012 Funding: $1,300,000 GLRI funds.

Project Explanation: IL DNR will advance its work monitoring and developing insights into the strategies for addressing Asian carp in the Illinois River. The primary objective is to understand population dynamics of Asian carp that would give insight into ability of directed harvest and other control measures to reduce overall populations within waters connecting to the Great Lakes, and reduce movement of Asian carp upstream toward the CAWS. Population-level effects and capabilities of harvest as a control strategy are outlined in the Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States. IL DNR will continue current research and training programs for commercial fisherman, as FY 2011 results suggest these will aid development of successful control options. Successful tools will be handed off to industry as identified. Understanding population dynamics is critical into 2012, as the Asain carp commercial fishing industry continues to grow and expand. The focus could shift from the Illinois River then as recruitment/stock overfishing is realized.

Humanitarian Uses: Expanding use of Asian carp for humanitarian purposes can be successful.

- Asian carp humanitarian uses can scale up to the level we need to reduce population numbers.
- The barrier for entry is low because of demand for low-cost protein sources.
- We have positive feedback from initial meetings on product development with Fortune 25-level partners active in this arena.
- Our primary humanitarian partner has an existing distribution system: eight regional food banks serving 102 Illinois Counties with over 2000 retail outlets.
- Partnerships within Illinois have formed, enabling over 2,200 high-quality meals to have been served to bolster nutritional programs within the State as part of 'Target Hunger Now!'. This is one of the largest humanitarian efforts undertaken by the State of Illinois; ultimately, hopes are that this effort provides protein-rich meals, assists in efforts to eradicate Asian carp, supports local fishing efforts and river industries, and creates jobs.

New research areas have been identified:

- Continued monitoring of Asian carp populations throughout the Illinois River, determining how populations affect movement of Asian carp upstream toward the Great Lakes.
- Ongoing control effort evaluation and information regarding Asian carp populations fished and harvested in the upper Illinois River.
- Determination of accuracy of current assessments of Asian carp densities and biomass in the upper Illinois River.
- Determination whether upstream movement can be stopped at specific lock and dams in the upper Illinois River.
- Understanding linkage between populations in the lower Illinois River and populations in the upper Illinois River.
- Development of population models for assessing risk of population increase in the upper Illinois Waterway (including tributaries).

FY 2010 Actions Undertaken: Monitoring and evaluation efforts in the Illinois River (including near the electric barriers in the CAWS) led to valuable baseline information regarding comparison with current population reduction efforts and evaluation of efficacy of methods applied to achieve that reduction. Southern Illinois University presented these results to the ACRCC, and has generated a report. Asian carp flesh was collected for comprehensive contaminant analysis and compositional analysis. These samples have been processed, and the results are included in the report. Contaminant analyses suggest:

- Contaminant concentrations varied among individual Asian carp and were generally low.

- Heavy metals such as mercury were generally low in these fish, although a few individuals (about 10%) had concentrations that mandated limited consumption by sensitive people (e.g., pregnant women).
- Metal concentrations were lower than in most commercially important fish species.
- Organochlorine pesticides (e.g., chlordane) were present in some fish at low concentrations, with the highest proportion population affected in northern river reaches.
- Concentrations of PCBs were below the Food and Drug Administration (FDA) action level for fish, and were generally low compared to most commercially available fishes.
- Other contaminant concentrations were low as well.
- IL DNR has results from a 2010 Illinois Environmental Protection Agency (IL EPA) fish contaminant analysis that helped induce a letter from the fish advisory board promoting use of Asian carp for humanitarian aid.

These samples are at INHS labs with processing and results forthcoming.

The Asian carp Marketing Summit convened on September 20-21, 2010. This two-day meeting of various federal, state governmental agencies, private interests, and university researchers discussed the ways and means to develop commercial harvesting of Asian carp as a solid resource management method.

The Fisheries and Illinois Aquaculture Center (FIAC) led a Certification, Incentive, and Development Program at Southern Illinois University – Carbondale (SIUC). The recently held Asian Carp Marketing Summit attended by federal, state, and private stakeholders recognized the importance of supporting commercial fishermen as a key component of the harvesting strategy.

- The first component supports existing and developing high-value products. This includes a pilot effort to support removal of Asian carp throughout the Mississippi and Illinois River systems via training, certification, incentive, and marketing projects targeted at Illinois-licensed commercial fishermen.
- The second component, conducted independently of the first component and not eligible for incentives, is a targeted, research-oriented fishing effort to understand the ecological effectiveness of harvesting. The FIAC, in conjunction with a subset of Illinois-licensed commercial fishermen, will conduct limited removal trials to assess the effectiveness of harvesting one million pounds from specific reaches of the Illinois River. This one-million-pound goal will assist in evaluating this strategy as an appropriate management tool for control of Asian carp. The harvested Asian carp will be converted into fish meal.
- The third component of this project is directed at gathering relevant marketing information to better improve methods of using markets to reduce Asian carp numbers.

- In 2010, harvest efforts in the lower Illinois River began successfully, and seem to encourage belief that this activity can reduce upstream movement of Asian carp toward the upper Illinois River.

FY 2011 Actions Undertaken:

- Post-processing of baseline hydro-acoustic surveys has established baseline population estimates of Asian carp from the upper Illinois River to the lower Illinois River. Ongoing efforts will allow assessment of fishing pressure on standing stocks of Asian carp, in turn enabling prediction of the total effort needed to achieve a lowered population level within these reaches.

- Results of recent analyses of contaminants within Asian carp flesh allowed the Illinois Fish Consumption Advisory Board to support use of Asian carp from the Illinois and Mississippi Rivers for humanitarian purposes.

- Determination that movement of Asian carp from lower reaches to upper reaches of the Illinois River is common and occurs rapidly.

- Determination that Asian carp appear to have negative impacts on zooplankton and likely native fishes.

- A massive-scale fish removal began, and is expected to reduce the Asian carp population within the central Illinois River by three million pounds. The effort should reduce the number of Asian carp moving toward the Great Lakes, as well as allow assessment and quantification of the efficacy of reduction efforts.

FY 2012 Actions Proposed:

Using best science and understanding the harvest and stock/recruitment variables in the upper Illinois River, IL DNR is further developing dynamic models to forecast and predict effects of harvest, other control efforts, and breadth of Asian carp populations. This will provide science-based direction for harvest and control strategies and regional regulatory oversight to achieve goals for (1) prevention of spread toward the CAWS and (2) further reduction of Asian carp populations. The 2012 activities will continue to include conducting monitoring counts in the upper, central, and lower Illinois River, and assessing the effectiveness of harvest to maximize reduction and reduce movement of Asian carp toward the Great Lakes. A goal is obtaining information about harvest success, with the ultimate goal of extirpating Asian carp from the Illinois River. However, because achieving that goal will be difficult and perhaps unlikely within our open systems, we must balance native species health with feasible reduction efforts in order to achieve maximum ecological benefit to the Illinois River watershed and connecting basins. The IL DNR emphasizes that it does not seek to impose future fishery management to sustainable levels in Illinois or elsewhere. This challenge has also been noted in detail by the National

Management and Control Plan for Bighead, Black, Grass, and Silver Carps in the United States (2007). As suggested in that Plan, an integrated management approach will seek to minimize danger to the native conditions while maximizing control efforts on Asian carp. IL DNR will also be completing pilot programs, identifying directions for growth, and bringing industry up to current standards.

- Counts. Baseline density and weight estimates are now available for Asian carp in the Illinois River, and these baselines and continual monitoring will be important. Also, the methods used to estimate the baseline require refinement with additional gear. This will inform managers regarding need for and speed of alternatives and exit strategies, as well as suggesting direction for such strategies regarding harvest and other control efforts throughout the river.
- Control estimate. The amount of harvest and other control efforts necessary to reduce population size and reproductive output of the two Asian carp species is unknown. Information about the populations in the upper and lower Illinois River is being referenced to determine how much mortality is needed and where harvest and other control efforts need to be applied.
- Fishing removal. Removal efforts in the upper Illinois River will be evaluated, in addition to continued evaluation of removal in the central/lower Illinois River. These efforts are expected to allow key mortality estimates and harvest estimates that will lead to a more accurate estimate of removal necessary to maintain a healthy ecology. This removal evaluation will increase the clarity of biological relationships between harvest and population growth.
- Environmental impact. IL DNR will further study the impact of Asian carp on native species in the Illinois River. Changes in native species and their food are being quantified to assess the risk of an Asian carp invasion in the Great Lakes. This dynamic relationship will be monitored annually, up and down the Illinois River and into the Great Lakes where practicable, to maximize the accuracy of predictions based on research findings.
- Movement. The Asian carp populations in the Illinois River are not isolated, and ongoing monitoring will evaluate annual differences. A monitoring network extending into the CAWS is fixed—thus tags are relatively cost-effective and beneficial for quantifying how movement is influenced by the density of fish in the upper, central, and lower Illinois River.
- Origin. As Asian carp are reduced in the upper Illinois River, the contribution of migrating Asian carp from the Mississippi River must be assessed. Presumably, control efforts underway throughout the Illinois River will reduce the probability of these new Asian carp arriving near the CAWS. Environmental chemical markers unique to rivers of origin will serve in the evaluation of this.

Expected Milestones:

- Ongoing 2012: Continuing work of IL DNR with partnerships outside of the framework project on an Asian carp humanitarian aid program.
- October 2012: Refinement of techniques used to quantify population density and biomass of Asian carp in the upper Illinois River.
- October 2012: Draft population estimate for all Illinois River populations of Asian carp.
- October 2012: Estimate of mortality of Asian carp as a result of control by harvest. This is critical for evaluating efforts at control.
- October 2012: Determination of patterns of movement in the upper Illinois River to CAWS as a function of river conditions and control efforts.
- October 2012: Evaluation of degree of migration into the upper Illinois River from downstream rivers.
- October 2012: Quantification of use of upstream locks and dams as potential secondary barriers.
- October 2012: Arrangement of a population modeling summit to assess models and techniques to characterize Asian carp in the Illinois River and other rivers.

Outcomes/Output:

- Provision of high-quality protein products to Illinois food banks and other humanitarian aid uses.
- Ability to transfer knowledge, management actions, and control technologies obtained from Asian carp activities to national or international levels.
- Conveyance of information to the ACRCC regarding control efforts to reduce the density of Asian carp approaching the Great Lakes
- Prediction of effects of harvest and other control efforts on movement of Asian carp populations toward the Great Lakes.
- Determination of potential impact of Asian carp on native fish and other ecosystem parameters if the carp invades the Great Lakes.

Potential Hurdles:

- Physical conditions of the river and possible low sampling efficiency.
- Avoidance of sustained and managed fishery.
- Minimization of “bi-catch” of native species.

2.2.3 Investigation of Certification Requirements for Asian Carp Usage

Lead Agency: IL DNR

Agency Collaboration: USAID

FY 2012 Funding: State Funded.

Project Explanation: Asian carp could be used as a human food source, but certification procedures that would document suitability of Asian carp from the Illinois River and Mississippi River for human consumption have not yet been assessed.

FY 2010 Actions Undertaken: IL DNR identified requirements necessary for certification. The major requirement is completion of current contaminant studies. With these in hand, efforts to communicate findings and identify pathways for fish into international relief efforts are underway.

FY 2011 Actions Undertaken:

- IL DNR has results from a 2010 IL EPA fish contaminant analysis that induced the fish advisory board to issue a letter promoting use of Asian carp for humanitarian aid.
- SIUC has obtained further results of contaminant and compositional analyses that further support the earlier findings that these fish are a healthy source of high-quality protein for human consumption. This information is needed by industry for international trade.

FY 2012 Actions Proposed:

- Communicate information to national and global organizations with compositional and contaminant information in hand.
- Affiliate efforts to encourage use of these fish for human consumption with action item 2.2.2 Illinois River Stock Assessment/Management Alternatives.

Expected Milestones:

- Completion of contaminant analysis and report.
- Possible issuance of additional letter to encourage further listing of Asian carp for global use.
- Achieving supply and health certifications to promote the good use of this protein for humanitarian uses.

Outcomes/Output:

- Identify partners and workable pathways to include packaged product in the international aid pipeline.

Potential Hurdles:

- Possible inability to supply fish in quantities desired.
- Possible inability to support both domestic and international needs.

2.3 Electric Barrier Actions and Waterway Separation Measures

2.3.1 By-Pass Barrier Operations

Lead Agency: USACE

FY 2012 Funding: $1,000,000 Base funding.

Project Explanation: USACE applies three different types of fish deterrent measures throughout the CAWS. Each is designed to prevent a distinct migration pathway of Asian carp toward the Great Lakes.

- The Bypass Barrier physically blocks known bypasses around the electric barriers that occur during periods of flooding from the Des Plaines River and the Illinois and Michigan (I&M) Canal, and halts possible fish movement through this area. The barriers placed in these locations are intended to stop juvenile and adult Asian carp. Additional and/or more permanent separation measures will be assessed in the Efficacy Study Report.
- The Electric Barriers create a waterborne, pulsed, direct current, electric field in the Chicago Sanitary and Ship Canal (CSSC), which exposes fish penetrating the electric field to electrical stimuli that act as a deterrent. As fish swim into the field, they feel increasingly uncomfortable. When the sensation is too intense, the fish are either immobilized or deterred from progressing farther into the field. Three barriers (Demo, IIA, and IIB) have been constructed so that two can operate fully at any given time and the third is available for emergencies or planned maintenance shutdown.
- Bar screens on sluice gates at Thomas J. O'Brien Lock and Dam were installed to impede entry of Asian carp to Lake Michigan. All potential impacts were considered to ensure public health and safety, and the purposes of these structures must be maintained as authorized by law.

FY 2010 Actions Undertaken: In FY 2010, the Assistant Secretary of the Army for Civil Works approved the report recommendations that would allow design and construction of the bypass barriers and bar screens to proceed. Construction of these, along with electric barrier IIB, began in 2010. Work in the I&M Canal was completed in June 2010.

FY 2011 Actions Undertaken: Work on the Des Plaines River barrier was completed in October 2010, thereby completing work on the bypass barrier project. The total cost was $7.25 million—over $6 million under budget. Subsequently, USACE began maintenance of the bypass barriers with base agency funds. The barriers were inspected periodically to ensure they remained free of debris to minimize damage by animals in the vicinity, and to prevent unintentional bypasses.

FY 2012 Actions Proposed: USACE will maintain the bypass barriers with base agency funds to ensure these remain free of debris so that flow through the mesh is unimpeded. Maintenance is also required to minimize damage by animals in the vicinity.

Expected Milestones: None.

Outcomes/Output: The barriers will perform as designed, thereby minimizing the risk of bypass around the electric barriers via the I&M Canal and the Des Plaines River.

Potential Hurdles: None.

2.3.2 Electric Barriers Operation and Improvement (formerly Expedited Construction of Barrier IIB)

Lead Agency: USACE with support from USGS

FY 2012 Funding: $21,575,000 Total funding (USACE $21,500,000 base funds; USGS $75,000 GLRI funds).

Project Explanation: The Electric Barriers operate by creating a waterborne, pulsed, direct current, electric field in the CSSC. Fish penetrating the electric field are exposed to electrical stimuli, which act as a deterrent. As fish swim into the field they feel increasingly uncomfortable. When the sensation is too intense, the fish are either immobilized or are deterred from progressing farther into the field. Three barriers (Demo, IIA, and IIB) have been constructed, but only two are fully operational at any given time.

Additionally, Congress authorized USACE to upgrade the demonstration barrier to a public facility in the Water Resources Development Act of 2007. Once completed, the permanent barrier will be capable of running at voltage levels high enough to repel smaller fish, similar to Barriers IIA and IIB, thereby providing additional protection against upward migration of Asian carp within the CAWS.

FY 2010 Actions Undertaken: Construction of Barrier IIB began in early FY 2010. Barrier IIA underwent maintenance in December 2009.

FY 2011 Actions Undertaken: USACE completed construction of Barrier IIB and placed it into active operation in April 2011. Barrier IIA was placed in warm standby and underwent maintenance in June 2011. Conceptual design of permanent Barrier I was completed in FY 2011, including location and basic configuration of the facility.

FY 2012 Actions: USACE will continue operation of the electric barriers. All three barriers are scheduled to undergo maintenance in FY 2012. Upgrades to barrier IIA are scheduled to improve its performance. USGS will support barrier maintenance operations.

Design and construction of the permanent barrier will occur in stages. Detailed design will begin in FY2012, leading to the award of the first construction contract by the end of the fiscal year.

Expected Milestones:

- 1st Quarter 2012: Conduct maintenance of Barrier IIB.
- Summer 2012: Complete permanent barrier I site design, and award a construction contract.
- Summer 2012: Start Barrier IIA upgrades.
- Summer 2012: Conduct maintenance of Demo, IIA and IIB.

Potential Hurdles: None

2.3.3 Modified Structures and Operations

Lead Agency: USACE

FY 2012 Funding: $65,000 Base funding.

Project Explanation: To determine whether modified lock and attendant works (sluice gates and pumping stations) operations could impede entry of Asian carp to Lake Michigan. All potential impacts were considered to ensure public health and safety, and the purposes of these structures must be maintained as authorized by law.

FY 2010 Actions Undertaken: In 2010, USACE evaluated whether and how to modify the operation of the Chicago and O'Brien locks to deter Asian carp, and to ensure that Asian carp are not introduced or allowed to migrate into the Great Lakes. In an interim Efficacy Study, USACE recommended installing screens on the sluice gates at the T.J. O'Brien Lock and Dam (other sluice gates in the CAWS are operated by Metropolitan Water Reclamation District [MWRD]). In coordination with USCG, and upon request by agencies involved with fish control and eradication efforts, USACE also decided to intermittently close the Chicago and O'Brien locks as needed to support those efforts. A team of experts led by the USFWS determined that temporary/intermittent lock closures are effective in support of fish suppression measures. However, the effectiveness of permanent lock closure will be considered in the Great Lakes and Mississippi River Inter-Basin Study (GLMRIS).

In July 2010, the Assistant Secretary of the Army for Civil Works approved the installation of the screens and accepted the recommended method of operating the locks. USACE delivered screens for two sluice gates at the T.J. O'Brien lock and dam in September 2010.

FY 2011 Actions Undertaken: Installation of the bar screens at O'Brien Lock and Dam was completed in January 2011.

FY 2012 Actions Proposed: The screens on the gates will be periodically inspected and cleared of debris.

Expected Milestones: None

Potential Hurdles: None.

2.3.4 Electric Barrier Effectiveness (formerly Tagged Fish)

Lead Agency: USACE

Agency Collaboration: USFWS, ILDNR

FY 2012 Funding: $2,100,000 Total funding ($100,000 GLRI fund for tagged fish/telemetry; $1,000,000 base agency funds for split beam hydro-acoustic monitoring; $1,000,000 GLRI funds for further barrier research).

Project Explanation: Continued validation and enhanced understanding of electric barrier effectiveness is one of the highest priorities for the immediate strategy to prevent Asian carp from reaching the Great Lakes. Proposed actions include tagged fish/telemetry, installation and operation of hydro-acoustics at the barrier, and pursuit of further research regarding barrier effectiveness.

<u>Telemetry</u>: The telemetry plan includes tagging fish with individually coded ultrasonic transmitters in the Upper Illinois Waterway (IWW) and CAWS. Telemetry is used to assess effectiveness of the electric barriers by monitoring movement of fish in the immediate vicinity of the barriers in order to determine if the fish can challenge and/or penetrate the Barrier. Additionally, telemetry is used to identify the leading edge of the Asian carp population and whether Asian carp can navigate through lock structures in the IWW system. Surrogate species (i.e. common carp, buffalo spp.) will be tagged at and near the Barrier for monitoring (Lockport Pool); Asian carp will be tagged in the Dresden Island and Brandon Road Pools. The acoustic network proposed is composed of stationary acoustic receivers supplemented by a mobile hydrophone unit.

<u>Split beam hydro-acoustic monitoring</u>: A hydro-acoustic monitoring system would be installed at Barrier IIB to continuously monitor upstream fish movement at the barrier. Split-beam technology was first developed in 1996, and has been used for a wide variety of fisheries applications, including monitoring in-river escapement of adult salmon, fish stock assessments in lakes, and entrainment studies at hydroelectric projects (Enzenhofer et al. 1998, Mueller and Degan 2004, Nestler et al. 1999). Split-beam sonar uses a transducer that is divided into four quadrants (left/right, up/down). The small time delays between receptions of an echo on each quadrant are used to determine the position, direction, and size of fish in real time.

Further barrier research: The technical report detailing experiments to determine optimal operating parameters at the electric barriers was recently released, and the report recommended topics for continued research on barrier effectiveness under various conditions. Some of the projects proposed are as follows:

- Canal wall effects study: The walls of the CSSC are extremely rough and irregular, and could provide shelter from the electrical field, allowing fish to pass. This field study would measure electric field strengths along the canal walls, including at the various notches and cracks, and compare the measurements to similar measurements from the middle of the canal.
- Laboratory research to assess the impact of various environmental conditions on barrier effectiveness and fish behavior: Laboratory tests will be conducted to confirm barrier optimal operating parameters by examining a number of factors including, but not limited to, how variations in canal water temperature and dissolved oxygen levels impact the effectiveness of the barrier. USACE would also conduct tests that expose fish to the electrical field for longer durations of time to determine if the fish become less affected by the field over time.

FY 2010 Actions Undertaken:

Telemetry: From July through November 2010, 105 tags were implanted into adult Asian carp and surrogate species:

- CSSC/Chicago River above Barrier: 20 common carp.
- Lockport Pool above Barrier: 18 common carp; two freshwater drum.
- Lockport Pool below Barrier: 29 common carp.
- Brandon Road pool: one grass carp; one smallmouth buffalo; 17 common carp.
- Dresden Island pool: 17 bighead carp.

The acoustic network was deployed using USACE receivers, as well as receivers from other agencies (MWRD) and academia (SIUC). Receivers are located from Chicago River/Bubbly Creek down to Dresden Island Lock and Dam, and then continue in the middle and lower Illinois River. Receiver, mobile tracking, and tag data are shared in case tags from other studies are picked up in another acoustic network. Tag life of the transmitters used for adult fish typically last about 2.5 years.

As of April 2011, over 1.2 million detections have been noted, but none indicated that tagged fish have crossed the Barrier. Inter-pool movement from tagged common carp has been detected (From Lockport Pool downstream to Brandon Road Pool; and from Brandon Road Pool upstream to Lockport Pool), which indicates movement through Lockport Lock. Some tagged common carp have also been detected near the Barrier, then back downstream in the following days, suggesting a potential challenge to the Barrier, but unsuccessful breach.

Split beam hydro-acoustic monitoring: None. This project will be initiated in FY 2012.

Further barrier research: None. This project will be initiated in FY 2012.

FY 2011 Actions Undertaken:

Telemetry: Stationary receivers were supplemented with addition of four new receivers around Barrier IIB. These new receivers, deployed in May 2011, have the capacity to be deployed for 5 years, and the data can be downloaded from shore, eliminating need for physical retrieval in the electrified zone of water. Additionally, these receivers use a positioning system which will enable us to determine the exact position of the tagged fish in the water. This is an improvement over the currently deployed receivers, which give us presence/absence data.

In 2011, 77 tags were implanted into adult and small surrogate species:

- 47 tags into adult surrogate species in Lockport Pool (43 common carp, two mirror carp, one freshwater drum, one channel catfish)
- 30 tags into small, non-Asian carp species placed immediately upstream and downstream of Barrier 2B (species include white sucker, green sunfish, pumpkinseed, skipjack herring, largemouth bass, smallmouth bass, crappie, and bullhead).

The total number of tagged fish in the system is 182. This includes the 152 adult fish (Asian carp and surrogate species) and 30 small fish (all non-Asian carp species).

The small fish ranged in length from 2.1 to 7.5 inches. They were tagged and released in two batches, in June and October 2011, and distributed evenly above and below Barrier 2B in each batch. Stationary receivers are continuously monitoring movement of the small fish, and the new positioning system will allow us to determine exact movement responses by individual fish. Since these tags are smaller, they also have a much shorter battery life (~100 days).

As of October 2011, over 2.7 million detections have indicated no tagged fish have crossed the Barrier in the upstream direction (with an 82% detection rate). Inter-pool movement from tagged common carp has been detected, indicating movement through Lockport and Brandon Road Lock. Some tagged common carp have also been detected approaching the Barrier, then back downstream in the following days, suggesting a potential challenge to the Barrier, but unsuccessful breach. A full report on all results will be available in late January 2012.

Split beam hydro-acoustic monitoring: None. This project will be initiated in FY 2012.

Further barrier research: None. This project will be initiated in FY 2012.

FY 2012 Actions Proposed:

Telemetry: Recommended for 2012 is tagging additional surrogate species to replace tags implanted in 2010 whose battery life has been exceeded or fish that died or moved out of system.

The focus should be at and around the Barrier, utilizing the 5-year life of the receivers deployed at the Barrier system.

Split beam hydro-acoustic monitoring:

1. Design of a pilot study for hydro-acoustic fish monitoring at the CSSC Electric Barrier System.
2. Installation of the hydro-acoustic fish monitoring system.
3. Monitoring of fish movements with adjustments as necessary. If fish move upstream through the barrier, river managers are to be alerted.

Further barrier research: In 2012, USACE will assemble an expert interagency team to review and develop new research recommendations for barrier effectiveness. The team will identify, prioritize, and recommend work for further research.

Expected Milestones:

Telemetry:

- February 2012: Full report on telemetry data (2010-2011).
- May 2012: Acoustic network enhanced.
- Summer 2012: Complete adult fish tagging efforts
- Fall 2012: Small fish study at Barrier IIA or IIB.
- Monthly: Periodic downloads of stationary receiver data; acoustic network maintenance.
- Quarterly: Mobile tracking of tagged fish in the CAWS.

NOTE: Specific studies concerning small fish will be developed with input from MRRWG in January 2012.

Split beam hydro-acoustic monitoring:

- June 2012: Complete system design for a pilot study.
- Sept 2012: Award of installation contract.

Further barrier research:

- Jan 2012: Assemble expert panel.
- April 2012: Develop detailed research plan.
- June 2012: Initiate research studies.
- 4th Quarter FY 2013: Publish report.

Outcomes/Output:

Telemetry: Validation of barrier effectiveness for all sizes of fish, including frye and young of year.

Split beam hydro-acoustic monitoring: After installation of the monitoring system has been completed, data acquisition will be continuous, 24 hours/day. Automated data filters will be used to process only information regarding fish movements. Monitoring results will be summarized bi-weekly, and an annual report will be provided to the MRRWG, agency partners, and any other interested parties.

Further barrier research: Results of the research will be used to verify the optimal operating parameters of the electric barrier, and will be documented in the Efficacy Interim Report IIB.

Potential Hurdles:

Telemetry:

- Availability of fish for implantation (especially for small fish study).
- Weather impacts on fish mortality rate.
- Movement of tagged fish out of detection range (open system).

Barrier Research:

- Requirement of timely appropriations and funding allocations to achieve stated milestones

2.3.5 Eagle Marsh Temporary Barrier Fence Maintenance

Lead Agency: Indiana Department of Natural Resources (IN DNR)

FY 2012 Funding: $50,000 GLRI funds.

Project Explanation: It is unclear whether the permanent solution near Eagle Marsh will be in place by September 30, 2012, so contingencies are necessary to continue fence maintenance until completion of the permanent solution.

FY 2010 Actions Undertaken: Completion of Eagle Marsh fence in October 2010.

FY 2011 Actions Undertaken: Multi-weekly inspections along the fence and routine maintenance to keep the fence free of debris.

FY 2012 Actions Proposed: Funding is in place to maintain the fence until September 30, 2012.

Expected Milestones:

- Multi-weekly inspections along the fence to confirm that no gaps exceed 2 inches (which would allow adult Asian carp to pass).
- Regular mowing, burning, and debris removal to prevent blockage of the fence when flooding occurs.

Outcomes/Output:

- Repair of damage to the fence as necessary.

Potential Hurdles:

- Intense flooding at the fence that could substantially damage the structure.

2.3.6 Wabash-Maumee Aquatic Nuisance Species (ANS) Controls Report

Lead Agency: USACE

Agency Collaboration: Natural Resource Conversation Service (NRCS), USGS, USFWS, Allen County, and the Little River Wetlands Project

FY 2012 Funding: No additional Fy 2012 funds necessary.

Project Explanation: The aquatic connection that forms across the Eagle Marsh in Fort Wayne, IN was identified in the fourth quarter of FY 2010 as the highest risk aquatic pathway within Focus Area 2 of the GLMRIS. The risk posed by Asian carp in close proximity to the location led the IN DNR, supported by USEPA, NRCS, USGS, USACE, Allen County, and the Little River Wetlands project, to complete construction of a temporary barrier to Asian carp migration across the marsh on September 28, 2010. The USACE is conducting a feasibility study to determine what action or set of actions could be taken to attain a long-term solution that would prevent interbasin transfer of aquatic nuisance species (ANS) across the Eagle Marsh in Fort Wayne, IN. The analysis will include identification of viable structural and non-structural alternatives to prevent interbasin transfer of all ANS, and a systematic evaluation of the completeness, effectiveness, efficiency, and acceptability of each viable alternative along with an estimate of the costs to implement each.

FY 2011 Actions Undertaken: The USACE formed an interagency team and is nearing completion of an analysis of the range of available options and technologies to prevent interbasin migration of Asian carp and other ANS across the Eagle Marsh. To initiate plan formulation, a value engineering study was implemented in FY 2011 to identify and screen potential ANS control measures. Finalization of the Wabash-Maumee ANS Controls Report is expected during the third quarter of FY 2012.

FY 2012 Actions Proposed: Utilizing carry-over funds from FY 2011, finalize the Wabash-Maumee ANS Controls report and communicate with stakeholders to attempt to identify a willing and able local sponsor for participation in a federal project, and/or to support other stakeholders interested in implementing the identified viable alternatives to prevent interbasin transfer of ANS at this location.

Expected Milestones:

- May 2012: Release of Wabash-Maumee ANS Controls report.

Outcomes/Output:

- May 2012: Wabash-Maumee ANS Controls report.

Potential Hurdles:

- Lack of willing and viable local sponsor

2.3.7 Chicago Sanitary & Ship Canal (CSSC) Electric Fish Barrier Marine Safety Risk Assessment and Risk Mitigation Measures

Lead Agency: USCG

Other Agencies Involved: USACE, USEPA

FY 2012 Funding: $248,000 Total funding ($150,000 GLRI funds/$98,000 Base funding).

Project Explanation: The Electric Barrier System on the CSSC presents multiple potential hazards to marine safety. Various regulatory actions prescribe operating rules and guidance to promote: (1) navigation safety for commercial and recreational mariners transiting the CSSC in the vicinity of the barrier, and (2) safe work practices and operating standards for commercial facility operations that operate or moor vessels in the vicinity of the barrier. The USCG operational commander desires a comprehensive review of marine safety risks associated with the fish barrier, adequacy of present risk mitigation strategies, and recommendations for alternatives to these strategies. USCG base funding will come from funding for Research Development Test and Evaluation (RDT&E) in order to complete the efforts related to this action item.

FY 2010 Actions Undertaken: The USCG R&D Center (RDC) reviewed preliminary fish-barrier safety test results, and began a research project to investigate safety for a rescuer responding to a person in the water within the electrified barrier zone.

FY 2011 Actions Undertaken: The RDC conducted rescuer safety testing in the electrified barrier zone, participated (as observers) in the February 2011 USACE Barrier Safety Testing, and conducted peer review of the Report on the Safety Testing.

During July 2011, the RDC conducted and will report on additional rescuer safety testing independent of the follow-on USACE safety testing.

The RDC began planning and development for this risk assessment and mitigation project in June 2011.

FY 2012 Actions Proposed: RDC will complete project development and begin project work, including development of probability versus consequence framework to determine the appropriate risk assessment tool, data acquisition and analysis to populate risk matrix, analysis of present regulatory scheme with respect to risk assessment, determination of risk mitigation gaps (if any), and recommendations for changes to risk mitigation measures, as applicable.

Expected Milestones:

- March 2012: Integrate preliminary risk mitigation measures.
- November 2012: Complete consequence investigation scientific measurements, and data acquisition.
- March 2013: Complete risk analysis and mitigation strategies.
- March 2013: Deliver final project report.

Outcomes/Output:

- A summary of the marine safety risks associated with the fish barrier, adequacy of present risk mitigation strategies, and recommendations for alternatives to these strategies.

Potential Hurdles:

- Data availability may be limited, and data acquisition methods have not been determined.
- Stakeholders' opinions differ as to need for or effectiveness of current risk mitigation measures.
- Risk mitigation measures without effective compliance may not yield any overall improvement in marine safety.

2.3.8 Management of Waterway Traffic in Support of Asian Carp Control Activities

Lead Agency: USCG

FY 2012 Funding: $210,000 in GLRI funds.

Project Explanation: The USCG manages federally navigable waterways through establishment and enforcement of Regulated Navigation Areas (RNA), safety zones, and security zones. Many waterways in the Chicago Area are designated as federally navigable waterways, including the Illinois River, the Des Plaines River, the CSSC, branches of the Chicago River, and the Calumet-Saganashkee Channel.

When operations associated with the electric fish barrier, rapid response actions, research projects, or any other Asian carp activity impact the flow of traffic on a navigable waterway, the USCG creates a RNA or safety zone and provides notice to the public and mariners to inform them of the planned activities and expected impact on navigation. If a partial or full closure of a navigable waterway is required, the USCG may deploy assets on scene to enforce the closure. For extended closures, the USCG may also establish a temporary vessel traffic service that tracks delayed vessels and facilitates orderly resumption of traffic after the closure is lifted.

In order to create a RNA or safety zone, the USCG must complete a rulemaking project, including public notice in the *Federal Register*. To streamline this process, the USCG created a safety zone in 2010 that covers 77 miles of the CAWS and allows the USCG to restrict or stop traffic for Asian carp activities. However, the USCG still strives to provide at least a 30-day notice to waterway users prior to a waterway closure.

FY 2010 Actions Undertaken:

- On May 1, 2010, the USCG put in place a Temporary Interim Rule that established a 77-mile-long safety zone from Brandon Road Lock to Lake Michigan in Chicago, IL, including segments of the navigable waters of the Des Plaines River, the CSSC, branches of the Chicago River, and the Calumet-Saganashkee Channel. The purpose of the safety zone was to provide the USCG Captain of the Port with the ability to take targeted and expeditious action to protect vessels and persons from the hazards associated with any federal and state efforts to control ANS.

FY 2011 Actions Undertaken:

- On December 2, 2010, the USCG put in place a Temporary Interim Rule which established a RNA on the waters located adjacent to and over the electric fish barrier. The RNA prescribes requirements for vessels passing over the barrier in order to protect them from hazards associated with the barrier. This Temporary Interim Rule also established a safety zone that restricts vessels from transporting non-potable water across the barrier with the intention of discharging the water on the other side.

- On July 18, 2011, the USCG put in a place a Final Rule which established a permanent safety zone covering the same 77 miles of waterways covered by the Temporary Interim Rule issued in May 2010.

FY 2012 Actions Proposed:

- The USCG will issue and enforce a series of full waterway closures to support Electric Fish Barrier maintenance and ANS control activities throughout FY 2012. The USCG will also renew the Temporary Interim Rule issued in December 2010.

Expected Milestones:

- None. Activities are carried out as needed.

Outcomes/Output:

- Appropriate control of vessel traffic to protect vessels and persons from the hazards associated with any federal and state efforts to control ANS.

Potential Hurdles:

Waterway closure requests received by the USCG less than 35 days prior to the event do not provide enough time for the USCG to carry out the rulemaking process or provide public notice. Waterway restrictions and closures should be planned ahead and coordinated among agencies whenever possible in order to facilitate the regulatory process and minimize the impact to waterway users.

2.4 CAWS Barrier System and Great Lakes Mississippi River Study Activities

2.4.1 Efficacy Study

Lead Agency: USACE

FY 2012 Funding: $500,000 Base funding.

Project Explanation: The study investigates hazards that could reduce the efficacy of the Electric Barrier System located in Romeoville, Illinois. The project includes an analysis of potential bypasses, optimal operating parameters, deterrent systems, modified structures and operations, fish monitoring and reduction, and potential for migration via other pathways.

FY 2010 Actions Undertaken: USACE completed Efficacy Study Interim Reports I (Barrier Bypasses), IIIA (Acoustic-Bubble-Strobe Deterrent System) and III (Modified Structures and Operations), and initiated work on Interim Report II (Optimal Operating Parameters) and the Comprehensive Efficacy Study. Construction of measures to address potential barrier bypasses via overland flooding and/or through existing drainage pathways was completed along the Des Plaines River and I&M Canal under emergency authority granted by Congress in Section 126 of the Energy and Water Development Appropriations Act of 2010.

FY 2011 Actions Undertaken: USACE released Interim Report IIA (Optimal Operating Parameters Laboratory Research and Safety Tests) in September 2011, which recommended increasing the barrier settings to those thought more effective in deterring small fish. Work on the Comprehensive Efficacy Study Report continued, including evaluation of other potential measures to deter the migration of the Asian carp, other assisted transits/vectors (bait buckets, ballast water, navigation transiting through the CAWS), and measures to control access to Lake Michigan through the Little Calumet and Grand Calumet Rivers. This report also will summarize and update efforts previously described in the above-referenced interim reports.

USACE also completed Interim Risk Reduction Measures recommended in Interim Reports I and III, as discussed in Section 2.3.1. These measures included the bypass barriers and sluice gate bar screens, respectively.

FY 2012 Actions Proposed: The Comprehensive Efficacy Study report will be completed and will undergo an independent external peer review. The study report will be released to the public in FY 2012.

Expected Milestones:

- 3rd Quarter 2012: Independent external peer review and public review of Comprehensive Efficacy Report.
- 4th Quarter 2012: Complete Comprehensive Efficacy Report.

Potential Hurdles:

- Future extension of Section 126 emergency authority for recommended actions/measures.
- Determination of relative risks and trade-offs of pursuing identified actions.

2.4.2 GLMRIS Focus Area I: Chicago Area Waterway System

Lead Agency: USACE

Agency Collaboration: USFWS, USGS, USEPA, National Oceanic and Atmospheric Administration (NOAA), USCG, U.S. Department of Transportation (USDOT), U.S. Department of Agriculture (USDA), IL DNR, MWRD

FY 2012 Funding: $3,000,000 Base funding.

Project Explanation: GLMRIS is a congressionally authorized feasibility study directing the USACE to consult with appropriate federal, state, local, and nongovernmental organizations in order to investigate the range of options and technologies available to prevent spread of ANS between the Great Lakes and the Mississippi River Basins through the CSSC and other aquatic pathways. The study will identify potential hydraulic connections between the two basins, identify and explore existing and potential ANS, and assess ANS control technologies. These control technologies include but are not limited to physical or hydrologic separation.

The study is proceeding in two focus areas. Focus Area I is the CAWS, and Focus Area II consists of all aquatic pathways outside the CAWS, commonly referred to as the Other Pathways.

FY 2010 Actions Undertaken: USACE developed a Project Management Plan (PMP) to define the study scope, schedule, and budget; and initiated the National Environmental Policy Act (NEPA) scoping process.

FY 2011 Actions Undertaken: USACE released the PMP in November 2010; conducted 12 NEPA scoping meetings throughout the Great Lakes and Mississippi River Basins and released a report summarizing comments received; prepared an ANS White Paper listing High Risk Alien Species with potential for Inter-Basin dispersal; and initiated efforts to gather data to establish the baseline study condition.

FY 2012 Actions Proposed: Complete ANS control technologies report. Complete data acquisition efforts for social and cultural resources, commercial navigation, commercial passenger navigation, recreation/fishing, commercial fisheries, flood risk management, and water supply/discharge and water quality. Establish baseline conditions and initiate development of alternatives.

Expected Milestones:

- November 2012: Expected completion of data acquisition activities.

Outcomes/Output:

- June 2011: ANS White Paper.
- July 2011: NEPA Scoping Meeting Summary Report.
- September 2011: Commercial Passenger Navigation Report.
- December 2011: ANS Control Technologies Report.
- December 2011: Commercial Cargo Summary Report.
- April 2012: Commercial Fisheries Report.
- November 2012: Recreation/Fishing Summary Report.

Potential Hurdles:

- Additional public outreach events may require additional funds, and impact schedule.
- Congressional action may accelerate schedule, impacting scope of activities.

2.4.3 Feasibility Assessment of Inter-Basin Transfer of Aquatic Invasive Species (AIS) between the Des Plaines River and CAWS

Lead Agency: USGS

Agency Collaboration: USACE

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Transfer of AIS or eDNA via surface and subsurface fractures or solution features may be occurring. These additional hydraulic connections between Des Plaines River and CAWS could allow transfer of AIS and/or eDNA and should be addressed.

FY 2010 Actions Undertaken: Completed field work except for well drilling. Completed analysis of available data, characterization of bed sediment on the Des Plaines River, bathymetric and water characterization survey of the CSSC and parts of the Des Plaines River, and assessment of geology in the area of concern (including several surface geophysical surveys). Identified areas where the geology, hydrology, and water quality indicate areas of potential for fractures capable of allowing presence and transfer of Asian carp eggs, fry, or other invasive species. Monitoring wells and additional hydrogeology characterization in these areas are planned. Coordination of efforts with USACE has occurred to avoid duplication of efforts.

FY 2011 Actions Undertaken: Completed a literature review and report on the hydrology and geology of the study area that is accessible at http://il.water.usgs.gov/asian_carp/. Drilled and installed monitoring wells at identified locations to intercept fractures in the bedrock. A dye tracer test in November 2011 characterized water movement (location, pathways, and rate) from the Des Plaines River, through the fractures, and into the CSSC. The tracer will help identify the pathway and aid the effort to determine the approximate transport time between the river and the canal.

FY 2012 Actions Proposed: Efforts will focus on project completion. Complete analysis of the 2011 tracer study is expected, along with the draft report that will (1) summarize all research conducted in conjunction with the project, and (2) offer preliminary conclusions regarding the potential for inter-basin transfer between the two waterways.

Expected Milestones:

- March, 2012: Complete analysis of dye tracer study.
- September 2012: Submittal of draft project report with preliminary conclusions for USGS review.
- January 2013: Publication of final project report.

Outcomes/Output:

- January 2013: Report and conclusions regarding the potential for inter-basin transfer of invasive species between the Des Plaines River and CAWS.

Potential Hurdles: None

2.4.4 Ecological/Biological Risk Assessments

Lead Agency: USFWS

Agency Collaboration: USGS

FY 2012 Funding: $500,000 GLRI funds.

Project Explanation: Four species of nonindigenous carps (bighead carp, silver carp, large-scale silver carp, and black carp) have been listed as injurious wildlife under the Lacey Act. However, many other species of carp and their relatives exist, whose introductions to the waters of the United States are possible. Long-term protection of the Great Lakes and other areas of the United States will require an integrated approach of risk assessment and risk management to prevent establishment and impacts of carps and their relatives. Risk assessment involves risk screening—evaluation of the history of impacts in the world, climate matches between worldwide established locations of these fish and the Great Lakes, and projections of impacts to various locations such as the Great Lakes and its basin. Risk screening will focus on risks of establishment of Crucian carp (*Carassius carassius*), Prussian carp (*Carassius gibelio*), and related species in the Great Lakes, and their consequent impacts. This information will be useful for state and federal decision makers in their efforts to develop regulatory and non-regulatory approaches to managing risks of introductions and impacts of carp species other than Asian carp.

FY 2010 Actions Undertaken: NA

FY 2011 Actions Undertaken: USFWS worked with NOAA to develop biological/ecological models for Lake Michigan, Lake Erie, and Lake Huron in order to help predict potential for establishment and impacts of Asian carp within each water body. Results will ultimately provide managers with information to help protect and rehabilitate Great Lakes fishery resources. In addition, the USFWS collaborated with partner agencies to develop mitigation plans in the event of Asian carp establishment in the Great Lakes.

FY 2012 Actions Proposed: Screening reports will be completed for Crucian carp, Prussian carp, and some other related species.

Expected Milestones:

- September 30, 2012: Risk screening reports completed regarding Crucian carp, Prussian carp, and some other related species.

Outcomes/Output:

- September 30, 2011: Rapid screening will identify risks to the Great Lakes from Crucian carp, Prussian carp, and some other related species. Identified risks will be shared with Great Lakes States and federal regulatory authorities.

Potential Hurdles:

- Needed data may be difficult to acquire for certain species.

2.4.5 Forecasting Spread and Bio-economic Impacts of AIS from Multiple Pathways to Improve Management and Policy in the Great Lakes

Lead Agency: NOAA Center for Sponsored Coastal Ocean Research

Agency Collaboration:

FY 2012 Funding: $747,617 Total funding ($687,617 GLRI funds/ $60,000 Base funding).

Project Explanation: Without accurate forecasts of the arrival and bio-economic impact of non-indigenous species, natural resource management cannot cost effectively respond to current invasions or prevent future invasions. This project draws on scientific, economic, risk analysis, and management expertise to (1) increase capabilities for forecasting both ecological and economic impacts of current and future species invasions, (2) quantify major uncertainties and ways to reduce uncertainty, and (3) identify actions to improve cost-effective management of invasive species in the Great Lakes. The six major goals of the project, including sources of funding, are:

1. Forecast the probability of establishment. Researchers will draw on the literature and ongoing studies to identify which non-indigenous species are likely to be introduced into the Great Lakes via three major pathways: (a) shipping, (b) organisms in trade (pet,

horticulture, aquaculture, biological supplies, live food, and live bait industries), and (c) canals, especially the Chicago Area Waterway System. (GLRI funding)

2. Forecast the potential habitat of species within the Great Lakes. Investigators will use multiple ecological niche models, based on new Geographic Information System (GIS) layers (produced by the project) of habitat and species distributions within the Great Lakes. (GLRI funding)
3. Forecast the potential spread of invaders within the Great Lakes. Investigators will compare natural background dispersal (predicted by current models) to that predicted from activities of oceanic ships, lake ships, and recreational boaters. (GLRI funding)
4. Forecast ecological impacts. Researchers will use food web modeling to develop quantitative scenarios of ecological impacts, with uncertainties specified via structured expert judgment. (NOAA funding)
5. Forecast regional economic impact. Researchers will link the food web models to a Great Lakes regional economic model (a computable general equilibrium model) to account for feedbacks between ecological and economic systems, and quantitatively value ecosystem goods and services affected by invasive species. (NOAA funding)
6. Use the linked ecological and economic models to evaluate alternative management strategies with cost-benefit analyses that focus on prevention of species introduction, early detection and rapid response (EDRR) efforts, slow-the-spread strategies, and integrated control options. (GLRI and NOAA funding)

FY 2010 Actions Undertaken: Because FY 2009 NOAA funds were not awarded until the end of the fiscal year, FY 2010 (first year of GLRI funding) was effectively the first full year of project activities. Main first-year activities included: creating annotated lists of potential risk species relevant to pathways identified above, reviewing literature on species with high risk for invasion, updating food web models for impact assessments to incorporate uncertainty and stochasticity, and beginning development of a regional economic model.

FY 2011 Actions Undertaken: During FY 2011, the project's external advisory board was constituted. The board's input, along with relevant scientific information, are aiding finalization of the list of the project's target priority species of concern. Work began on developing methodology to forecast suitable habitat and dispersal through key pathways in the Great Lakes. The Ecopath with Ecosim (EwE) food web models are under development for all the Great Lakes. The computable general equilibrium economic (CGE) model is under development to include the interaction between the economy and the food web. Questions for use in the structured expert elicitation have been identified, focusing on the potential biomass, production, and diet of future invasive species. Additional actions in synergy with other ongoing projects included developing preliminary risk assessments for the shipping and the CSSC pathways; identifying bait fish wholesalers as potential bottlenecks to facilitating surveillance for fish species of high risk in the live trade pathway; identifying plant species of high risk traded by the plant industry and developing a risk assessment tool for the State and private sector; and completing the first part of the environmental niche model for *Hydrilla* which suggested that the Great Lakes may be at high risk of invasion by this species.

FY 2012 Actions Proposed: During FY 2012, completion of most or all model development activities is expected in order to assess dispersal, potential habitat, and ecological and economic impacts of the selected invasive species on a continuous basis through the end of the project's award period in FY 2013. In collaboration with relevant management agencies, emphasis will also shift toward development and evaluation of alternative management responses to circumstances within each of the key Great Lakes pathways.

Expected Milestones:

- Delivery of forecasts of the potential for introduction and establishment of selected species by lake ship traffic and some other pathways (continuous).
- Published GIS data layers for invasive species in Great Lakes (continuous).
- September 2012: Complete data layers of current distribution of selected invasive species in their native and introduced ranges (continuous)
- September 2012: Complete habitat suitability maps for selected invasive species in Great Lakes (continuous)
- Complete forecast of natural background dispersal for selected invasive species in Great Lakes (continuous).
- Complete forecast of dispersal of selected invasive species in Great Lakes via key pathways (continuous).
- September 2012: Complete scenarios of effectiveness and costs of alternate management responses to selected invasive species in Great Lakes (continuous).
- Provision of results to external advisory panels that will allow them to develop management recommendations regarding selected invasive species in Great Lakes (continuous).
- Communication of results to decision makers via advisory panels (continuous).

Outcomes/Output:

- Improved ability to prioritize potential invasive species for prevention, early detection, and other management efforts.
- Improved understanding of invasion risk among managers and policy-makers responsible for shipping, organisms in trade, and canal pathways.
- Improved understanding among managers of which locations and habitats to target for efforts at early detection of and monitoring for invasive species.

- Increased basic information regarding benefits and costs of alternative management and policy responses to invasive species.

Potential Hurdles:

- Possible limitations in occurrences of species about which data are to be acquired, as well as costs and limited effectiveness of management alternatives, could lead to uncertainties about results of implementing recommendations.
- A new invasion or invasions could supersede ongoing analyses, and rapidly change research and management priorities.

2.4.6 GLMRIS Focus Area 2: Other Pathways

Lead Agency: USACE

Agency Collaboration: USGS, USFWS, NOAA, NRCS, Minnesota Department of Natural Resources (MN DNR), Wisconsin Department of Natural Resources (WI DNR), IN DNR, Ohio Department of Natural Resources (OH DNR), Pennsylvania Fish and Boat Commission (PAFBC), Nebraska Department of Environmental Quality (NEDEC), Michigan Department of Natural Resources (MI DNR), IL DNR

FY 2012 Funding: $ 300,000 GLRI funds.

Project Explanation: GLMRIS is a congressionally authorized feasibility study directing the USACE to consult with appropriate federal, state, local, and nongovernmental organizations to investigate the range of options and technologies available to prevent spread of ANS between the Great Lakes and the Mississippi River Basins through the CSSC and other aquatic pathways. Focus Area 2 of GLMRIS encompasses all locations where an aquatic pathway exists or may form across the basin divide that separates precipitation flowing to the Great Lakes from precipitation flowing to the Mississippi River and its tributaries.

FY 2011 Actions Undertaken: The GLMRIS Other Aquatic Pathways Preliminary Risk Characterization report was finalized and posted for public distribution in November 2010. The results of the preliminary characterization and the plan to complete it in 2011 were conveyed to the ACRCC and subsequently to the public during a series of 12 NEPA public scoping meetings. The final risk characterization and a draft of it were under development during the 3rd and 4th quarters of FY 2011, with final report approval and public release expected in the first quarter of FY 2012.

FY 2012 Actions Proposed: Finalize the GLMRIS Focus Area 2 Risk Characterization. This report is intended to (1) provide a definitive inventory of locations along the basin divide where interbasin flow of surface water is reasonably likely to occur from a storm event up to the magnitude of a 1 percent annual return frequency storm, and (2) establish an ANS Transfer Risk Rating for each location. The results of the risk characterization will be conveyed to and discussed with federal, state, local, and non-governmental organizations and the public for comment, as well as for possible further identification of measures that could be most effectively and efficiently implemented at the local level to prevent interbasin transfer of ANS. Based on the results of the risk characterization, agency collaboration, and public input, development of ANS Control Reports will begin at each aquatic pathway warranting site-specific structural and non-structural measures to prevent interbasin transfer of ANS. Funding will provide for continued collaboration among both Focus Area Teams and state, local, and federal partners to help prioritize use of limited funding, identify prospective non-federal project sponsor(s), and initiate an ANS Controls Report on one high-risk site to identify the full range of structural and non-structural measures for preventing interbasin transfer of ANS at that location.

Expected Milestones:

- February 2012: Complete biological assessments
- May 2012: Complete Draft Other Pathways Assessment Report
- June 2012: Complete Draft Other Pathways Assessment Report and hold GLMRIS Focus Area 2 Risk Characterization Public Meeting/Webinar.
- Summer 2012: Initiate development of ANS Control Reports at high-risk location(s).

Outcomes/Output:

- June 2012: Focus Area 2 Risk Characterization Report.
  - Inventory of Aquatic Pathways.
  - Relative Risk Rating and Characterization at each aquatic pathway.

Potential Hurdles:

- Disparate stakeholder participation.
- Possible difficulty in identifying non-federal sponsors for project implementation.

2.4.7 Wabash/Maumee Hydrologic Support to Prevent Interbasin Transfer of Asian Carp

Lead Agency: USGS-Indiana Water Science Center

Agency Collaboration: USACE (GLMRIS—Other Pathways), IN DNR

FY 2012 Funding: $85,000 GLRI funds.

Project Explanation: Presence of adult bighead carp has been confirmed within the Wabash River basin for at least 15 years. The Wabash River basin intermittently connects with the Maumee Basin (Lake Erie) during flood stage through a former glacial channel at Eagle Marsh in northeast

Indiana. This proposed effort would support flow modeling by the USACE to develop feasible plans for separating the basins to prevent migration of ANS while maintaining the marsh as viable flood relief for Fort Wayne, Indiana.

Existing stage gage operation is needed to validate periods when Eagle Marsh floods sufficiently for the adult carp barrier fence to operate and to indicate needs of maintenance and cleaning. Links to these gages are as follows:

- 03323583 EAGLE MARSH EAST NEAR FORT WAYNE, IN
- 03323584 EAGLE MARSH WEST NEAR FORT WAYNE, IN

Additional stream-flow and temperature gages are needed to assist with planned USACE efforts to modify area hydrology in order to better separate the Wabash and Maumee basins and prevent migration of ANS such as Asian carp and the round goby. Requested funding would cover: (1) operation of the existing gages at the Eagle Marsh carp fence, and (2) installation of two additional hydro-acoustic stream flow and temperature gages in the area to operate for 1 year in order to establish flow properties for modeling the effect of proposed basin separation on flooding.

FY 2011 activity: Installed and operated stage only gage at temporary (4-year) mesh fence to detect flood stage conditions at Eagle Marsh. Funding for this operation ended on September 30, 2011.

FY 2012 Actions Proposed: Continue USGS support of adult carp barrier fence function by operating and maintaining two existing water-level (stage) gages on east and west sides of fence. (The water-level gages indicate when water levels are sufficiently high for fish to reach the fence, and warn staff to verify presence of adult carp.) Construct and operate gages at the following locations, and report stream-flow and temperature data there: (1) Graham-McCullough Ditch near where it empties into Little River and (2) Little River below confluence with Aboite Creek or Junk Ditch near mouth at St. Mary's River. The continuous stream flow and temperature data would be used to assess and design a permanent barrier system to prevent Asian carp migration at Eagle Marsh.

Expected Milestones:

- Provisional stream-flow and temperature information online, 1 year after installation.

Outcomes/Output:

- Availability of provisional data on USGS NWIS-Web, and provision of information to USACE and IL DNR partners for effective use in hydraulic simulation of ANS separation alternatives.

Potential Hurdles:

- Landowner access for stream-flow gages. Will attempt to locate at existing road crossings to use government controlled right-of-way.

2.4.8 Risk Assessment Coordination

Lead Agency: GLFC

Agency Collaboration: ACRCC-affiliated agencies with interest and ability to assist.

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Coordination of risk assessment projects to ensure that they complement each other for maximum benefit is needed to provide the most complete assessment possible of the risk of Asian carp invading the Great Lakes. Several projects that will include risk assessments of Asian carp to the Great Lakes are ongoing or proposed. Additional Great Lakes risk assessment projects at agencies and universities have relevance to Asian carp risk assessments for the Great Lakes. Additional research at multiple agencies and universities will generate information relevant to risk assessments specified in the Asian Carp Control Strategy Framework (Framework). An example is the NOAA Center for Sponsored Coastal Ocean Research (CSCOR) supporting research at the University of Notre Dame. Moreover, information from ongoing risk assessments will be useful to researchers as they continue their analyses of invasion pathways, dangerous invaders, and possible prevention/control methods. Coordination among these many projects will enhance the effectiveness of the Framework in its efforts to control Asian Carp.

FY 2011 Summary: To be determined (TBD).

FY 2012 Action: The Great Lakes Fishery Commission (commission) will coordinate Asian carp risk assessment projects funded by the Framework. The commission will serve as liaison between projects funded by federal funds outside of the framework, or those embedded within the framework but not explicitly identified that have relevance to projects listed below. The commission also will coordinate with eDNA and science coordinators to ensure prompt and accurate sharing of information among groups.

Framework projects to be coordinated are:

- 2.4.4 Great Lakes Ecological Models for Risk Assessment, led by USFWS.
- 2.4.5 Forecasting Spread and Bio-economic Impacts of AIS from Multiple Pathways, led by NOAA.

Expected Milestones:

- Regular (at least quarterly and more frequently if needed) conference calls to assess progress on all Framework risk assessment projects and to minimize overlap of projects.
- Two face-to-face meetings of framework risk assessment project lead personnel to provide detailed progress updates and stimulate discussion about gaps that remain in knowledge about Asian carp risk.

- Commission service as liaison with other federally funded projects with relevance to framework risk assessment projects.
- Commission service as liaison with eDNA and science coordinators to direct potential use of eDNA and new control technologies to areas of greatest risk.
- Provision of information to the Asiancarp.gov website as appropriate.
- Communication of information obtained by risk assessment projects to the ACRCC, the Communications Work Group, and other interested parties as appropriate.

Potential Hurdles:

- Unexpected difficulties meeting timeframes of individual coordinated projects.

2.4.9 An Assessment of Silver and Bighead Carp Movement and Spawning Activities in the Wabash River Watershed, Indiana

Lead Agency: IN DNR

Agency Collaboration: Purdue University

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: The potential trajectories and rates of movement by silver and bighead carps throughout the Wabash River, and especially into the Little River and Eagle Marsh, have not been determined to date. Additional Vemco VR2W passive receivers will be added to the existing network of passive receivers in the upper and middle Wabash River to allow better determination of Asian carp use of smaller tributary rivers (e.g., Eel River and Wildcat Creek). The network will be used to passively track the currently tagged 99 silver and one bighead carp surgically implanted with Vemco V16-4L acoustic tags. An additional 100 acoustic tags will be surgically implanted in 50 silver and 50 bighead carp (this number may be adjusted in response to the ready availability of specific species). Tagged fish will continue to be tracked using a Vemco VR100 manual receiver deployed from a motorboat or canoe, depending on river levels. Bongo net tows will also be employed for Asian carp eggs to determine the upstream extent and duration of Asian carp spawning in the Wabash River and the East Fork White River.

FY 2010 Actions Undertaken: No project activities in FY 2010.

FY 2011 Actions Undertaken: Developed and installed a network of 15 total Vemco VR2W passive receivers in the Little River, the upper and middle Wabash River, and the Tippecanoe River. This network was used to passively track 99 silver and one bighead carp surgically implanted with Vemco V16-4L acoustic tags. Tagged fish were also tracked using a Vemco VR100 manual receiver deployed from a motorboat or canoe. Bongo net tows were also deployed in the middle and upper Wabash River and in the upper East Fork of the White River to try to determine how far upstream Asian carp were spawning in these rivers. The single tagged bighead carp and 68 of the 99 tagged silver carp were detected at least once after tags were implanted and the fish released. One of these detections was in the Huntington-Forks region of the upper Wabash River near the mouth of the Little River, but no fish were ever detected at a receiver in the lower portion of Little River. Asian carp eggs were detected as far upstream as Wabash, Indiana, in the Wabash River, and two suspected Asian carp eggs were observed near Medora, Indiana on the East Fork of White River. Unfortunately, verification of the eggs observed at Medora was not possible due to rupture after preservation. The eggs obtained at Wabash were at the gastrula stage, and they likely had been drifting in the river for 10-12 hours prior to capture in the bongo nets. This suggests that the actual spawning event for these eggs was considerably farther upstream from the collection point. Regardless, this is the smallest river reach within which Asian carp eggs have been observed to date (D. Chapman, USGS, and personal comm.). In addition, evidence of Asian carp spawning in the Wabash River under conditions not consistent with those previously reported was documented. Eggs were detected in the Wabash River near Lafayette, Indiana, as late as the 3rd week in July, and there was no substantial increase in the hydrograph usually expected prior to spawning by these species.

FY 2012 Actions Proposed: Five additional Vemco VR2W passive receivers will be added to the existing network of passive receivers in the upper and middle Wabash River to allow better determination of Asian carp use of smaller tributary rivers (e.g., Eel River and Wildcat Creek). The network will be used to passively track the currently tagged 99 silver and one bighead carp surgically implanted with Vemco V16-4L acoustic tags. An additional 100 acoustic tags will be surgically implanted in 50 silver and 50 bighead carp (this number may be adjusted in response to the ready availability of specific species. Tagged fish will continue to be tracked using a Vemco VR100 manual receiver deployed from a motorboat or canoe, depending on river levels. Bongo net tows will also be employed for Asian carp eggs to determine the upstream extent and duration of Asian carp spawning in the Wabash River and the East Fork White River.

Expected Milestones:

- July 31, 2012: Conduct bongo net surveys for Asian carp eggs in Wabash River and East Fork White River.
- September 30, 2012: Passively and manually track existing and newly tagged Asian carp.
- October 30, 2012: Submit Phase II project report.

Outcomes/Output:

- October 30, 2012: Phase II project report.
- December 31, 2012: Peer-reviewed papers on project findings.
- October 30, 2012: Personal and technical communications with colleagues and stakeholders.

Potential Hurdles:

- Inclement weather and flood conditions may delay some project activities, although all project activities will still be completed within the contract period.

2.4.10 Enhanced GLMRIS Stakeholder Engagement

Lead Agency: USACE

FY 2012 Funding: $200,000 GLRI funding.

Project Explanation: GLMRIS is a congressionally authorized feasibility study directing the USACE to consult with appropriate federal, state, local and nongovernmental organizations to investigate the range of options and technologies available for preventing spread of ANS between the Great Lakes and the Mississippi River Basins through the CSSC and other aquatic pathways. The study has garnered significant public attention. Over 950 comments were submitted through the GLMRIS Web site, via mail, and at 12 NEPA public scoping meetings held throughout the Great Lakes and Mississippi River basins in late 2010 through early 2011. Interested stakeholders include other federal agencies, Native American tribes, state agencies, local governments, and non-governmental organizations.

Although the study team has attempted to be open and transparent with stakeholders regarding the study, study progress, and interim products, several stakeholders have expressed a desire for a more direct role in the study process. This effort will assess the current stakeholder engagement efforts, and develop and implement recommendations to improve the effectiveness of the stakeholder engagement.

FY 2012 Actions Proposed: Release additional interim products, such as commercial cargo baseline assessment, ANS control technologies report, commercial fisheries baseline assessment, Wabash-Maumee controls report, and assessments of probability of transfer via other aquatic pathways. Conduct public discussions of reports regarding ANS controls technologies and other aquatic pathways. FY 2012 GLRI funds would support a baseline assessment of GLMRIS public participation and implementation of selected recommendations offered therein. The baseline assessment would be conducted by the Institute of Water Resources (IWR) Public Participation Center of Expertise. IWR would examine current public engagement plans, interview GLMRIS team members, and identify areas and methods to expand stakeholder engagement.

Expected Milestones:

- March 2012: Expected completion of assessment of stakeholder engagement.

Outcomes/Output:

- Recommendations offered to improve effectiveness of stakeholder engagement.
- Recommendations assessed and plan developed to implement recommendations.

Potential Hurdles:

- Additional public outreach events may impact study schedule.

2.5 Research and Technology Development

2.5.1 Investigate Tow Boats and Barges as Potential Vectors

Lead Agency: USCG (Research and Development Center)

Agency Collaboration: Members of the planning workgroup include personnel from USGS, Sea Grant (University of Wisconsin), and USCG District 9. In addition to developing the experimental plan, personnel will also review draft reports.

FY 2012 Funding: No additional FY 2012 funds necessary. Experiments conducted in 2010 and 2011. Final report to be funded with FY 2010 and 2011 GLRI funds.

Project Explanation: Entrainment and survival experiments conducted in spring 2011, coupled with the tank survey conducted in 2012, are expected to provide necessary information allowing determination of potential for towboats and barges to transport Asian carp across the USACE Electric Barrier System.

FY 2010 Actions Undertaken: A survey of the volume of water transported by towboats and barges was conducted in late summer 2010. Ballast tanks and voids on 132 barges (empty and loaded) and 14 towboats were visually inspected in August 2010. A total of 969 individual ballast tanks and voids were inspected. Only 5 percent of the tanks contained a measurable amount of water (more than 2 inches). Water temperature and dissolved oxygen (DO) concentrations in ballast tanks were within documented ranges of tolerances for Asian carp and other carp species. Normal ballasting procedures were described by barge operators.

FY 2011 Actions Undertaken: Entrainment and survival experiments occurred aboard a modified barge in the Illinois River near Peoria, IL during spawning events in June 2011. Four barge ballast tanks outfitted with 3-inch valves were flooded to approximately 50 inches depth. At varying time intervals, the tank contents were pumped out using 3-inch pumps barge operators normally use to ballast tanks. The water was pumped into a plankton net, and the contents were examined for entrained larvae. Caged larvae collected locally were suspended in the ballast tanks for the same time periods and were examined to determine survival rates. Finally, locally captured larvae were carefully poured in front of the intake hose for 2-inch and 3-inch pumps, and were discharged into a plankton net to determine the potential to survive one pass through the pumps. Two sets of these three experiments were conducted. Results indicated Asian carp larvae could survive in ballast tanks but they would be unlikely to survive a single passage through a ballast pump.

FY 2012 Actions Proposed: The first draft of the report on the entrainment and survival experimental results was delivered to the R&D Center in November 2011. Following review and revisions, the final report will be delivered in March 2012.

Expected Milestones:

- November 2011: Draft report of experiment results.
- March 2012: Final report of experiment results.

Outcomes/Output:

- September 2011: Survey results and normal barge ballasting procedures.
- March 2012: Final report covering entrainment potential into barge tanks, survival rates in barge tanks, and pump entrainment and pump effects.

Potential Hurdles:

- Seasonality of spawning and possible inability to find spawning Asian carp.

2.5.2 Assessment Study of Potential Impacts of Steel-hulled Barges on Fish Movement across Electric Barrier II

Lead Agency: USACE

FY 2012 Funding: $500,000 GLRI funding.

Project Explanation: Studies of the Demonstration Barrier (Barrier I), operating at parameters lower than the current operation of Barrier II, indicated that immobilization of fish (due to the electric barrier) swimming alongside barges took about three times longer than if the fish were swimming through the electric field without any substantial steel hull present. As the steel hull approaches the barrier the steel warps the electric field toward the hull, thus providing a shielded area where fish would feel reduced or completely eliminated effects from the barrier. Therefore, steel-hulled barges may increase the possibility that fish are not affected by the electric barrier. The results of the studies at the Demonstration Barrier were used to design Barriers IIA and IIB so that steel-hulled effects on the electric field would be eliminated or minimized. However, continued field testing of potential steel-hull effects over Barriers IIA and IIB is needed because fish could be stunned and swept through the barriers with the barge and revived once again upsteam of the barriers.

FY 2011 Actions Undertaken: Develop scope of work and coordinate for resources. This testing will begin in FY 2012.

FY 2012 Actions Proposed: Design and conduct experiments to test the effectiveness of the Electric Barriers IIA and IIB in the presence of steel-hulled barges and other vessels.

Expected Milestones:

- March 2012: Design experiment and probes.
- June 2012: Manufacture materials for experiment.

- September 2012: Obtain data.
- June 2013: Publish report.

Potential Hurdles: None.

2.5.3 Research on Potential Asian Carp Vectors as a Source of Fish or eDNA Movement in the CAWS

Lead Agency: USACE, USGS, USFWS

Agency Collaboration: IL DNR, MWRD, USEPA

FY 2012 Funding: $900,000 GLRI funds (USACE $650,000; USGS $200,000; USFWS $50,000).

Project Explanation: Anecdotal evidence suggests potential vectors for Asian carp DNA to enter the CAWS without originating from a live, free-swimming bighead or silver carp. Potential vectors include introduction of tissue containing Asian carp DNA from:

- Barges (dead fish being transported to new areas; tissue attached to upstream-bound tugs or barges; trapped fish between lashed barges).
- Waterfowl (piscivorous bird excrement).
- Combined Sewer Outfalls (specifically in regions of Chicago where Asian carp are sold in markets on the street).

Investigation of these potential sources of DNA is necessary to either justify or invalidate the hypothesis that these could be contributing to positive eDNA sample results.

FY 2010 Actions Undertaken: This research began in FY 2011.

FY 2011 Actions Undertaken: The interagency calibration team has developed a subtask to specifically address potential for alternative vectors to contribute to a positive eDNA result. This research started in 4th quarter FY 2011.

FY 2012 Actions Proposed: Study will be completed in FY 2012. Additionally, eDNA content and viability after consumption, digestion, and passage by piscivorous birds will be studied, as well as dead fish from barges. A conceptual model begun in FY 2011 will be amended later in 2013 after reception of results from relevant studies cited in Action Items 2.6.3 and 2.6.5.

Expected Milestones:

- April 2012: Start bird and carcass studies.
- June 2012: Repeat Storm Sewers Study.
- July 2012: Obtain results from repeated Storm Sewers Study.
- September 2012: Complete lab studies of birds and carcasses.

- November 2012: Complete field surveys of birds and carcasses.
- Dec 2012: Complete reports of bird and carcass studies.
- August 2013: Complete full conceptual model.

Outcomes/Output:

- Validation or invalidation of specific vectors suspected as likely contributing to positive eDNA results in samples.
- Conceptual model of viable vectors.

Potential Hurdles:

- Possible unreliability of and inadequate participation in surveys (conducted by lockmasters querying barge pilots regarding carcass transport and disposal).
- Logistical challenges to procurement of samples for waterfowl excrement study.

2.5.4 Assessing Risks of Great Lakes Invasion by Understanding Asian Carp and Bluegreen Algae Dynamics

Lead Agency: USGS

Agency Collaboration: None

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Bluegreen algae (primarily *Microcystis sp.*) blooms resulting from the mussel invasion may provide an excellent food source for bighead carp, enhancing their invasion. Noxious bluegreen algal blooms, under some circumstances, can be enhanced by interaction with silver and bighead carp, and presence of these carp may enhance toxin production by noxious algae. This project focuses on assessing the risk of Asian carp survival in the Great Lakes based on Asian carp feeding habits.

FY 2010 Actions Undertaken: USGS hired the necessary personnel and obtained permits for laboratory work. Work also began to culture the bluegreen algae and construct the tank to house and feed Asian carp.

FY 2011 Actions Undertaken: During the second year of this project, it expanded to outdoor water enclosures in order to accommodate larger fish than those used during the first year of the project. Water enclosures were purchased and set up to complete this work. Laboratory investigation of small fish continued for both species; some work with small silver carp (especially the bioenergetics portion) will conclude in 2012. During the first set of trials, completed in January 2011, bighead and silver carp juveniles were fed a combination of bluegreen algae/green algae. A second set of trials then commenced whereby bighead and silver carp were fed bluegreen algae, sequestered by type of carp, and tested for effects of toxin production by algae.

FY 2012 Actions Proposed: Data acquisition for both silver and bighead carp has been completed. Efforts will focus on completing bioenergetics modeling for silver and bighead carp, as well as finishing the manuscript and publishing the findings.

Expected Milestones:

- March 2012: Submit manuscript to scientific journal for publication.

Outcomes/Output:

- Final publication of research findings (publication date dependent on journal).

Potential Hurdles: None

2.5.5 Risk Assessment of Asian Carp Establishment in the Great Lakes Based on Available Food Sources

Lead Agency: USGS

Agency Collaboration: None

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Asian carp have been observed to diversify their diets beyond preferred pelagic plankton sources and feed on organic matter ("detritus") under certain conditions and on the basis of availability of food resources. Silver carp are also thought to derive substantial nutrition from bacteria, both consumed and cultured in the gut. However, whether these food sources are adequate for growth and survival of Asian carp is unknown. Scientists are testing an established model that indicates Asian carp cannot survive in Lake Michigan based on available food types. Alteration of his model occurs as documentation of new findings on what the carp will eat (e.g., types of algae) appears.

FY 2010 Actions Undertaken: USGS hired the necessary personnel and purchased the equipment required to test the model that assumes Asian carp cannot survive in Lake Michigan. Personnel began testing the model on bighead carp. In addition, personnel looked at the behavior of Asian carp in seeking out and eating alternative food. Cladophora, one of these alternative food sources, is being grown in culture for testing. Data acquisition began for this project in July 2010.

FY 2011 Actions Undertaken: Observation in the lab indicated that the juvenile bighead and silver carps can consume microcystis algae and Cladophora (alternative food sources), which are abundantly available in the Great Lakes. The model is being validated and applied to predict fish growth assuming this food source. Scientists completed all behavioral work involving consumption of alternative foods in aquaria and water enclosures. Data acquisition was completed for determining the validity of the bioenergetics model for all ages and sizes of bighead and silver carp.

FY 2012 Actions Proposed: Acquisition of data for both silver and bighead carp has been completed. Efforts will focus on finishing manuscripts and publishing findings.

Expected Milestones:

- December 2011: Submit manuscripts on model variation findings and assessment of alternate foods for review and publication.

Outcomes/Output:

- Final publication of research findings (publication date dependent on journal).

Potential Hurdles: None

2.5.6 Use of Seismic Technology to Divert and Eradicate Asian Carp

Lead Agency: USGS, USACE

Agency Collaboration: IL DNR, USACE, USFWS

FY 2012 Funding: $1,225,000 Total funding ($550,000 GLRI funds [$500,000 USGS; $50,000 USACE] /$675,000 Base funding).

Project Explanation: Methods now available to control nuisance and non-native invasive fishes are inadequate. Some methods are expensive, labor intensive, non-selective, and/or length-specific. Proximity of Asian carp to the Great Lakes Basin highlights the need to develop quickly available additional control methods to affect their behavior, thereby impeding their spread into the Great Lakes, or to remove Asian carp through direct mortality. Seismic technology possibly could affect the behavior of nuisance and non-native invasive fishes or eradicate them over a range of age classes; seismic technology thus is a viable candidate for participation in integrated suppression efforts.

FY 2010 Actions Undertaken: The USGS has now conducted three separate experiments (Snake River cutthroat trout, Northern pike, and bighead and silver carp) evaluating use of water guns as a deterrent. Experiments assessed the feasibility of water gun deployment for use as a barrier and to determine acute and chronic lethal thresholds in fishes exposed to pulsed sound pressure levels. Studies were conducted in situ because the magnitude of water gun operations precludes these in a laboratory setting. In these studies, a water gun prototype (343-cubic-inch water gun developed by Bolt Technology) capable of generating 840 pounds per square inch (PSI) (254 decibels [db] at 1 meter) was used in all experiments to maintain consistency. Initial studies demonstrated that the water gun can induce significant negative physiological effects in fish at sound pressure levels exceeding PSI, 9 meters from the sound source.

FY 2011 Actions Undertaken: Plans for FY 2011 include hiring a postdoctoral fish ecologist, purchasing additional water guns, constructing an array of these for mobilization, and conducting additional tests on behavioral modification in carp and lethality in threatened and endangered species. Research in FY 2011 will determine whether pulse pressures emitted from water guns can repel carp as a static barrier, and will assess whether water guns as a mobile barrier can repel and divert the carp. Using results from these two studies, we will then determine the viability of utilizing these pulse pressures within the CSSC and at shipping locks.

FY 2012 Actions Proposed: The USGS will evaluate use of water guns to control, divert, and/or eradicate Asian carp. Experiments will utilize metrics of fish movement and determine the feasibility of water guns for barrier applications and increased capture efficacy. Studies will also evaluate the safety of water gun applications in proximity of hard structures such as canal walls and in locks used for barge passage. Additional efforts will be directed at water gun usage during electric barrier maintenance in conjunction with USACE, USCG, and IL DNR.

Expected Milestones:

- July 2012: Complete Asian carp behavioral experiment.
- July 2012: Complete structural integrity study.
- September 2012: Complete water gun barrier maintenance support activities.

Outcomes/Output:

- July 2012: Expected provision of information from behavioral experiment concerning effectiveness of water guns for use as a static barrier.
- September 2012: Expected water gun use during maintenance of electric barriers, enabling USACE to conduct routine operations proximate to the electric barriers.

Potential Hurdles:

- Inability to procure equipment for operational needs.
- Possible unexpected carp behavior that complicates experimental studies.

2.5.7 Expand Research on the Identification of Asian Carp Attraction/Repulsion Pheromones

Lead Agency: USGS

Agency Collaboration: State agencies, USFWS

FY 2012 Funding: $240,000 Base funding.

Project Explanation: A pheromone is a chemical substance that influences certain behaviors in fish and other organisms. Sex pheromones detected through the fish's sense of smell trigger reproductive interactions. The Asian carp's sex pheromones synchronize sexual readiness within the population and induce specific behaviors such as attraction, nest preparation, and spawning behaviors. Production of female sexual pheromones may also be induced through hormonal treatments.

Field studies are required to evaluate the effectiveness of hormonally induced sex pheromone production in caged female carp as an attractant to aid in capturing wild carp. Technologies must be identified for observing the response of wild carp to attractive and repellant stimuli in the field.

FY 2010 Actions Undertaken: Physiological screening assays indicated very high sensitivity of the carp's sense of smell for sex hormone metabolites associated with sex pheromones. The metabolites result from chemical processes in the fish's body.

FY 2011 Actions Undertaken: Behavioral assays began in 2011 to verify behavioral attraction to sex hormone metabolites determined highly stimulatory during physiological assays of the carp olfactory system. Proof-of-concept studies were initiated to determine if production of attractive sex pheromones could be hormonally induced in females with the aim of using caged, treated females as a source of attractive pheromones to help capture wild carp. An evaluation began of technologies for observing the response of wild carp to attractive or repellant stimuli in the field. A feeding stimulus developed as a positive control for field tests was highly attractive.

FY 2012 Actions Proposed: Following from proof-of-concept studies initiated in 2011, field tests will be conducted to develop protocols for use of sex attractants as lures in the field. These studies will document the response of Asian carp to caged female carp that have been hormonally induced to produce attractive pheromones to lure male Asian carp for capture and removal. Alternatively, use of sex hormone metabolites identified in carp sex pheromones will be applied as attractants. This assessment will consider the responsiveness of free-ranging fish categorized by species, sex, stage of sexual maturation and gonad development. The studies will also attempt to determine the effective range over which fish are responsive and the persistence with which they respond. Utility of the feeding stimulus as a potential lure will be examined.

Accurate documentation of the response of wild fish is critical for developing pheromone lures for carp control. Several underwater imaging technologies to be evaluated include side-scan and DIDSON sonar imagery, pit tagging of fish for detection, and 3-D sonic tag telemetry to observe wild fish and confirm their response to these attractive stimuli.

Expected Milestones:

- October 1-March 31 2012: Conduct comparison of technologies for detecting position and movements of fish in the field in response to an attractive or repellent fixed-point stimulus, (1) considering range and accuracy of detection, and (2) handling stress imposed on the fish by the different approaches.
- March 31- September 31 2012: Conduct replicated studies to assess attraction of free-ranging carp to caged, hormonally induced, female carp. The studies will also include an evaluation of the responsiveness to sex hormone metabolites that appear to make up the pheromone.

Outcomes/Output:

- Protocols for hormonal induction of pheromone production in Asian carp.
- Protocols for conducting behavioral observation of free-ranging fish responding to fixed-point stimuli.
- Draft protocols for use of caged females as pheromone stimulus lures to assist in capture of free-ranging fish.
- USGS report on feasibility of using pheromones to capture and harvest Asian carp.

Potential Hurdles:

- Possible insufficient availability of reproductive-stage fish for hormonal induction of sex pheromones.
- Selection of study site that allows sufficient control of free-ranging carp to conduct replicated field trials.

2.5.8 Identify Potential Compounds for Inclusion in a Toxicant Screening Program for Control of Asian Carp

Lead Agency: USGS

Agency Collaboration: Viterbo University, USFWS

FY 2012 Funding: $250,000 Base funding.

Project Explanation: A lack of registered piscicides (chemicals poisonous to fish) severely limits the tools that aquatic resources managers have available to control aquatic invasive fish. Identification and registration of new piscicides would increase the ability of managers to deal with aquatic invasive fish. Furthermore, increased scrutiny of rotenone due to human health implications could result in potential loss of this piscicide, creating a gap that would have to be filled. This project will analyze structures and activities of chemicals with known piscicidal capabilities described in a variety of industrial, pesticide, and pharmaceutical libraries. Chemicals similar in structure or activities to known piscicides will be evaluated for potential use in controlling aquatic invasive fish such as bighead or silver carp.

FY 2010 Actions Undertaken:

- Initiation of a literature review and analysis of structure/activity relationships (SAR).
- Initiation of a literature review to catalogue chemicals with known piscicidal activity.

FY 2011 Actions Undertaken:

- Continuation of the comprehensive literature review to catalogue chemicals with known piscicidal activity. Results of the literature search are being compiled in a database for review to identify common structural features and correlate those features with modes of action.

- Integration of results of bighead and silver carp enzymatic and molecular profiles (including responses to rotenone) into the SAR analysis. This will allow inclusion in the SAR analysis of active sites for potential chemical receptors (e.g., Asian carp appear to have greater phosphatase activity than native planktivores identifying a chemical which becomes active only after cleavage of a phosphate group may have greater toxicity to Asian carp than to native planktivores).
- Continuance of the SAR review of pharmaceutical and pesticide databases to identify candidate fish toxicants. The SAR review will incorporate results of the literature search and information provided from incorporation of the enzymatic and molecular profiles in order to narrow the search criteria.

FY 2012 Actions Proposed:

- Continue the comprehensive literature review to catalogue chemicals with known piscicidal activity. Results of the literature search are being compiled in a database for review to identify common structural features and correlate those features with modes of action.
- Continue the SAR review of pharmaceutical and pesticide databases to identify candidate fish toxicants. The SAR review will incorporate results of the literature search and information provided from incorporation of the enzymatic and molecular profiles in order to narrow the search criteria.
- Identify, in collaboration with the USFWS La Crosse Fish Health Center, sources of native fish cell lines suitable for use in cytotoxicity (cell toxicity) assays.
- Develop, in collaboration with the USFWS La Crosse Fish Health Center, bighead and silver carp cell lines suitable for use in cytotoxicity assays. Because silver and bighead carp cell lines are not currently available, development of cell lines of these species likely must occur before screening can proceed.
- Complete cytotoxicity screening assays with candidate fish toxicants identified in SAR review. Cytotoxicity screening will be completed using cell lines of bighead and silver carp and at least two representative non-target fish.
- Confirm, using *in vivo* bioassays with fish, the acute toxicity of chemicals that selectively cause cytotoxicity in Asian carp cell lines. *In vivo* bioassays will include non-target native fishes; the number of species included will depend on fish availability.

Expected Milestones:

- March 2012: Completion of initial SAR review of pesticide and pharmaceutical libraries.

- March 2012: Identification of sources of required cell lines.

- July 2012: Development of bighead and silver carp cell lines, selection of non-target fish cell lines, and initiation of *in vitro* cytotoxicity assays.

- August 2012: Initiation of *in vivo* screening.

Outcomes/Output:

- Approximately one dozen candidate fish toxicants identified for further testing.
- Draft manuscripts of cell line development and toxicant screening.

Potential Hurdles:

- Delayed development of Asian carp cell lines.

2.5.10 Developing Targeted Control Systems for Asian Carp Based on Species-Specific Digestive System Characteristics

Lead Agency: USGS

Agency Collaboration: INHS, Purdue University, and South Dakota State University.

FY 2012 Funding: $80,000 Base funding.

Project Explanation: Current toxicants used to control AIS are non-selective and applied throughout the entire water column, resulting in equal exposures of native and invasive species to the toxicant. Development of a delivery system that is selectively consumed by or active in an invasive species could reduce non-target species exposure to the toxicant and may enhance selectivity and reduce effects to non-target species. Development of such delivery methodologies will require full understanding of native and invasive species gill and gut enzyme activity and physiology, because a targeted delivery system will likely require selective or non-selective uptake via oral or gill adhesion delivery routes, with ultimate delivery in/through the gastrointestinal tract. A complete understanding of the differences between the gastrointestinal system of native planktivores (fish that eat plankton) and that of Asian carp is critical to the development of any targeted delivery system.

FY 2010 Actions Undertaken:

- In August and September 2010, native planktivorous fish from the Illinois River were sampled, and concentrations of 19 digestive enzymes and lysozymes, as well as pHs, were compared among the species.
- Fecal samples from gizzard shad and bigmouth buffalo were collected, and the bacterial composition for each species was identified using modern genetic techniques. A contract with the University of Illinois for genetic sequencing of microfauna was initiated.

- Characterization of gill morphology of native planktivores began. Initial 3-dimensional images were generated. This information will provide a better understanding of how planktivorous fishes capture particulate matter, and ultimately aid in designing a targeted delivery system for piscicides that minimizes impacts to native fishes.

FY 2011 Actions Undertaken:

- Continued digestive tract sampling (enzymes and bacterial flora) of native planktivores (gizzard shad and bigmouth buffalo) in the Illinois River in March. Samples will be collected seasonally to assess seasonal plasticity in native planktivore digestive tracts.
- Established collaborations with Purdue University to collect digestive tract samples (enzymes and bacterial flora) of native planktivores from the Wabash River, Indiana. This will help identify possible geographic differences in the digestive tract enzymes or bacterial flora of native planktivore populations.
- Developed a contract with University of Illinois for bacterial sequencing, and submitted samples to serve in efforts at describing the bacterial fauna of the digestive tracts of gizzard shad and bigmouth buffalo. Characterizing the bacterial fauna will allow us to better understand how Asian carp and the native planktivores differ in the way they process food.
- Synthesized the differences in digestive physiology (enzymatic and symbiotic flora) among planktivorous fishes, and applied those differences to the attempt to develop a targeted piscicide delivery system.

FY 2012 Actions Proposed:

- Establish collaborations with South Dakota State University to collect digestive tract samples (enzymes and bacterial flora) of native planktivores from the James River, South Dakota. This will help identify possible geographic differences in the digestive tract enzymes or bacterial flora of native planktivore populations.
- Collect digestive tract samples during winter (October through February). Overwintering feeding habits of Asian carp and native planktivores in northern rivers is essentially unknown. Gut content samples collected in March 2011 indicated that silver carp may be feeding at temperatures and times that native planktivores are not. This information will determine the optimal time for applying an oral toxicant that will minimally impact native fish while maximally impacting Asian carp.
- Continue to synthesize the differences in digestive physiology (enzymatic and symbiotic flora) among planktivorous fishes, and apply those differences to the attempt to develop a targeted piscicide delivery system. Publish results of the work regarding enzymes in a peer-reviewed article.

Expected Milestones:

- February 2012: Complete collection of digestive tract samples.
- March 2012: Complete analysis of digestive tract samples.
- April 2012: Collect Asian carp and native planktivore digestive tract samples.
- May 2012: Complete enzymatic assays of digestive enzymes.
- July 2012: Draft report assessing the digestive tract.
- August 2012: Draft report comparing enzymatic differences.

Outcomes/Output:

- Synthesis of differences in digestive physiology (enzymatic and symbiotic flora) among planktivorous fish and comparison of those in Asian carp (work on Asian carp enzymes is part of Framework project 2.5.12). Incorporation of these identified differences into development of a targeted piscicide delivery system that minimizes the impact of an oral toxicant on native planktivores.
- Publication in 2011 and 2012 of manuscripts describing the digestive enzymes of native planktivores and the temporal and spatial changes in digestive tract activity.

Potential Hurdles:

- Possible difficulties collecting digestive tract samples during winter months.
- Possible inaccessibility of sampling sites during winter months.

2.5.11 Great Lakes' Tributary Assessment for Asian Carp Habitat Suitability

Lead Agency: USGS

FY 2012 Funding: $225,000 Base funding.

Project Explanation: This project focuses on determination of a minimum river length, water velocity, and water temperature characteristics required for spawning and growth of bighead and silver carp, in order to assess the risk of these carp creating a breeding population in Great Lakes tributaries. USGS researchers have determined the densities of the eggs as these develop, and how much time the bighead and silver carp require to begin swimming and migrating laterally from flowing water into nursery habitat. This information about egg and larvae transport requirements will be used to create a tool that takes into account the hydraulics of a river (water velocity and dispersion rates) and the water temperature (affects egg and larvae development rates) in order to determine if a river is sufficiently long for (1) bighead and silver carp to spawn and (2) the eggs/larvae to be carried to nursery areas. Scientists can then efficiently identify Great Lakes tributaries that pose elevated risk for reproduction of bighead and silver carp.

FY 2010 Actions Undertaken:

- Completion of development series for Asian carp at different temperatures.
- Study leading to discovery that Asian carp begin to swim vertically before they can swim horizontally, enabling them to remain suspended in the water column at an earlier developmental stage than previously assumed.
- Measurement of egg diameters and specific gravity at progressive development stages to characterize these for a transport model.
- Completion of acquisition of hydraulic data at the Milwaukee River in Wisconsin in August 2010.

FY 2011 Actions Undertaken:

- Completion of acquisition of hydraulic data at the St. Joseph River in Michigan and Indiana in December 2010.
- Processing at the Illinois Water Science Center (ILWSC) of the data obtained at the Milwaukee and St. Joseph Rivers, in order to determine dispersion coefficients and areas where river conditions may be unfavorable for egg transport.
- Completion of water-quality data acquisition at the St. Joseph River in September 2011. Completion of water-quality data acquisition at the Maumee River in Ohio in August 2011.
- Initiation in summer 2011 of flume experiments at the University of Illinois at Urbana-Champaign to better characterize egg transport.

FY 2012 Actions Proposed:

FY 2012 funding would focus on development of the tributary assessment tool with the University of Illinois and acquisition of data at an additional tributary.

Expected Milestones:

- Development of Asian Carp Tributary Assessment tool by University of Illinois and USGS, including field verification at a known spawning reach outside the Great Lakes Basin.
- Acquisition of field data at a Lake Erie tributary.

Outcomes/Output:

- Further hydraulic and water-quality data obtained at an additional tributary to be incorporated into the tool for assessing suitability of tributaries for Asian carp spawning.
- Preliminary computer assessment tool for evaluating suitability of tributaries for Asian carp spawning.

Potential Hurdles:

- Acquisition of field data depends on weather conditions (storms could occur during periods of warm weather).

2.5.12Technologies Using Oral Delivery Platforms for Species-Specific Control

Lead Agency: USGS

Agency Collaboration: Advanced BioNutrition Corporation, INHS, Purdue University, University of Wisconsin – LaCrosse, University of Illinois Urbana-Champaign, Viterbo University

FY 2012 Funding: $1,025,117 Base funding.

Project Explanation: No current technology can specifically target bighead or silver carp for control within aquatic ecosystems. Current piscicidal chemicals are not selective for bighead or silver carp, and current methods to apply these in aquatic systems equally expose all animals present. Developing targeted delivery systems with high specificity for bighead and silver carp would increase the ability of management agencies to control or limit Asian carp while minimizing potential impacts to native species. Similarly, developing new chemical tools specifically toxic to bighead or silver carp would lead to more success in management efforts to control Asian carp. Indeed, developing new selective chemical control tools appears essential to successful management of Asian carp.

FY 2010 Actions Undertaken:

- Acquired analytical instrumentation (Beckman Multisizer™ 4 particulate counter, a real-time quantitative polymerase chain reaction system, and microplate photometer) to quantify particle size profiles, and to identify and characterize digestive systems of Asian carp and native fish.
- Determined baseline digestive enzyme profiles of Asian carp in order to identify unique differences to exploit for a selective targeted delivery system.
- Evaluated uptake and physiological response of Asian carp and bigmouth buffalo to varying doses of the piscicide, rotenone. These data were critical to determine the rotenone loading of a selective targeted delivery system.
- Established a contract with Advanced BioNutrition Corp. to prepare and deliver a selective targeted delivery system for determining particle retention and delivery analysis in Asian carp.
- Completed analysis of approximately 15 particle formulations and sizes of potential selective targeted delivery systems, and initiated work to increase particle performance characteristics.
- Supported by funding through the USGS Science Support Program (SSP), initiated work to determine filtering characteristics of native unionid (freshwater mussels) and zebra

mussels, and initiated comparative analyses of native unionid and zebra mussel digestive enzyme profiles. Preliminary results indicate possibly unique seasonal differences that may be applicable to a selective targeted delivery system utilized to control zebra mussels.

FY 2011 Actions Undertaken:

- Initiated work to describe filtering characteristics of bighead and silver carp exposed to a selective targeted delivery system and microspheres, in order to determine their particle retention characteristics.
- Continued digestive tract sampling (enzymes and bacterial flora) of bighead and silver carp at the Illinois River in March. Samples will be collected seasonally to assess seasonal plasticity in bighead and silver carp digestive tracts.
- Established collaborations with Purdue University to collect digestive tract samples (enzymes and bacterial flora) of bighead and silver carp from the Wabash River, Indiana. This will help identify any geographic differences in the digestive tract enzymes or bacterial flora of bighead and silver carp populations.
- Developed contract with University of Illinois for bacterial sequencing, and submitted samples to describe the bacterial fauna of the digestive tracts of bighead and silver carp. Characterizing the bacterial fauna will allow us to better understand how Asian carp and the native planktivores differ in how they process food.
- Identified differences in digestive physiology (enzymatic and symbiotic flora) of bighead and silver carp, and applied those differences to development of a targeted piscicide delivery system.
- Supported by funding through the USGS SSP, continued work to determine the filtering characteristics of native unionid and zebra mussels and comparative analysis of native and unionid and zebra mussel digestive enzyme profiles.
- Initiated characterization and comparison of the gill raker structure of bighead and silver carp with that of native planktivorous fish to better understand particle retention capabilities of bighead and silver carp.
- Completed evaluations of bighead and silver carp retention of a selective targeted delivery system.
- Completed comparisons of selective targeted delivery system release mechanisms through in vitro assays of varied particle-release mechanisms exposed to bighead or silver carp digestive tract contents in order to determine the most efficient release mechanisms for delivering targeted particulate load.
- Initiated work to determine rotenone-incorporated particle characteristics from particle retention and digestive enzyme profile evaluations.
- Initiated work to evaluate toxicity of a selective targeted delivery system of rotenone in order to determine field exposure rates for controlling bighead and silver carp.

- Assessed differences in digestive physiology between Asian carp and native planktivorous fish to aid selection of a release mechanism for new selective toxicants.
- Initiated acquisition and outfitting of a bio-assay trailer for on-site evaluation of a selective, targeted, delivery system of rotenone to bighead and silver carp and non-target species.
- Initiated *in vivo* bioassays of GD-174 and analogues with bighead, common, and silver carp. Developed analytical methods to quantify GD-174 and analogues in bioassays.

FY 2012 Actions Proposed:

- Identify potential field trial locations to evaluate a selective targeted delivery system of rotenone. The evaluation was initially to occur in 2011 but was delayed due to unavailability of the number of fish needed for the studies.
- Submit Experimental Use Permit application to EPA to allow field trials of a selective targeted delivery system of rotenone. This also was to occur in 2011 but was delayed due to unavailability of the number of fish needed for the studies.
- Establish collaborations with South Dakota State University to collect digestive tract samples (enzymes and bacterial flora) of bighead and silver carp from the James River, South Dakota. This will help identify any geographic differences in the digestive tract enzymes or bacterial flora of bighead and silver carp populations.
- Complete work to evaluate the toxicity of a selective targeted delivery system of rotenone in order to determine field exposure rates for controlling bighead and silver carp.
- Initiate work to evaluate inclusion of palatability enhancers (e.g., algal constituents, amino acids, etc.) to increase consumption of rotenone by bighead and silver carp via a selective targeted delivery system.
- Develop application techniques for delivering a selective targeted delivery system of rotenone to bighead and silver carp. This work will include optimization of toxicant loading rates, treatment concentration rates, and treatment duration to achieve maximum control of Asian carp.
- Initiate non-target testing of a selective targeted delivery system of rotenone to native fish and mussel species.
- Initiate a contract to develop microspheres for encapsulation and release of piscicidal compounds. USGS will work with bio-medical microsphere development companies to develop and evaluate various formulations of microspheres for use as a potential selective targeted delivery system of chemicals for controlling AIS.
- Complete comparisons of seasonal and regional gill raker ultrastructures of Asian carp and native planktivorous fish.

- Complete work with University of Illinois Urbana-Champaign on bacterial sequencing to describe the bacterial fauna of the digestive tracts of bighead and silver carp.
- Supported by funding through the USGS SSP, determine toxicants for inclusion in potential selective targeted delivery systems, and determine optimal toxicant loading rates, treatment concentration rates, and treatment duration to achieve maximum control of dreissenid mussels.
- Identify potential field trial locations to evaluate a selective targeted delivery system of rotenone.
- Submit Experimental Use Permit application to EPA to allow field trials of a selective targeted delivery system of rotenone.
- Initiate field trials of a targeted delivery system of rotenone.

Expected Milestones:

- March 2012: Apply for Experimental Use Permit to conduct field application of Rotenone-incorporated targeted delivery system formulation at limited application sites.
- February 2012: Evaluate efficacy of bighead and silver carp to selectively retain and digest a selective targeted delivery system of rotenone.
- 2012: Use transcriptome sequence information to identify the modes of detoxification of piscicides (e.g., Rotenone) in bighead and silver carp and native planktivores.
- March 2012: Initiate a contract with a bio-medical microsphere development company to develop and evaluate various formulations of microspheres for use as a selective targeted delivery system of chemicals to control AIS.
- September 2012: Complete seasonal and regional comparisons of gill raker ultrastructures of Asian carp and native planktivorous fish.
- August 2012: Synthesize the differences in digestive physiology (enzymatic and symbiotic flora) of bighead and silver carp with that of gizzard shad and bigmouth buffalo.
- August 2012: Complete initial evaluations of potential palatability enhancers to aid in retention of rotenone via a selective targeted delivery system.
- August 2012: Conduct on-site field evaluations in a mobile bio-assay trailer of a selective targeted delivery system of rotenone to native fish and mussel species.
- September 2012: Conduct an experimental field application of a selective targeted delivery system of rotenone.
- 2013: Evaluate a selective targeted delivery system of management chemicals for controlling dreissenid mussels.
- Determine the optimal application techniques for delivering a selective targeted delivery system of rotenone to control Asian carp.

Outcomes/Output:

- Development of a selective targeted delivery system of rotenone for selective control of bighead and silver carp.

- Development of a selective targeted delivery system of a mollusicide for selective control of dreissenid mussels.

Potential Hurdles:

- Possible delays in development and delivery of test formulations of targeted delivery systems.
- Possible inability to secure test locations and test animals.
- Possible difficulties incorporating palatability of rotenone into a selective targeted delivery system.
- Differential ingestion and possible unavailability of a selective targeted delivery system of rotenone.

2.5.15 Develop Alternate Traps/Technologies to Enhance Asian Carp Capture Rates

Lead Agency: IL DNR

FY 2012 Funding: $600,000 GLRI funds.

Project Explanation: Current research is evaluating other lethal and sub lethal and barrier technologies that can stop and/or repel fish within the CAWS. An environmental scale application is warranted to evaluate legitimate alternatives to these chemicals for rapid and/or emergency responses and use in barrier maintenance operations.

A scale application of a water gun for barrier defense was successful in 2011. Further development of this can suggest how to deploy it most successfully and develop this as a useful barrier. Although USGS will be developing the tool and impacts on fish (air bladders), IL DNR has asked the University of Illinois and INHS to develop a sonic telemetry array that can track fish in real time 3-D and track fish response to water gun carbon dioxide treatment, or to develop other promising physical/chemical tools: for example, in some areas, lock chambers may assist in eliminating upstream threats of Asian carp and other ANS. In application of these tools, a model of flow may be useful to accurately predict amounts of chemicals needed. Promising results from 2011 suggest remote sensing technologies may also be added to monitor fish without tags in a real-time assessment.

Additionally, a working group of net makers, fisheries biologists, Great Lakes and riverine commercial fishers, and hydroacoustic and pheromone experts has developed several tools/items of gear to use in the CAWS and Illinois Waterway. Deep panel gill nets, large hoop nets (6 feet) are ordered, and are to be implemented immediately (late 2011-early 2012) throughout the CAWS where Asian carp do not exist in number, and also throughout the Illinois River for evaluation purposes. Large, semi-permanent pound nets, purse seines, trawls, and bagged seines have also been recognized. Action to deploy these nets and evaluate success is a priority early in 2012. These items of gear are much larger than some being used, and can be used for extended periods of time, increasing ability to detect fish.

These systems would be built, combined, and refined for optimum performance in the Dresden Island and Brandon Road pools downstream of USACE's electric barriers, where low densities of carp are known to occur. The best designs and methods would then be deployed upstream of the electric barriers in the CAWS and/or Great Lakes rivers where eDNA technology indicates possible presence of Asian carp.

FY 2010 Actions Undertaken: INHS evaluated several barrier techniques with responses in laboratory and field (pond) settings. Water gun trials occurred in fall 2010 as well. Both show promise for killing and/or repelling fish. Evaluation of deployment of these tools at a scale environmentally relevant occurred through 2011.

- Literature review of chemical tolerances for largemouth bass, bluegill, silver carp and bighead carp was completed.
- Laboratory studies quantified behavioral responses of largemouth bass, bluegill, silver carp, and bighead carp to concentrations of DO and carbon. Work with bighead carp is ongoing.
- Laboratory studies quantified physiological responses of largemouth bass, bluegill, silver carp, and bighead carp to low DO and elevated carbon dioxide concentrations at two times. Work with bighead carp is ongoing.
- Behavioral studies that will quantify the ability of elevated concentrations of carbon dioxide to induce avoidance behaviors in silver carp, largemouth bass, and bluegill began, and are ongoing

FY 2011 Actions Undertaken:

- Completed lab and field trials suggested that oxygen stripping does not seem a viable alternative; however carbon dioxide does affect fish in a natural ecosystem. Further assessment at an ecological level will be necessary to verify efficacy and indicate how this could be deployed.
- An application in the CAWS was modeled.
- Experts convened to formulate alternate capture methods, and developed net designs.
- Purchase and deployment of large, 6-foot hoop nets and deep water gill nets were recommended for early 2012.

- Other gear was identified for 2012 development. Work began to detail implementation of a Great Lakes-style trap net to fish extended periods of time in the CAWS in order to maximize fishing effort and increase detection of fish.
- Chemical barrier findings to date are as follows:
  - Low DO does not show strong promise as a chemical barrier to deter movement of Asian carp. Silver carp are hypoxia tolerant, and even low levels of oxygen induce only minor discomfort and disturbance. Feasibility of implementing such a system in a waterway would be low, and minor deviations from anoxia would reduce the efficacy of an oxygen barrier.
  - Elevated concentrations of carbon dioxide (approximately 30-70 milligrams per liter [mg/L], pH approximating 6.5) have potential as a chemical barrier to deter movement of carp. Exposure to elevated concentrations of carbon dioxide elicits significant physiological responses in silver carp, and both species show strong behavioral modifications (coughing, twitching, gasping etc.) when placed in a high carbon dioxide environment. Carbon dioxide dissolves easily in water, so achieving this concentration (at least in a controlled laboratory setting) is logistically straightforward.
  - Silver carp show a behavioral avoidance response to carbon dioxide concentrations around 70 mg/L, and swim away from water with carbon dioxide at this concentration.
- Preliminary field studies have shown that manipulating pH in ponds to levels that would deter carp is relatively straightforward.

FY 2012 Actions Proposed:

- Finalize plans.
- Implement barrier plans at an environmentally relevant scale.
- Implement and fine-tune 2011 net design work.

These methods could include any of the following, as results from 2011 dictate:

- Chemical/thermal barriers including carbon dioxide/oxygen/chlorine/pH/other, lab studies, ecosystem-sized deployment, lock chamber treatments, heated lock chamber from local industry could lower cost, zone treatment in CAWS.
- Hydrogun: Water gun and other elimination/deterrent technology.
- Attractant and/or repellant pheromones.
- Physical (block) net at key location(s) including rapid responses and key locations for short-term deployment.
- Super-shocker.
- MWRD DO model efforts.

- Sound/bubble/light barriers.

Expected Milestones:

- September 30, 2012: Demonstrate a working gear, trap net, pheromone trap, or other to herd, haul, and direct fish—overseen by working group of experts; compare these to existing technologies.
- September 30, 2012: Demonstrate an operating deterrent system to repel or kill Asian carp and other ANS in the CAWS, protecting both the Great Lakes and Mississippi River Basins.

Outcomes/Output:

- Additional tools for stopping and eliminating Asian carp from the waterway.
- Additional barriers may be more successful in controlling different life stages of carp than barrier currently exhibits.
- Additional tools to be utilized wherever Asian carp exist to increase likelihood of capture.

Potential Hurdles:

- Costs of applying new technologies may exceed costs of existing methods.
- New technologies may not improve upon sampling efficiencies when deployed.

2.5.16 Development of a Rapid and Quantitative Genetic-Based Asian Carp Detection Method

Lead Agency: USGS

Agency Collaboration: University of Illinois at Urbana-Champaign for genetic analysis, and INHS, Purdue University, and South Dakota State University for assistance in sample collections.

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Early detection is a vital part of managing any invasive species, including Asian carp. Methods for early detection have relied on the capture of fishes or the presence of DNA (eDNA) from sloughed cells from Asian carp. We propose to determine the relative abundance of Asian carp through quantification of microbial populations unique to the Asian carp gut microbiota in a manner similar to microbial source tracking. This technique has the potential to detect Asian carp more effectively than traditional nets, and is therefore an avenue that must be investigated. Microbial source tracking is based on the concept that microbes from a polluted site can be traced to an animal, thus indicating the origin of fecal contamination. This approach has been successfully applied to identify the sources (e.g., human, cow, swine, water fowl) of fecal contamination in rivers, lakes, and drinking water distribution systems. Similarly, if key microbial populations can be identified in the fecal matter of Asian carp, these could be used for development of a genetic-based method to detect the presence of Asian carp in water bodies. The goal of this project is to develop and validate a genetic-based method that can complement the current surveillance methods for Asian carp, an invasive fish species within many water bodies in the U.S.

FY 2010 Actions Undertaken: Fecal samples were collected from Asian carp, gizzard shad, and bigmouth buffalo in September 2010, and stored at -80 degrees Celsius (°C) pending analysis.

FY 2011 Actions Undertaken:

- Established a collaborative agreement with University of Illinois Urbana-Champaign.
- Established sampling schedules with Purdue University and South Dakota State University for collection of samples from the Wabash River, IN, and James River, SD, respectively. This will help indicate differences among populations.
- Research protocol was completed and is under review by Upper Midwest Environmental Sciences Center Animal Care and Use Committee.
- Initiated and continue regular sampling on the Illinois River, IL; Wabash River, IN; and James River, South Dakota. Results will help identify temporal and spatial differences among enteric bacteria.
- Identified bacteria colonizing the fore, mid, and hind-gut of gizzard shad, bigmouth buffalo, and Asian carp using Next-Generation sequencing technologies.
- Began processing fecal samples for bacterial identification.

FY 2012 Actions Proposed:

- Complete genetic analysis of enteric bacteria from remaining samples.
- Develop quantitative polymerase chain reaction (qPCR) assay (a genetic model) for unique microbes.
- Validate qPCR assay(s) using existing fecal sample collections (blind samples).
- Develop Asian carp-specific qPCR test.
- Test Asian carp-specific qPCR test with blind samples.
- Complete final report.

Expected Milestones:

- September 2012: Identify how the unique microbial population changes throughout the year.
- September 2012: Develop qPCR method to detect Asian carp-specific microbial populations.
- September 2012: Complete final report.

Outcomes/Output:

- A molecular technique that provides an alternative to current methods (which rely on detection of sloughed Asian carp cells), and which may provide greater sensitivity and/or information complementing that obtained using current techniques.

Potential Hurdles:

- Weather may delay or preclude field collections, particularly during the winter.
- Bacterial sequencing will be performed by the University of Illinois Genomics Core. Because this is a high-demand laboratory, and sample analysis of partial runs is neither cost- nor time-effective (partial runs require more processing time per sample than full runs), digestive tract samples will be pooled until a full sample set is obtained. The demand by other projects on the Genomics Core remains unknown; thus the impact of this demand is indeterminate.

2.5.17 Chicago Area Waterway System Monitoring Network Evaluation

Lead Agency: USGS

Agency Collaboration: MWRD Greater Chicago, University of Illinois – Department of Civil and Environmental Engineering, USACE

FY 2012 Funding: $ 190,000 GLRI funds.

Project Explanation: Currently, flow monitoring stations on the CAWS are insufficient for evaluation of data from ongoing sampling programs targeting Asian carp detection in the CAWS, or for evaluation of proposed waterway separation scenarios. Hydraulic and water quality models of the CAWS are an important tool for data-based decision-making. Development and calibration of these models require flow data from throughout the CAWS. Phase I of this project will compile historical flow and water-quality data from the CAWS into a single database that will streamline model development and calibration. Phase II of this project will evaluate the historical database and the current network of gaging stations on the CAWS to identify the critical inputs and gaps in information. Phase III of the project will fill the data gaps through synoptic field measurements and possible new monitoring locations.

FY 2010 Actions Undertaken: Feasibility and value of the model for waterway simulation were demonstrated via use of detailed synoptic flow data from acoustic Doppler current profiler (ADCP) discharge measurements and rhodamine dye distribution data obtained during rotenone applications on the CAWS; this was a preliminary calibration of a 3-D hydraulic model for a small portion (River Mile 296-291) of the waterway.

FY 2011 Actions Undertaken: USGS hosted a CAWS stakeholder's meeting at the IL DNR office in Chicago to address the critical shortfalls in waterway monitoring. Mining of historical CAWS data and compilation of a database began.

A synoptic survey of water temperature for the entire CAWS occurred in September 2011 to provide a snapshot of continuous water temperature and thermal loads to the waterway. Updates (entries of new information) continue to the CAWS database on-line observatory (USGS-Chicago Waterway Observatory: http://il.water.usgs.gov/data/cwo/).

2012 Actions Undertaken: A draft of the network evaluation report was in progress as of November 2, 2011. A new streamflow gaging station with a side-looking acoustic Doppler current profiler (ADCP) was installed on October 12, 2011, on the Calumet-Sag Channel near Rt. 83 near Lemont, IL in order to determine the contribution of flows in the Cal-Sag Channel. Flow data from this gage will be important for calibrating hydraulic models of the CAWS.

2012 Actions Proposed: Continue mining historical CAWS flow and water-quality data, and compiling a single database to streamline model development and calibration. Complete a network evaluation of historical and current CAWS monitoring stations to identify gaps in the critical information. Conduct field reconnaissance, and undertake synoptic measurements and other appropriate data acquisition to address data gaps at strategic waterway locations. Compile a list of recommendations for the CAWS monitoring network.

Expected Milestones:

- Oct. 1-Mar. 31, 2012: Continue mining historical CAWS monitoring data and enter these data onto the existing CAWS database on-line observatory (USGS-Chicago Waterway Observatory).
- Jan. 1 - May 31, 2012: Undertake CAWS monitoring network evaluation and analysis.
- June 1-Sept. 30, 2012: Address data gaps with field reconnaissance and synoptic data acquisition at strategic locations on the CAWS.
- Sept. 30 2012: Complete recommendations for CAWS monitoring network.

Outcomes/Output:

- Ongoing compilation of flow data from the CAWS into USGS database and the USGS-Chicago Waterway Observatory for model development and analysis of waterway separation scenarios.
- USGS Report on monitoring network evaluation methods and identification of critical gaps in monitoring.
- Synoptic data at strategic CAWS locations.

Potential Hurdles:

- Timely access to historical data may prove difficult.

2.5.18 Asian Carp Control Methods Coordination

Lead Agency: USGS

Other Agencies Involved: All ACRCC Agencies and Framework Project Leaders

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: USGS has been asked by the ACRCC to assume a leadership role in science activities conducted within the Asian Carp Control Strategy Framework. A USGS Science Coordinator is leading this effort—working with federal, state, and other organizations to maximize development of Asian carp management tools and enhance integration among science projects to meet the goals and objectives of the ACRCC.

FY 2011 Actions Undertaken: USGS organized and hosted the Asian Carp Science Meeting in February 2011 to bring together scientists and managers working on Framework projects, increase project awareness, and identify opportunities for integration and collaboration. Building on this effort, USGS took on a science coordination role leading the ACRCC Framework Integrated Control Focus Area, and is working in collaboration other Focus Area Coordinators (Risk Assessment, eDNA, and Monitoring) to ensure application of efficient, effective, and strategic science to meet Framework goals.

FY2012 Actions Proposed: USGS will continue to engage scientists and researchers, and affiliate work by their Agencies and respective staffs on FY2012 Framework projects. USGS will be leading/conducting a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis with other Focus Area Coordinators that will provide information on Framework science successes, gaps, and management research needs to help strategically guide direction of future science efforts. USGS is helping to coordinate another face to face science meeting in collaboration with the Council on Environmental Quality (CEQ) and other Focus Area Coordinators that is planned for December in conjunction with the 2011 Midwest Fish and Wildlife Conference.

Expected Milestones:

- November 2011: Completion of SWOT analysis of Framework projects in collaboration with other ACRCC Focus Area Coordinators; evaluation of results and identification of gaps in knowledge or overlap to ensure research is maximized to meet management needs and attain Framework goals.
- December 5-7, 2011: Symposium of CEQ and Framework focus area leads at the Midwest Fish and Wildlife Conference in Des Moines, Iowa. The plan is to have a 1-day symposium as part of the conference followed by 1 day of closed-door sessions. During the second day of meetings, the plan is to meet by focus areas in the morning and have MRRWG and USGS scientists meet in the afternoon.
- Completion of review of all Framework study designs and plans regarding actions undertaken within the projects, and how these affiliate with other projects; report on

results; meetings/discussions with agencies and organizations to develop strategic direction.

- Using the results of the actions above, continued development of a Map of an Integrated Pest Management Framework with all agencies/organizations involved. This science-based framework would help prioritize and guide Asian carp control efforts, and would build on and mesh with existing Asian carp control management plans as appropriate.

Potential Hurdles: None

2.5.19 Seismic Monitoring for Asian Carp Water Gun Deployment

Lead Agency: USGS

Agency Collaboration: IL DNR, USACE

FY 2012 Funding: $213,700 GLRI funds.

Project Explanation: Effects on structures such as the controlling works, electric barrier, etc., and on canal walls, are unknown from deployment of one or more water guns (or hydrogun, seismic cannon, sonic cannon, or carp cannon) to modify behavior of Asian carp within the CSSC and the rest of the CAWS. This plan is to outline data acquisition needed to complete an assessment of the distribution of seismic energy resulting from use of water gun(s) within the CSSC and other parts of the CAWS near O'Brien Lock and Dam, so that engineers can determine potential impacts on the structures and canal walls. Use of the water gun(s) has been proposed for the time period during which maintenance of the electric barrier occurs, in order to help remove fish from the area between Electric Barriers IIA and IIB.

FY 2010 Actions Undertaken: In September 2010, the water gun was deployed in old sand and gravel pits connected to the Illinois River, and was monitored with surface geophysical instrumentation for seismic signals generated on land. The monitoring showed ground responses to the water gun at magnitudes approximating signal strength to a car driving on the dirt road nearby or people walking near the geophones. However, the conditions at this location with unconsolidated sands and gravels differ considerably from the predominantly bedrock conditions present in the CSSC, and more of the seismic energy from the water gun would be expected to transfer to the bedrock, as well as reflect back into the CSSC. Also, concerns regarding sheet piles and other structures were not assessed.

FY 2011 Actions Undertaken: USGS coordinated with USACE and IL DNR to develop an agreed-upon Scope of Work. Work focused on acquisition of background data, and continues into 2012.

FY 2012 Actions Proposed: Acquisition of seismic data will be completed in two phases. The first phase will be to assess the "background" seismic signatures of boat and barge traffic along the CSSC and other locations within the CAWS during "normal" operation. The second phase will be acquisition of seismic data during controlled deployment of the water gun(s) within the CSSC upstream of the electric barrier, and also at a lock and dam to determine potential effects on structures.

Expected Milestones:

- Acquisition of seismic data with water gun deployment within the CSSC and the O'Brien Lock and Dam (2 months from beginning of acquisition of background data).
- Late Spring 2012: Processing and review of background data (2 months following acquisition of background data).
- Early Summer 2012: Processing and review of seismic data with water gun deployment at the three locations (3 months after acquisition of all data).
- Acquisition of seismic data with water gun deployment at lock and dam structure (2 months from beginning of acquisition of background data, depending on weather).
- Processing and review of background and seismic data with water gun deployment (3 months after acquisition of all data).

Outcomes/Output:

- Report summarizing data acquisition methods, background data, and data obtained with water guns—10 months after acquisition of all field data.

Potential Hurdles:

- Issues regarding property and canal access could arise (possibility of impaired coordination between various property owners and the USCG).

2.5.20 Deterrence/Destruction of Asian Carp Using Resonant Frequency (Continuous Wave Sonar)

Lead Agency: USGS

Agency Collaboration: U.S. Navy, University of Maryland

FY 2012 Funding: This project has been deferred until additional funding becomes available.

Project Explanation It has been shown that underwater ensonification at the resonant frequency of the lung can damage and even kill. This is due to the resonance creating damage within the air-filled cavity. The fish most vulnerable to underwater sound have swim bladders. Carp fit into this category and thus would be expected to be sensitive to underwater sound at the resonant frequency of the swim bladder. This three-part effort would provide a tool for effective control of carp movement, especially within restricted waterways where the carp could not avoid the sound. This approach also has the advantage that it would specifically target carp because other fish would either not be susceptible to this approach or would respond to a different resonant frequency.

FY 2012 Actions Proposed: In order to test this hypothesis, it is necessary to (1) determine the resonant frequency of the Asian carp swim bladder, (2) determine the underwater sound intensity required to induce an attempt by the fish to avoid the sound, and (3) increase the sound level to determine the lethal level, expressed as survival time as a function of level. Frequencies for different life history stages will also be recorded, as it will be necessary to stop adult, sub-adult, and juvenile fish. Additional resonant frequencies will be recorded for other non-target fish, and possibly for turtles and aquatic invertebrates.

Expected Milestones: To be established when funded.

Outcomes/Output:

- These studies will help establish resonate frequencies capable of deterring Asian carp from progressing upstream in the CSSC.
- Data from these experiments will determine the efficacy of specific frequencies to divert carp. Continuous wave sonar will provide an additional acoustic deterrent, and can be used in concert with electrical barriers, water guns, and gas barriers to achieve an integrated carp deterrent system.

Potential Hurdles:

- Possible difficulty finding locations suitable to conduct tests to determine resonant frequencies.
- Depending on resonant frequencies, possible unavailability of data projectors and need to fabricate them.

2.5.21 Other Science Contributing to Asian Carp Efforts

Lead Agency: USGS

FY 2012 Funding: $656,883 Total funding ($100,000 GLRI funds/ $556,883 Base funding).

Project Explanation USGS has been conducting research on Asian carps since they first became abundant in Missouri, Illinois, and Mississippi rivers. Initially, this research focused on distribution, habitat use, life history, conditions conducive to spawning, and age determination. As more was learned, additional research into the ecological impacts of bighead and silver carps on river ecology began, and continues today. Information gleaned from these studies has directly or indirectly benefited many Framework projects, from monitoring and surveillance to risk assessment and control. This is research that supports Framework efforts and is important for achieving Framework goals.

FY 2012 Actions Proposed: Funding will support ongoing research on control technologies and ecological studies of riverine populations (including analysis of bighead carp diet to ascertain level of consumption of larval fishes).

Expected Milestones:

- Throughout 2012: Research results and products relevant to the Framework will be shared in a timely manner.

Outcomes/Output:

- Research will support Framework efforts and contribute to achieving the Framework goals.

Potential Hurdles: None.

2.6 eDNA Analysis and Refinement

2.6.1 eDNA Monitoring of the CAWS

Lead Agency: USACE

Agency Collaboration: IL DNR, USFWS, USEPA

FY 2012 Funding: $650,000 GLRI funds.

Project Explanation: This task encompasses long-term activities that revolve around genetic surveillance monitoring in the CAWS upstream of the Lockport Lock and Dam and Des Plaines River, consistent with the *Strategy for eDNA Monitoring in the CAWS and Upper Des Plaines River* of the *April 2011 MRRP*. USFWS, IL DNR, and USACE all have activities under eDNA monitoring, linked to response actions such as rapid response and enhanced monitoring. Samples are collected from the designated sites by USFWS or IL DNR, filtered by USACE, and then shipped to USACE-Engineer Research and Development Center (ERDC) for processing.

FY 2010 Actions Undertaken: The ACRCC CAWS Workgroup implemented the MRRP for the entire CAWS and Upper Illinois River system. This was a collaborative effort among IL DNR, USFWS, and USACE. Sampling focused on areas such as the North Shore Channel, Chicago Lock to Bubbly Creek, TJ O'Brien Lock, Des Plaines River, and above and below the Electric Barrier System. Results were processed within about 2 weeks and posted to the Chicago District website: http://www.lrc.usace.army.mil/AsianCarp/eDNA.htm.

FY 2011 Actions Undertaken: The ACRCC CAWS Workgroup implemented the MRRP for the entire CAWS and Upper Illinois River system, focusing on the following sites for sampling starting in May 2011:

- North Shore Channel from the Wilmette Control Works to the North Branch Chicago River.
- Chicago Lock to Bubbly Creek, including the Chicago River and South Branch Chicago River.
- Little Calumet River downstream of O'Brien Lock and Lake Calumet.

Additional sites will be used for sampling associated with rapid response actions or to monitor the Upper Des Plaines River, CSSC and Calumet-Sag Channel confluence, the CSSC upstream and downstream of the Electric Barrier System, or other locations determined strategically important (e.g., re-sampling a site with previous positive detections of Asian carp DNA).

An eDNA snapshot sampling event was also conducted in October 2011 to test the hypothesis that one or two Asian carp may be contributing to eDNA-positive samples in the CAWS. The eDNA snapshot, funded separately by GLRI, sampled at six sites (720 samples) over a 3-day period. The snapshot results became available in January, and are therefore exempt from the rapid response decision matrix as outlined in the MRRP.

FY 2012 Actions Proposed:

The USACE proposal for eDNA sampling within the CAWS has been shaped by the MRRWG's recommendation for an eDNA strategy in January 2012. Although the 2012 eDNA sampling strategy will likely aim to achieve the same objectives as the 2011 strategy, opportunity is available to refine and shape the sampling strategy using 2011 data, eDNA snapshot results, and results from the eDNA calibration study in a manner that may lead to more efficient ways of collecting and filtering samples. In 2012, USACE will still plan to coordinate the sampling collection with IL DNR and USFWS assistance, filter the samples at a local USEPA laboratory, and process the samples at the USACE-ERDC. USACE and USFWS will continue to work together to transition leadership of eDNA oversight of sampling, filtering, and processing from USACE to USFWS, as aligned with progress of the eDNA calibration study in 2013.

Expected Milestones:

- Spring 2012: Beginning of 2012 eDNA sampling (TBD by MRRWG).
- Fall 2012: eDNA sampling complete (TBD by MRRWG).
- Weekly posting of results on USACE website
- January 2013: transition of eDNA to USFWS.

Outcomes/Output:

- Continued trend data for positive and negative eDNA results in the CAWS.
- Refined standardized processes.
- USFWS leading oversight of eDNA sampling, filtering, and processing (after transition).

Potential Hurdles:

- Weather delays and rainfall could impact sample collection, filtering, and processing.
- Possible shortfall of resources required or desired to conduct sampling.

2.6.2 USFWS Fisheries Program Capacity for eDNA Sampling for Early Detection

Lead Agency: USFWS

FY 2012 Funding: $300,000 Base funding.

Project Explanation: USFWS Great Lakes Fish and Wildlife Conservation Offices have the expertise and capability to collect samples to be analyzed for eDNA at the La Crosse Fish Health Center. However, no comprehensive, effective, and efficient program is currently conducted in the Great Lakes to detect incipient invasions. Fulfilling this task will provide USFWS Fish and

Wildlife Conservation Office facilities with resources and expertise to conduct integrated, long-term early detection activities.

FY 2011 Actions Undertaken: Within the 2011 Framework, the University of Notre Dame will receive support under a 3-year grant through USFWS to develop and refine eDNA technology for use in a Great Lakes-wide early detection program. At the same time, USFWS will begin the transition of this technology to its La Crosse Fish Health Center. As identified in the FY 2011 Framework, the USFWS Fish and Wildlife Conservation Offices will test and refine capabilities to begin monitoring for eDNA outside the CAWS once the technology transition to USFWS is complete. USFWS will also begin work on development of an eDNA sampling protocol to be incorporated into long-term monitoring strategy in collaboration with participating agencies.

FY 2012 Actions Proposed: Monitor for eDNA outside the CAWS utilizing a statistically tenable sampling protocol.

Expected Milestones:

- December 2012: Fully developed capacity for implementing an eDNA sampling program at USFWS Great Lakes Fish and Wildlife Conservation Offices.
- January 2013: Support for establishment of a biologically based, statistically tenable eDNA sampling protocol for use basin-wide.
- May 2013: Implementation of an eDNA draft sampling protocol for other areas of concern, with particular focus on southern Lake Michigan, western Lake Erie, and other potential hotspots.

Outcomes/Output:

- USFWS conservation offices conducting eDNA sampling in areas of concern, with emphasis on southern Lake Michigan, western Lake Erie, and other potential invasion hotspots.

Potential Hurdles:

- Possible issues with eDNA calibration outcomes/output.
- Limitations due to weather and difficulties accessing sites.
- Delay/difficulty in developing quality assurance (QA)/quality control (QC) process regarding sample contamination.

2.6.3 eDNA Calibration and Increased Efficiency

Lead Agency: USACE, USGS, USFWS

Agency Collaboration: USEPA

FY 2012 Funding: $2,150,000 GLRI funds (USACE $1,925,000; USGS $225,000).

Project Explanation: eDNA is a genetic surveillance tool that indicates presence of bighead and silver carp DNA in the environment. It was used as a monitoring tool for the ACRCC's MRRWG April 2011 MRRP. USACE, in partnership with USFWS, USGS, and USEPA, is developing a proposal to conduct an eDNA calibration study that will help provide context to a positive eDNA result. Variables investigated will include detection limits and decay rates; improvement in current field sampling techniques may result from investigation of optimal sampling methods. Additionally, by determining the number of genotypes expressed in the collected eDNA samples, we can determine the minimum population of bighead or silver carp needed to yield a positive eDNA sample from the field. eDNA calibration is critical to enhance eDNA sampling for monitoring, and to render current sampling designs and protocols more effective. Interim products will become available to improve management decisions and interpretations of eDNA results.

FY 2010 Actions Undertaken: This research was to begin in FY 2011.

FY 2011 Actions Undertaken: A series of experiments, executed by the interagency team, are aimed at determining the relationship between (1) the number and distribution of positive Asian carp eDNA detections and (2) the density of Asian carp. The following are objectives of the work initiated in September 2011:

- Obtain and house silver and bighead carp species of specific sizes, sexes, and sexual maturity for use in the eDNA calibration studies.
- Develop a higher-throughput DNA extraction capability, convert the current PCR band-based assay to a TaqMan real-time qPCR assay, and assess whether different water sampling protocols might improve Asian carp detection probabilities.
- Develop a better understanding of DNA assay sensitivity under no flow conditions. (Improved assay sensitivity to observe PCR products at lower concentrations will yield eDNA detections at lower concentrations)
- Develop a better understanding of DNA assay sensitivity and eDNA degradation under flowing water conditions.
- Develop quantified relationships between different major environmental factors and eDNA degradation under no flow conditions.
- Develop guidance on using calibration data to broadly estimate Asian carp abundance under no flow conditions.

- Develop a hydrodynamic eDNA transport and an optional fish movement predictive model to characterize fish occurrence.
- Develop a model to estimate the probability that eDNA sampled in the CAWS entered that water body via one or more possible routes or vectors (optional).
- Project Management: conduct interim reporting to ACRCC.

FY 2012 Actions Proposed: The objectives listed above are expected to carry into FY 2012, with completion in FY2013. This project will be complete by September 2013. Interim results will be reported as these become available, and should be used to refine current monitoring protocols.

Expected Milestones:

- May 2012: High-throughput technique complete.
- July 2012: Report describing an optimized water sampling protocol.
- September 2012: eDNA shedding studies complete.
- September 2012: Report detailing a robust protocol for rapid extraction and analysis of eDNA samples.
- October 2012: Part I of report describing a series of descriptive, and in some cases quantitative, relationships between Asian carp biomass, number, and behavior, and eDNA detection using PCR. Also determination of rate and extent of dispersion of Asian carp eDNA in non-flowing or sluggish water.
- February 2013: Report describing the relationship between environmental factors— water temperature, light exposure, zooplankton and microbial biomass, and pH—and eDNA degradation rates, with a focus on no flow (i.e., lentic) water systems.
- June 2013: Part II of report describing a series of descriptive, and in some cases quantitative, relationships between Asian carp biomass, number, and behavior, and eDNA detection using PCR. Also determination of rate and extent of dispersion of Asian carp eDNA in flowing water compared to those in non-flowing water.

Outcomes/Output:

- Implementation of rapid extraction and analysis of eDNA samples and optimized water sampling to allow for eDNA sensitivity and degradation analysis in the calibration study; savings in cost and time of processing as eDNA leadership transitions to USFWS.
- Guidance on estimating potential population sizes of various Asian carp genotypes based on eDNA sampling results in non-flowing or sluggish water.
- Standards for interpreting eDNA results based on the sensitivity represented by (1) relationships between Asian carp biomass, number, and behavior, and eDNA detections; and (2) rate and extent of dispersion of Asian carp eDNA under conditions of non-flowing or sluggish water and flowing water.

- Standards for interpreting eDNA results based on environmental factors that cause varying degrees of eDNA degradation.
- Hydrodynamic eDNA transport model to extrapolate eDNA behavior in the system, and to identify likely carp population scenarios associated with an array of eDNA monitoring outcomes/output.
- Fish movement predictive model to model fish response to water velocity and electricity, providing a means for estimating fish movement at the barrier and barrier effectiveness/percent passing (optional).
- Model to estimate the probability that eDNA sampled in the CAWS entered that water body via one or more possible routes or vectors (optional).
- Progress of each task tracked by earned value management and reported at quarterly intervals. Earned value will demonstrate the value of work performed expressed in terms of the budget assigned to that work.

Potential Hurdles: None.

2.6.4 USFWS Fisheries Program Capacity for eDNA Sample Processing

Lead Agency: USFWS

Agency Collaboration: USACE

FY 2012 Funding: $1,160,000 Total funding ($460,000 GLRI funds/$700,000 Base funding)

Project Explanation: This program will provide additional funding necessary to complete building the capacity to process samples, transition the work of processing eDNA samples from USACE to USFWS, and begin eDNA sample analysis at La Crosse Fish Health Center.

FY 2010 Actions Undertaken: This template was not in place in 2010. La Crosse Fish Health Center staff toured the University of Notre Dame lab facilities and received eDNA sample processing procedures and protocols.

FY 2011 Actions Undertaken: USFWS staff engaged with USACE staff at the ERDC lab in Vicksburg, Mississippi. Sample processing protocols and equipment lists were shared with Service staff, and input was provided to a draft eDNA calibration Project Management Proposal (PMP). Follow-up discussions outlining a draft transition timeline were held, and included in the final eDNA Calibration PMP. USFWS, GSA, and the current La Crosse Fish Health Center building landlord are negotiating a new lease agreement to construct an eDNA laboratory addition, and are expecting establishment of terms by fall 2011. A preliminary design is complete, with a final design expected as lease terms are finalized. Construction began late fall 2011, and procurement of equipment began in July 2011. Personnel actions associated with this project have begun, with initial recruitment actions were expected in early fall 2011.

FY 2012 Actions Proposed: When eDNA calibration plans and budgets are established, a final eDNA sample processing transition timeline will be implemented by the USFWS and USACE. Four newly hired La Crosse eDNA staff will engage USACE staff as needed to facilitate this transition. Construction of an eDNA lab at the La Crosse, Wisconsin site will begin or continue. Equipment will be installed and tested. The Service will work toward assuming a lead role for eDNA sample processing. Additional supplies and two additional personnel will be added to allow for processing up to 120 samples per week.

Expected Milestones:

- Spring and Summer 2012: Additional eDNA equipment procurement, installation, and testing: Ongoing.
- Ongoing in 2012: Construction of eDNA Lab.

Outcomes/Output:

- January 2013: USFWS assumes lead in eDNA sample analysis, and processes 120 samples per week at La Crosse Fish Health Center.

Potential Hurdles:

- Possible uncertainty in eDNA calibration outcomes.
- Weather possibly affecting construction timelines.

2.6.5 eDNA Genetic Marker Development

Lead Agency: USACE, USGS, USFWS

Agency Collaboration: USGS, USFWS

FY 2012 Funding: $220,000 GLRI funds (USACE $70,000; USGS $50,000; USFWS $100,000).

Project Explanation: The goal is to develop high-fidelity, sensitive genetic markers for detecting the presence of Asian carp DNA in filtered water samples based on RT PCR or qPCR. Specifically, the goal is to develop optimized fluorescent oligonucleotide probes for use in qPCR assays for eDNA of silver carp and bighead carp. Development of new qPCR-based eDNA markers for Asian carp will allow more direct control over eDNA processing schedules, should provide for greater efficiency of eDNA processing, and may provide for a greater degree of sensitivity to eDNA at low concentrations. This work will serve as a basis for advancing future studies of eDNA calibration.

FY 2010 Actions Undertaken: Not applicable.

FY 2011 Actions Undertaken: A series of experiments, executed by the interagency team, focused on developing genetic markers based on quantitative PCR. The following are objectives of work initiated in September 2011:

- Develop genetic markers that provide an increased ability to estimate the minimum number of Asian carp represented in an eDNA sample pursuant to use of high-throughput mechanisms for detecting individual variants in pooled samples.
- Independently validate accuracy and robustness of new protocols and markers.

FY 2012 Actions Proposed: The objectives listed above are expected to carry into FY 2012, with completion by April 2012.

Expected Milestones:

- June 2012: Acquisition of field samples complete.
- March 2013: External laboratory confirmation testing using new markers complete.
- March 2013: Part I of a report describing a set of highly polymorphic mitochondrial DNA (mtDNA) markers that provide some degree of inference as to minimum numbers of individual Asian carp within a pooled eDNA sample.
- August 2013: Part II of a report describing a set of highly polymorphic mitochondrial DNA (mtDNA) markers that provide some degree of inference as to minimum numbers of individual Asian carp within a pooled eDNA sample.

Outcomes/Output:

- New qPCR markers for bighead and silver carp.
- Greater efficiency of eDNA processing.
- Greater degree of sensitivity to eDNA at low concentrations.

Potential Hurdles:

- Possible issues arising from testing new markers at different interagency labs.

2.6.6 Environmental DNA Surveillance – Applied Early Detection

Lead Agency: University of Notre Dame/USFWS

Agency Collaboration: Great Lakes States

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Using Asian carp as an initial case study, and in partnership with state and federal agencies, a demonstration surveillance program will be implemented within high-risk areas of multiple tributaries to multiple Great Lakes. In subsequent years, surveillance efforts will extend to additional species and invasion hotspots (e.g., ports, ballast water discharge areas) associated with other invasion pathways (e.g., maritime shipping, trade in live organisms). The most important outcome will be early detection of incipient invasions, which will guide rapid management responses to reduce establishment and spread of Asian carp and other invasive species in the Great Lakes.

FY 2010 Actions Undertaken: The project proposal was developed and approved.

FY 2011 Actions Undertaken: Priority rivers were identified with partners and Asian carp experts. Sampling of six rivers was initiated in locations identified as capable of supporting reproductively viable Asian carp populations. Ponds, lakes, harbors, and lagoons in the Chicago area at which Asian carp reportedly had been captured were also sampled. The water samples from these locations were tested for bighead and silver carp eDNA (30,000 PCR reactions). Additional molecular markers were or are being developed for grass carp, back carp, goldfish, and snakehead. A meeting addressing surveillance of Asian carp included representatives of USGWS, Department of Fisheries and Oceans Canada, USGS, and other organizations. Assessment of and consultation regarding Asian carp spawning habitat in Great Lakes tributaries also occurred.

FY 2012 Actions Proposed:

- Sampling of four rivers identified as capable of supporting reproductively viable populations of Asian carp.
- Process water sampling and tests for bighead and silver carp (20,000 PCR reactions).
- Test sampling for black carp and grass carp (5,000 PCR reactions).
- Development and testing of markers for four additional target species.
- Detection threshold mesocosm studies for four additional target species.
- Sampling of 40 of the remaining water bodies throughout Chicago.
- Processing of 1,200 samples and testing for presence of goldfish and other targeted species.
- Development of an eDNA protocols manual to facilitate transitioning of technology to other agencies—to include details of water collection procedures, QA/QC protocols, laboratory techniques, and staff training.

Expected Milestones: See Project Timeline and Milestones Table below. Note that the end of each year of the project will coincide with the end of fiscal years 2011, 2012, and 2013.

Project Timeline & Milestones	Year 1	Year 2	Year 3
Objective 1: Asian carp surveillance in the Great Lakes			
1. Identify priority rivers with partners and Asian carp experts	x		
2. Sampling of 14 rivers identified as capable of supporting reproductively viable populations of Asian carps Milestones: Six rivers surveyed (yr 1), Four additional rivers surveyed (yrs 2 & 3)	x	x	x
3. Process water samples and test for presence of bighead and silver carp Milestones: 30,000 PCR reactions (yr 1.), 20,000 PCR reactions (yr.2), 20,000 PCR reactions (yr 3)	x	x	x
4. Test samples for black carp and grass carp Milestones: 5,000 PCR reactions (yr.2), 7,500 PCR reactions (yr.3)		x	x
5. Sampling of Lake Michigan and Lake Erie using large volume centrifuge trials			x
Objective 2: ***Marker development and detection capability for priority invasive species***			
1. Identify priority species for molecular marker development	x		
2. Development of grass carp, black carp, goldfish, and snakehead markers	x		
3. Development and testing of markers for eight additional target species Milestones: Four additional markers produced each year (yrs. 2 & 3)		x	x
4. Detection threshold mesocosm studies for target species Milestones: Four detection thresholds determined each year (yrs. 1, 2, & 3)	x	x	x
Objective 3: ***Intentional release of species in trade: delimitation of Chicago as a case study***			
1. Identify and sample ponds, lakes, harbors, and lagoons with reported Asian carp captures	x		
2. Sample and process priority ponds in Chicago for presence of Asian carps	x		
3. Sample remaining water bodies throughout Chicago Milestones: 40 lakes sampled each year		x	x
4. Process samples and test for presence of goldfish and other targeted species Milestones: 1,200 PCR reaction in each year (yrs. 2 and 3)		x	x
Objective 4: Development of eDNA surveillance program for the Great Lakes			
1. Surveillance of Asian carps meeting with USFWS, DFO Canada, USGS, and other key persons.	x		
2. On river assessment and consultation for Asian carp spawning habitat of rivers samples as part of Objective 1	x		
3. Biannual reports to all primary federal contacts and key personal on sampling effort and results Milestones: One report December (yr. 1.), June, December reports (yrs 2 &3).	x	x	x
4. Development of an eDNA protocols manual to facilitate transitioning technology to other agencies, which includes detailing water collection procedures, QAQC protocols, laboratory techniques, and staff training. Milestones: Interim reports provided in December reports. Final report May 2013.		x	x
5. Development of an eDNA sampling plan for high risk port facilities most likely to receive new invasive species via maritime shipping pathway. Interim report December 2012, Final report May 2013.			x

Outcomes/Output:

- Demonstration of the effectiveness of eDNA surveillance by evaluating the presence, absence, and extent of Asian carps in 14 rivers likely capable of supporting reproductively viable populations in the Great Lakes.
- Development of molecular markers for other invasive species and screening of their eDNA in samples previously collected and at additional high-risk sites (e.g., ports, ballast water discharge sites), as resources allow.
- Assessment of the threat of accidental and deliberate release of Asian carp and other species (e.g., northern snakehead) from the trade pathway, using Chicago area lakes, ponds, and lagoons as an initial test case.

- In collaboration with partners, transfer of eDNA technology and surveillance program to willing agencies for early detection of species to prevent and slow the spread of biological invasions in the Great Lakes.

Potential Hurdles:

- Possible issues of sampling logistics (e.g., access, weather).
- Possible uncertainties in genetic marker development outcomes.

2.7 Enforcement and Outreach Activities

2.7.1 Outreach to Northeast Illinois' Bait Shops

Lead Agency: IL DNR

Agency Collaboration: University of Notre Dame

FY 2012 Funding: $30,000 GLRI funds.

Project Explanation: Investigation of potential pathway of ANS through bait industry

FY 2010 Actions Undertaken: IL DNR sampled at 52 Chicago-area bait shops in nine Illinois counties. The samplings occurred in February and March 2010 and during summer 2010. Visual inspections were completed, and water samples were collected for eDNA analysis.

- Visitation of bait shops during winter 2010.
- Visitation of bait shops during summer 2010.
- Detection of no visual evidence of Asian carp in bait shops.
- Report from Notre Dame 2011 showing no positive DNA results from any of the 52 Chicago-area bait shops in the nine counties.
- Responses to questionnaire indicating that no bait shops collect bait from the wild, and that most purchase bait from one of three regional minnow suppliers.

FY 2011 Actions Undertaken: Building upon 2010 studies, the priority for 2011 was to investigate the few Illinois bait wholesalers multiple times throughout the year. Additional sensitivity to other ANS such as goldfish, grass carp, and black carp was emphasized as well.

FY 2012 Actions Proposed:

- A relatively affordable study of an industry that can bypass the majority of efforts against Asian carp, and can screen for multiple species with a single water grab.
- Provide education opportunities while at the bait shop and wholesaler.
- With 2010 and 2011 results in mind, 2012 will minimally look within the Chicago bait trade, and possibly extend beyond the borders to wholesalers outside of state boundaries.

Expected Milestones:

- Summer 2012: Initiate follow-up study to confirm results, broaden surveillance, and take region-wide approach, possibly looking at wholesalers instead of end suppliers.

Outcomes/Output:

- Wholesalers into Great Lakes states will be identified as Asian carp-free or as posing some level of risk.

Potential Hurdles:

- Possible incompatibilities of seasonal bait trade with test dates.
- Possible lack of cooperation by out-of-state wholesalers.
- Unknown level of illegal bait suppliers.
- Possible difficulty of detection in rotating bait stocks.

2.7.2 Increased Lacey Act Enforcement of Illegal Transport of Injurious Wildlife

Lead Agency: USFWS

Agency Collaboration: State agencies.

FY 2012 Funding: $400,000 GLRI funds.

Project Explanation: Although transfer of AIS is currently illegal, stricter enforcement is necessary to mitigate the risk of transfer.

FY 2010 Actions Undertaken: The USFWS, Office of Law Enforcement expanded surveillance and enforcement of illegal transportation of federally listed invasive species. Service wildlife inspectors increased their efforts to target and interdict federally listed invasive species at border locations. In addition, the Service has acquired a van that can be utilized to remotely scan containers, and vehicles and can be deployed at all international ports of entry. This van will allow Service wildlife inspectors to be more effective and efficient in their search for invasive species.

In addition, the Office of Law Enforcement is working with state partners to control the spread of invasive species (including Asian carp) through investigations here in the United States. Specific information is considered law enforcement sensitive.

FY 2011 Actions Undertaken: Actions identified above continued in 2011. Specifics are considered law enforcement sensitive.

FY 2012 Actions Proposed: Investigative and inspection work will expand in 2012. Specifics are considered law enforcement sensitive.

Expected Milestones: None

Outcomes/Output:

- Prosecutions of individuals involved in illegally importing or transporting federally listed injurious species in interstate commerce.

Potential Hurdles: None.

2.7.3 Community Action Initiatives to Increase Awareness, Surveillance, and Enforcement of Unlawful Live Asian Carp

Lead Agency: IL DNR

Agency Collaboration: City of Chicago Department of the Environment

FY 2012 Funding: $400,000 GLRI funds.

Project Explanation: While both bighead and silver carp are listed under the Lacey Act as illegal to transport alive, many local communities and/or markets continue to buy and sell live Asian carp for consumption and/or release into the wild according to ethnic customs or traditions. IL DNR has increased officer presence, friendly enforcement activities, and communications related to Asian carp in a manner similar to the bait shops visits (Action Item 2.7.1), as well as communicating with local management and regulatory entities such as the City of Chicago, Department of the Environment. This has proved successful in promoting open dialogue between store owners, the public, and enforcement officials. As well as creating active communication between the entities, community involvement would focus on fish processors, markets/grocers, and other retail food establishments where live Asian carp are or were likely to have been. We will also strive to break down any cultural and language barriers to achieve highest success. These activities will focus on grocers known for preferring live fish for release or food preparation, and on other high-risk locations.

FY 2010 Actions Undertaken:

- Discussions with City of Chicago, Department of the Environment to coordinate regulations
- Coordination with Conservation Police Officers (CPO) to coordinate enforcement efforts in Chicago area restaurants and market places.

FY 2011 Actions Undertaken: Random sampling throughout the year coordinated through IL DNR CPOs focusing on informing people and enforcing the Lacey Act. Objects of attention in this regard were:

- Restaurants and markets in the greater Chicago area.
- Live fish haulers moving through Illinois.

FY 2012 Actions Proposed:

IL DNR staff and CPOs working with city inspectors will conduct education and outreach activities, as well as on-site enforcement if necessary through informal site visits at fish processors, fish markets, and retail food establishments. In addition, import and export audits and inspections will ensure compliance with both the federal Lacey Act and Illinois Injurious Species Rule. CPOs will also be tasked with ensuring adherence to other laws and regulations by commercial fisherman.

Interpretive materials will be developed for distribution to increase awareness of enforcement, and additional outreach materials will be important for non-English speaking business owners and consumers.

In 2012, IL DNR will continue efforts started in 2011 at working throughout the greater Chicago Area, and will expand the program to statewide site visits and surveillance. Additional areas where live Asian carp may be moving within the State intentionally or unintentionally will be identified. To expand these efforts, IL DNR will coordinate efforts with the City of Chicago and USFWS.

Because unintentional contamination has been suspected in other ANS, fish transportation and importation for food or stocking will also be investigated. Increased officer presence, education, and communication will enhance our understanding of this. The following activities will occur:

- At least four investigations of live fish in markets per year, regionally.
- Coordinated outreach and education for best management practices and regulations.
- Development of techniques to share information across language/cultural barriers.
- Increased surveillance of live fish haulers.
- Development of recommendations for policy or regulatory changes to address any identified gaps in control/management of Asian carp and of other ANS.

Expected Milestones:

- Develop outreach and interpretive materials to increase awareness among businesses and consumers.
- Increase enforcement and establish expectations regarding live fish sales in Illinois.
- Increase coordination with City of Chicago and USFWS regarding these issues.

Outcomes/Output:

- Increased awareness among and education of businesses and consumers by December 2012.

Potential Hurdles:

- Possible difficulties in inspecting non-registered locations or black market dealers.

2.7.4 Increased Web Outreach

Lead Agency: USFWS

Agency Collaboration: Web content will be supplied by all members of the ACRCC

FY 2012 Funding: $50,000 GLRI funds.

Project Explanation: The ability to provide information in a timely and accessible format is a critical component in the ACRCC's stakeholder participation efforts. The ongoing maintenance and continued expansion of AsianCarp.us as both a window into the ACRCC actions and reliable source of information on Asian carp requires additional resourcing support.

FY 2010 Actions Undertaken: From its inception in 2009, the URL AsianCarp.org was built and managed by USFWS to update the public and media on ACRCC actions. In 2010, use of the URL by the ACRCC continued, and the URL housed general information on Asian carp and updates on ACRCC actions under the Framework such as rapid response activities and results of ongoing monitoring and sampling. The ACRCC Communication Work Group also began to add web-delivered products to the website, such as downloadable fact sheets and ACRCC documents. The website routinely drew 4,000 to 5,000 hits a month from all around the United States and the world, quickly becoming one of the primary outreach tools of the ACRCC.

FY 2011 Actions Undertaken: The ACRCC decided that it would be more appropriate to house the ACRCC's website on a government server. USFWS served as the lead agency in rebuilding the website, and put in the formal request to use the URL www.AsianCarp.us. Rebuilding the website entailed transfer of all current AsianCarp.org information onto a new server while concurrently restructuring the format of the website to provide information in a more user-friendly manner to attract a wider audience. The new website laid the groundwork for expanded use of new media and multimedia in the ACRCC's outreach activities.

FY 2012 Actions Proposed: As the site administrator, USFWS will continue to provide staff support to maintain and enhance the website. To further increase awareness about the website and ACRCC actions, USFWS will expand into new media (e.g., Twitter, Flickr, YouTube) and paid information delivery systems (e.g., Vocus, Information Distribution Systems) to distribute information to a still greater audience.

Expected Milestones:

- February 2012: Creation of official ACRCC Twitter account.
- March 2012: Creation of official ACRCC YouTube account.
- June 2012: Evaluation of target audiences and use of the site by the public through review of Google analytics.

Outcomes/Output:

- Fostering public understanding regarding the role of the ACRCC and the actions it undertakes.
- Identification of information gaps to better target outreach and communication activities.

Potential Hurdles: None

2.7.5 Asian Carp Outreach and Education

Lead Agency: NOAA through the Sea Grant Great Lakes Network

FY 2012 Funding: $98,000 GLRI funds (approximately equal to $14,000 per state program).

Project Explanation: The Great Lakes Sea Grant Network (GLSGN) includes the seven Sea Grant programs from the States of Minnesota, Wisconsin, Indiana-Illinois, Ohio, Michigan, Pennsylvania, and New York. These programs are geographically positioned to provide local outreach and education on Asian carp, and to address regional response and control issues at various public forums in their individual states. These state programs will work with and advise the ACRCC and provide advice in order to (1) develop additional educational materials, (2) develop productive partnerships, and (3) conduct education and outreach within their individual states. In order to perform this function, the programs require funding for material development, staff time, and travel expenses. Having Sea Grant perform these needed services and functions locally, within each state, is more efficient, effective, and economical.

GLSGN has the organizational experience and a plan for the timely and successful achievement of this campaign's goals and objectives, including concrete, measureable activities. Collaboration will involve quarterly meetings and conference calls to ensure that project objectives are met. A regional communication and education plan will be developed. Partners will play important roles by assisting with coordination, providing advice and expertise, leveraging resources, and assisting in implementation. NOAA will contact the lead investigators on related GLRI-funded or other sponsored projects to identify points of synergy in order to leverage resources, expertise, and reach of the projects to meet mutual goals.

FY 2012 Actions Proposed: The GLSGN will respond to opportunities and requests for education and outreach on Asian carp and regional control efforts within each of the eight Great Lakes states. Target audiences may include anglers, charter captains, teachers and students, the general public, elected officials, resource managers, decision makers, marina operators, boaters, port directors, coastal county commissioners and mayors, and many partner or collaborating organizations including The Nature Conservancy, DNRs, USEPA, USGS, GLFC, the International Joint Commission, and others.

Expected Milestones:

- In cooperation with ACRCC and its Communication Working Group, identification of: (1) a list of already developed Asian carp outreach materials, (2) gap analysis, and (3) additional materials to be developed.
- Participation in development of materials.
- As needed and requested, participation of Sea Grant Education and Outreach and Extension staff in conducting and contributing to local/state outreach regarding Asian carp.

Outcomes/Output:

- Specific materials to be developed and specific activities regarding education and outreach on Asian carp to be determined on an as-needed basis in cooperation with stakeholders.
- Expansion of existing GLRI AIS efforts.

Potential Hurdles:

- Possible limitations of knowledge of Asian carp distribution and establishment.
- Possible lack of education materials.
- Misinformation.
- Possible conflicts regarding ecosystem services (e.g., Asian carp marketing vs. management/control).

2.7.6 Asian Carp Video Footage

Lead Agency: GLFC with Michigan Department of Natural Resources and Environment (MI DNRE)

Agency Collaboration: ACRCC-affiliated agencies with interest and ability to assist.

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: Success of efforts to keep the invasive Asian carp out of the Great Lakes depends on stakeholder awareness of what an Asian carp looks like, and understanding of possible effects of an invasion on the Great Lakes ecologically, socially, and economically. Outreach from the ACRCC and its partner organizations has increased understanding of why the Great Lakes are important and what actions are necessary to maintain healthy lake ecosystems. The commission, in partnership with the State of Michigan and other ACRCC partner organizations, seeks to create outreach materials in the form of video footage for public consumption. To aid in the education effort, this video project has two major components:

1. Developing an Asian Carp Identification DVD

The earliest detection of Asian carp in currently non-inhabited waters is likely to come from a stakeholder. While Michigan has issued a brochure and maintains an online reporting system for reporting possible observations of Asian carp, it can be difficult for the lay person to distinguish between an Asian carp and other species, particularly for juvenile fish. The goal of this effort is to develop and distribute a professional quality video and public service announcement (shorter version public service announcement [PSA]) that shows people (general public, stakeholders, agency biologists, law enforcement officers, commercial fishers) how to identify juvenile and adult Asian carp, and how to distinguish these from other species, including bait species. Developing a video that provides both a visual and an audio explanation will increase people's engagement with seeking and correctly identifying Asian carp. The final product could be placed on the Asian carp website and other agency websites; DVDs could be cheaply produced and widely distributed.

2. Producing B-roll Media Footage for News and Social Media

Most, if not all, ACRCC partner agencies have received requests from news agencies and other sources for high-resolution, broadcast-quality video footage of Asian carp. However, available footage of this is rare. This proposal calls for creation of b-roll footage to be produced in a manner that is easily distributed via social media sites (e.g., Facebook, YouTube, etc.), as well as via traditional news organizations (news and documentary organizations) to ensure that the message of the ACRCC is distributed widely regionally and nationally.

FY 2011 Actions Undertaken: Michigan has developed a brochure to help anglers identify differences between juvenile Asian carp and commonly used bait species. Michigan will work with the commission and a hired video crew to develop and edit the footage, and will consult with the Communications Subcommittee as needed. Production of Asian carp video footage is expected to occur during summer and fall 2011. Identification of needed footage will begin with a brainstorming session of members of the Communications Work group, to identify and reach consensus on the types of footage that would be most useful to distribute. The commission, in consultation with the State of Michigan, will contract production of the video footage to a video production company. The commission will help coordinate the film crew's interactions with officials who will assist in providing access to Asian carp (e.g., the INHS's Havana, IL field station; USFWS field offices; etc.). Need for production of some footage at an aquarium is also anticipated. Editing of the footage and development of the PSA will continue into fall 2011.

FY 2012 Actions Proposed: Generate and distribute video footage to social media outlets and to traditional news media organizations for public education and information.

Expected Milestones:

- March, 2012: The video and PSA are posted and distributed.
- March, 2012: Film footage becomes freely available to the public, media organizations, and social media sites.

Outcomes/Output:

- Stakeholders are increasingly aware of and able to identify Asian carp.
- Law enforcement actions become more effective, as officers can readily identify Asian carp.
- Stakeholders, basinwide, are enabled to help detect the presence of Asian carp.
- Management agencies, basinwide, have a valuable tool to communicate with stakeholders and reduce reporting of "false positives."
- Local, regional, and national news outlets have high-quality, high-resolution, broadcast-quality video footage to present with stories about Asian carp and invasive species.
- Stakeholders are able to access high-quality footage of Asian carp on popular social media sites, including Asiancarp.gov.
- Overall education regarding Asian carp and the harm they cause throughout the Great Lakes (and other waters) is readily available in multiple formats.

Potential Hurdles:

- Poor natural conditions for production of video footage.

2.7.7 Communications, Outreach, and Education Displays for Public Consumption on the Threats of Asian Carp to the Great Lakes Ecosystem and Economy

Lead Agency: GLFC

Agency Collaboration: ACRCC partner agencies and relevant outside agencies and organizations working on similar issues.

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: In partnership with ACRCC partner agencies, organizations are seeking to create educational and outreach materials in the form of informational, tabletop, outreach displays for public education.

Two Asian carp displays currently housed at the GLFC are easily shipped throughout the basin. Demand over the past 6 months has exceeded the commission's ability to supply the displays to all those requesting them. Production of three more displays is proposed for agencies of the ACRCC, to be housed at those agencies conducting outreach, including the USFWS, USEPA, and USACE. The displays will be used by the ACRCC partners at a variety of events throughout the Great Lakes and widely viewed by the public who attend.

FY 2010 Actions Undertaken: Two tabletop informational displays were created. The two displays are housed at the GLFC for use around the basin. A number of silver and bighead Asian carp models were created. The models of carp are spread among numerous federal and state agencies and non-governmental organizations for use at events around the basin to highlight the carp issue. The displays were used extensively in a few locations, but the number of displays was too small to satisfy the demand.

FY 2011 Actions Undertaken: Outreach activities have occurred around the basin directed at informing the public about Asian carp. Activities are continually conducted by organizations formally associated with the ACRCC and by numerous organizations around the basin (e.g., Ontario Federation of Anglers and Hunters [OFAH], Great Lakes United, and numerous State Sea Grant offices). Most organizations also have performed informal Asian carp outreach continually where public concern about Asian carp is evident.

FY 2012 Actions Proposed: Printing of three additional display panel sets and purchase of the frames and carrying cases for each. Displays will be identical to those housed by the commission, which conveys a consistent and recognizable message to all recognized entities (e.g., GLFC, USFWS, USEPA, OFAH, Great Lakes United, Sea Grant, etc.) that conduct public outreach and education about Great Lakes health and invasive species.

Expected Milestones: None

Outcomes/Output:

- Three Asian carp 5'x5' tabletop portable displays for use by ACRCC agencies and organizations for public outreach around the Great Lakes Basin.
- Shipment of displays to appropriate agencies.

Potential Hurdles:

- Lack of coordination and unwise scheduling of the displays could result in inefficient usage at events around the region.

2.7.8 Early Detection Workshop

Lead Agency: USFWS

Agency Collaboration: All ACRCC partner agencies

FY 2012 Funding: $30,000 GLRI

Project Explanation: To standardize a comprehensive and integrated sampling approach across the Great Lakes Basin, an interagency workshop will focus on producing a manual to standardize sampling procedures. This manual will be used to clarify who will perform sampling, where this sampling will occur, and how to integrate the complementary sampling effort of the various stakeholder agencies.

FY 2010 Actions Undertaken: N/A

FY 2011 Actions Undertaken: USFWS developed a provisional plan for sampling eDNA and traditional gear.

FY 2012 Actions Proposed: USWFS will host an interagency workshop involving all ACRCC partners to develop a manual of standardized sampling procedures. The manual will clarify which agencies will perform sampling, where the sampling will occur, and how to integrate the complementary sampling efforts of the ACRCC agencies.

Milestones:

- Produce a manual and pilot program to standardize sampling procedures.
- Begin implementation of the program by mid-2012.
- Evaluate and adopt the program during winter season 2012-2013.

Outcomes/Output:

- Stronger, more efficient program of policies and procedures moving forward into 2013.

Hurdles:

- None expected.

2.8 Funding Opportunities and Agency Preparation for AIS

2.8.1 State and Interstate AIS Management Plans

Lead Agency: USFWS

Agency Collaboration: States

FY 2012 Funding: No additional FY 2012 funds necessary.

Project Explanation: This project will provide ongoing resources for development and continued progress of state programs specific to AIS Management Plans.

FY 2010 Actions Undertaken: 2010 funding supported state and interstate pest management plans and Asian carp activities within eight Great Lakes states.

FY 2011 Actions Undertaken: USFWS continued to provide funds allocated through the GLRI in 2011 to Great Lakes states and others in order to enhance activities that prevent introduction of AIS into the Great Lakes. This included development of state-led rapid response actions conducted under new rapid response plans developed by Great Lakes states and approved by the ANS Task Force. Similar funds provided for Tribal plans were allocated through alternate funding sources.

FY 2012 Actions Proposed: USFWS will continue to provide funds allocated through the GLRI in 2012 to Great Lakes States and others in order to enhance activities that prevent introduction of AIS into the Great Lakes. As in 2011, funding for Tribes will be allocated through alternate funding sources.

Expected Milestones:

- September 2012: USFWS will provide funding to the eight Great Lakes States to implement their state aquatic invasive species management plans.

Outcomes/Output:

- Great Lakes states will have fully developed, revised, and implemented ANS management plans.

Potential Hurdles:

- States may have difficulty providing the 25 percent cost-share requirement (non-federal funds) as a requirement for receiving annual funding allocation for support of activities identified in approved state AIS management plans.

2.8.4 USFWS Great Lakes Asian Carp Monitoring Program

Lead Agency: USFWS

Agency Collaboration: USGS and/or academic institutions.

FY 2012 Funding: $1,150,000 Total funding ($150,000 GLRI funds/$1,000,000 Base funding)

Project Explanation: Continue development and implementation of an early detection surveillance program for bighead and silver carp in and near the Great Lakes. This program would complement the eDNA sampling and analysis programs implemented by academia and USFWS. Sampling would primarily target areas of high concern in the Great Lakes (e.g., southern Lake Michigan, western Lake Erie).

FY 2010 Actions Undertaken: NA

FY 2011 Actions Undertaken: FWS worked with partners to develop and implement a sampling plan, including collaboration with state, Tribal, non-governmental organizations, and Canadian/Provincial agencies and organizations. The USFWS undertook a provisional sampling program at initial sampling locations that included standard operating procedures using nets, sonar, and other "traditional" gear. FWS also convened a workshop to develop sampling program criteria and strategy to be implemented basin-wide.

FY 2012 Actions Proposed: USFWS will work with partners to continue developing and refining standard sampling protocol in the Great Lakes, and will continue implementing the protocol. USFWS staff/teams will be prepared, and may be mobilized, to respond to any Asian carp detected (using either traditional gear or eDNA) in the Great Lakes. In addition, USFWS will work with USGS or academic institutions to investigate spawning requirements for bighead and silver carp.

Expected Milestones:

- November 2012: Finalized/updated sampling protocol.
- Spring 2012: Sampling protocol implemented.
- Spring 2012: Deployment plans finalized (contingent on need).

Outcomes/Output:

- Ongoing early detection, rapid assessment, risk assessment, rapid response program for the Great Lakes.
- Information that will build upon existing knowledge of spawning/recruitment requirements for bighead and silver carp.

Potential Hurdles:

- Possible issues regarding sampling site logistics (e.g., access and working in Canada).
- Possible difficulty obtaining timely eDNA results.
- Inefficiency of traditional sampling gear, particularly in large, voluminous water bodies.

2.9 Other Asian Carp Support Activities

2.9.1 Other Asian Carp Support Activities

Lead Agency: USEPA

FY 2012 Funding: $2,232,983 GLRI funds.

Project Explanation: Support for Great Lakes National Program Office, CEQ, and federal agency activities. The threat of Asian carp introduction into the Great Lakes directly affects the Great Lakes ecosystem, the eight Great Lakes states, and the economics of several associated industries. A variety of actions and activities are contained in this Framework item. These include funding to support barrier defense, which includes separating newly discovered potential pathways of migration and fish suppression activities during maintenance of the electric barriers; contractor support to the agencies in developing reports, tracking activities, and providing field support as necessary; provision of response agencies' travel costs for relocation of personnel and equipment during response events; continued support of the Asian carp director and deputy to enhance collaborations among the federal, state, local, and tribal agency partners, as well as with other industry and private stakeholders; and provision to senior executives and the ACRCC of continued communication and outreach support activities.

FY 2012 Action: Funding will be used for Asian carp efforts to include the following:

- Federal Executive Committee and ACRCC support.
- Contractor support.
- Multi-agency barrier defense activities.
- Rapid response support.
- CEQ personnel support.

Expected Milestones: None

Potential Hurdles: None.

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	
EFFLUENT LIMITATIONS FOR THE	)	
CHICAGO AREA WATERWAYS SYSTEM	)	R08-09 Subdocket C
(CAWS) AND THE LOWER DES PLAINES	)	(Rulemaking- Water)
RIVER: PROPOSED AMENDMENTS TO	)	
	)	
35 Ill. Adm. Code Parts 301, 302, 303 and 304	)	
(Aquatic Life Use Designations)	)	

ATTACHMENT 7

C.C. Carey. B.W. Ibelings, E.P. Hoffmann, D.P. Hamilton, J.D. Brooks, Eco-physiological adaptations that favor freshwater cyanobacteria in a changing climate, Water Research 46, 1394-1407 (2012) H.W. Pearl, J. Huisman, Blooms Like It Hot, Science 320, 57-8 (2008).

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Eco-physiological adaptations that favour freshwater cyanobacteria in a changing climate

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ABSTRACT

Climate change scenarios predict that rivers, lakes, and reservoirs will experience increased temperatures, more intense and longer periods of thermal stratification, modified hydrology, and altered nutrient loading. These environmental drivers will have substantial effects on freshwater phytoplankton species composition and biomass, potentially favouring cyanobacteria over other phytoplankton. In this Review, we examine how several cyanobacterial eco-physiological traits, specifically, the ability to grow in warmer temperatures; buoyancy; high affinity for, and ability to store, phosphorus; nitrogen-fixation; akinete production; and efficient light harvesting, vary amongst cyanobacteria genera and may enable them to dominate in future climate scenarios. We predict that spatial variation in climate change will interact with physiological variation in cyanobacteria to create differences in the dominant cyanobacterial taxa among regions. Finally, we suggest that physiological traits specific to different cyanobacterial taxa may favour certain taxa over others in different regions, but overall, cyanobacteria as a group are likely to increase in most regions in the future.

1. Introduction

Cyanobacterial blooms present major challenges for the management of rivers, lakes and reservoirs. Blooms have adverse impacts on aquatic ecosystems and human health, with wide-ranging economic and ecological consequences (Hallegraeff, 1993; Mur et al., 1999). The increased frequency and intensity of blooms have been attributed to anthropogenic changes, principally nutrient over-enrichment and river regulation (Anderson et al., 2002). More recently, it has been predicted that a changing climate associated with rising levels of atmospheric CO_2 will increase the occurrence of blooms (Beardall et al., 2009; Paerl and Huisman, 2009; Paul, 2008), or at least favour cyanobacterial dominance of phytoplankton communities (Mooij et al., 2005). Decision support trees for bloom formation (e.g., Oliver and Ganf, 2000), as well as numerical model predictions that allow testing of multiple stressors (e.g., Trolle et al., 2011), suggest that there may be synergistic interactions amongst an array of environmental drivers to promote cyanobacterial blooms.

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Why would cyanobacteria, and not other phytoplankton, be favoured under future climatic conditions? It is possible that cyanobacteria have several physiological characteristics that may be acting in concert to allow them to dominate in a changed climate. Alternatively, there may be physiological attributes of different cyanobacterial taxa that may leave them vulnerable under some conditions expected with climate change. An improved understanding of the interactions amongst both the environmental drivers that are predicted to change in different regions and cyanobacterial physiology is crucial for developing management strategies to mitigate or avoid the potential of more frequent blooms under future climate scenarios (Brookes and Carey, 2011; Paerl et al., 2011).

1.1. Bloom increases and effects

Cyanobacterial blooms are not a new phenomenon and have been occurring for centuries in both marine and freshwater systems (Codd et al., 1994; Fogg et al., 1973; Hayman, 1992; Paerl, 2008). Since the 1960s, however, there has been a dramatic global increase in the number of publications and reports of cyanobacterial blooms (Anderson et al., 2002; Carmichael, 2008; Hallegraeff, 1993; Hamilton et al., 2009; Paerl and Huisman, 2008; Van Dolah, 2000), primarily in freshwater and estuarine environments (Paerl, 1988). While increased reports may to some extent be due to increased monitoring efforts (Sellner et al., 2003), there is substantial evidence that blooms are increasing not only in frequency, but also in biomass, duration and distribution (Anderson et al., 2002; Glibert et al., 2005; Hallegraeff, 1993; Smayda, 1990). Furthermore, it has been hypothesised that cyanobacteria may continue to increase in response to global climate change (Mooij et al., 2005; Paerl et al., 2011; Paerl and Huisman, 2009).

The proliferation of cyanobacteria can have numerous consequences. In addition to risks to human and animal health (Chorus and Bartram, 1999; Ibelings and Chorus, 2007), there may also be substantial economic costs for water treatment and losses in tourism, property values, and business (Dodds et al., 2009; Steffensen, 2008). With a global distribution, escalating bloom occurrence and worldwide concern (Lundholm and Moestrup, 2006), it is important to review the evidence for the likelihood of cyanobacterial increases with climate change and how this may be related to cyanobacterial eco-physiology. Cyanobacteria have an extensive evolutionary history, and fossil evidence indicates that they were abundant over 2.5 billion years ago (Summons et al., 1999), and may have emerged as early as 3.5 billion years ago (Schopf, 2000). They are the earliest-known oxygen-producing organisms, and have key roles in global primary production and nitrogen-fixation (Chorus and Bartram, 1999). The lengthy history and variable environmental conditions under which cyanobacteria evolved have resulted in the adaptation of some cyanobacterial taxa to extreme environments, and collectively they are widely dispersed across the globe (Badger et al., 2006). They exist across a multitude of hot, cold, alkaline, acidic and terrestrial environments, and can proliferate to be the dominant primary producers in freshwater, estuarine, and marine ecosystems (Chorus and Bartram, 1999; Mur et al., 1999). Our focus in this Review is on freshwater and estuarine cyanobacteria.

2. Anticipated changes to temperatures, stratification, nutrient loading, and hydrology

Over the past century, global mean surface air temperatures have increased by 0.74 ± 0.18 °C (Trenberth et al., 2007). This warming trend is expected to continue, with higher latitudes warming more than lower latitudes (Solomon et al., 2007). Warming will be strongest in winter for northern areas in Europe and North America and most of Asia, and warming is predicted to be stronger in summer for the southern areas of Europe and North America. Seasonal differences in South America are not projected to substantially change (Solomon et al., 2007). Of particular relevance for cyanobacterial blooms is the prediction that heat waves will become more frequent, more intense, and will last longer (Meehl et al., 2007).

Climate warming is expected to have a profound effect on the onset (earlier), strength (stronger) and duration (longer) of stratification of lakes (De Stasio et al., 1996; Peeters et al., 2002), even to the extent that some polymictic lakes may become dimictic, dimictic lakes may become warm monomictic, and monomictic lakes may become oligomictic (Gerten and Adrian, 2002). Variation in temperature on a diel scale is anticipated to become smaller, since daily minimum temperatures will likely increase more strongly than daily maximum temperatures. Hence, climate warming increases the likelihood that microstratification occurring during the day will be maintained during the night (Hanson et al., 2008).

Both deep and shallow lakes are expected to exhibit increased stratification, which can have large effects on phytoplankton biomass and community structure (Pomati et al., in press). For example, the water column stability of the deep peri-alpine Lake Zurich, Switzerland has increased by more than 20% over the past three decades (Livingstone, 2003). In shallow lakes, microstratification can resist turbulent mixing to reduce the mixing depth to a shallow mixed layer near the water's surface (Denman and Gargett, 1983). Wilhelm and Adrian (2008) determined the mixing regime of shallow, polymictic Lake Müggelsee (Germany) over a period of four years, and found that heat waves in 2003 and 2006 resulted in extended stratified periods that lasted up to two months.

Under future scenarios of modified hydrology, it is expected that nutrient loading will be increasingly variable, with regional differences. Across almost all regions, precipitation variability will increase in the future, and when precipitation events do occur, their intensity will be increased (Parry et al., 2007; Solomon et al., 2007). Warmer climates are predicted to experience higher precipitation extremes, and droughts will increase at low latitudes and mid-latitude continental interiors due to both decreased precipitation and increased evapotranspiration (Jeppesen et al., 2007; Parry et al., 2007). By the end of the 21st century, the distribution of the global land surface in extreme drought is predicted to increase from 1 to 3 % at the present day to 30% (Burke et al., 2006). Similarly, the incidence of extreme droughts every 100 years and mean drought duration are expected to increase by factors of two and six, respectively, by the 2090s (Burke et al., 2006).

Opposite to low-latitude regions, temperate and high-latitude regions are predicted to experience increased mean precipitation and the highest increase in precipitation intensity, primarily in the winters (Meehl et al., 2005; Parry et al., 2007). Runoff in the high latitudes of North America and Eurasia is expected to increase by 10–40 % by 2050, whereas runoff will decrease in the Mediterranean, southern Africa, western USA, and northern Mexico by 10–30 %. Cumulatively, however, the areas with decreased runoff will expand between the late 20th century and 2050 (Milly et al., 2002). Taken altogether, these changes are likely to have large effects on nutrient delivery to lakes, reservoirs and rivers as rainfall distribution and runoff characteristics change.

In response to these climatic changes, many lake physical and chemical characteristics will change, potentially synergistically, which will subsequently affect phytoplankton communities (e.g., Pomati et al., in press). While there are large regional differences in the expected climatic changes, we expect that in most scenarios different cyanobacterial taxa will likely be able to dominate under increasingly variable conditions.

3. Cyanobacterial evolution and adaptations

Cyanobacteria possess a range of unique and highly-adaptable eco-physiological traits (Litchman et al., 2010). These traits, which can be specific at the genus level, include: 1) the ability to grow in warmer temperatures; 2) buoyancy, due to gas vesicle production; 3) high affinity for, and ability to store, phosphorus; 4) nitrogen-fixation; 5) akinete production and associated life history characteristics; and 6) light capture at low intensities and a range of wavelengths. Cyanobacteria possess many other unique eco-physiological traits (e.g., toxin production), however, we chose to focus on the traits listed above because we predict that these cyanobacterial characteristics may allow adaptation specific to the climate changes that we expect in future conditions (and that we are already experiencing). These climate changes include higher temperatures (Parry et al., 2007), stronger and longer periods of stratification (Jeppesen et al., 2007), and modified hydrology (i.e., changed flows, more intense storms but reduced frequency, which will create sporadic nutrient delivery; Jeppesen et al., 2007, 2011).

Below, we evaluate how different traits may interact with a changing climate to allow cyanobacteria to dominate aquatic systems. Cyanobacteria are a diverse group, ranging in size from unicellular picoplankton to multicellular macroscopic colonies. Consequently, no cyanobacterium possesses all of the traits listed above, so the response of cyanobacteria to changes in the environment will likely vary greatly among genera, which makes it harder to generalise the expected outcome of different climate change scenarios. Similarly, different geographical regions are predicted to experience varying climatic changes, which will affect the environmental drivers that interact with cyanobacterial physiological traits. Finally, there are several other factors that contribute to the success of cyanobacteria in freshwater systems, such as grazing resistance, that may be affected by climate change. Cyanobacterial taxa are considered to be poor quality food for zooplankton grazers (e.g., *Daphnia* sp.) because of the morphology of their filaments and colonies, which clog filtering appendages (Arnold, 1971; Lampert, 1982, 1987), their toxins (Fulton and Paerl, 1987; Lampert, 1981, 1982), and because they lack certain required fatty acids, sterols, and nutrients (Ahlgren et al., 1990; Brett et al., 2006; Gulati and Demott, 1997; Holm and Shapiro, 1984). The effect of climate change on grazing resistance falls outside the scope of this paper, but we refer interested readers to reviews by Visser et al. (2005) or Ibelings and Havens (2008).

3.1. *Direct and indirect effects of increasing temperatures*

Temperature is an all-pervasive environmental parameter that affects the metabolism, growth, reproduction, and survival of living organisms, as well as the interactions among species (Ibelings et al., 2011; Kingsolver, 2009). Warmer temperatures will also result in a number of indirect effects (Dale et al., 2006), including increasing stratification and enhanced internal nutrient loading, that are likely to favour at least some cyanobacterial taxa (Boyd and Doney, 2002; De Stasio et al., 1996).

With an increase in water temperatures to values approaching physiological optima for a wide range of phytoplankton species, more phytoplankton will grow and replicate faster, at least until warming raises the water temperature beyond the optimal temperature for growth. Optimal temperatures and the degree to which growth rate increases with temperature, as determined by the rate of change in the rate-limiting anabolic process, differ greatly between phytoplankton species. As a consequence, climate warming will result in shifts in phytoplankton community composition (e.g., Winder et al., 2008), including shifts between cyanobacteria. Reynolds (1989, 2006) compiled literature data on the effect of temperature on phytoplankton growth under controlled conditions. The temperature at which maximum replication rates occurred for cyanobacteria varied from just over 20 °C for *Aphanizomenon flos-aquae* and *Planktothrix agardhii*, to 28 °C for *Microcystis aeruginosa*, and even 41 °C for *Synechococcus* sp. (Reynolds, 1989, 2006). The rate of acceleration, commonly measured as Q_{10} (acceleration over a 10 °C step, generally 10–20 °C) for *Synechococcus* sp. was ~2.6, whereas for *M. aeruginosa* it was ~9.6, the highest value recorded for all of the cyanobacterial or eukaryotic phytoplankton species in the assembled data. Based upon these data, *M. aeruginosa* will have a clear physiological advantage over other phytoplankton when water temperatures increase above 20 °C. For larger phytoplankton with a low surface area to volume ratio, which includes many bloom-forming, colonial cyanobacterial genera (e.g., *Anabaena*, *Aphanizomenon*), temperature dependence of growth tends to be controlled more by nutrient uptake and rates of intracellular assimilation than by photosynthetic rates (Foy et al., 1976; Konopka and Brock, 1978; Reynolds, 2006).

In contrast to the data presented above from Reynolds (2006), Lürling et al. (in press) tested – but rejected – the hypothesis that cyanobacteria have higher optimum growth temperatures and higher growth rates at their optimum temperature when compared to chlorophytes (green algae). Lürling et al. (in press) ran a controlled experiment with eight cyanobacteria (including *M. aeruginosa*, *Cylindrospermopsis raciborskii*, and *P. agardhii*) and eight green algae at six different temperatures (20 °C–35 °C), and found no significant difference in optimum temperatures for growth between the two taxonomic groups (optimum temperatures for both were ~29 °C). However, while the green algae grew faster at the lowest experimental temperature (20 °C), the mean growth rates at the optimal temperature (29 °C) were not significantly different, indicating that the cyanobacteria benefited more than the chlorophytes from an increase in temperature. Nevertheless, the data also suggest that increasing temperatures, at least in regards to their effect on replication rates, do not offer cyanobacteria a clear advantage over their competitors, even at their optimal growth temperature. Data from Lürling et al. (in press) also provide a warning against simplification, as there were considerable differences in response to temperature increases among different cyanobacterial species and even among strains. For example, Lürling et al. (in press) found that the Q_{10} for *M. aeruginosa* CYA140 was ~4.3, while the Q_{10} of *M. aeruginosa* PCC7941 was only ~2.1 (calculations by the authors based upon data in Lürling et al., in press). The former value was the highest Q_{10} of all phytoplankton tested, lending support to Reynolds (2006)' view that *M. aeruginosa* exhibits an exceptionally high Q_{10}. The latter value, however, is well within the range for most cyanobacteria (1.8–4.3), and even chlorophytes (1.1–3.7) (Lürling et al., in press). Finally, it is important to realise that both datasets (Reynolds, 2006; Lürling et al., in press) were obtained under laboratory conditions where nutrients and light were saturating for growth. Light-limited growth rates of *P. agardhii*, for example, have been shown to be independent of temperature (Post et al., 1985; Robarts and Zohary, 1987).

In natural systems, it has been shown that warmer water temperatures do favour cyanobacterial dominance in phytoplankton communities (Kosten et al., 2012). Similarly, it has been proposed that warmer temperatures will mean earlier and longer potential bloom periods, as well as lead to possible range expansions (Dale et al., 2006; Moore et al., 2008; Wiedner et al., 2007). If the direct effects of warming on cyanobacteria are limited, as suggested in the above paragraph (i.e., in regards to replication rates and Q_{10} values), consequently, indirect effects must underlie the observations on increased occurrence of cyanobacterial blooms with ongoing climate warming (Paerl and Huisman, 2008).

In the literature there appear to be conflicting opinions about the relative importance of the direct versus indirect effects of lake warming on cyanobacteria (direct effects examine differences in Q_{10} and replication rates, while indirect effects focus on how temperatures modify the environment in ways that indirectly affect cyanobacteria; e.g., via stratification). Jöhnk et al. (2008) presented model output showing that increased water temperatures favour cyanobacteria directly through increased growth rates. Paerl and Huisman (2008) reached a similar conclusion on the basis of temperature-dependent growth rates from the literature: while the growth rates of most eukaryotic taxa decline at temperatures exceeding 20 °C, cyanobacterial growth rates for many taxa, including *M. aeruginosa* and *P. agardhii*, continue to increase. Others posit that cyanobacteria may only benefit indirectly from temperature increases, especially from enhanced water column stability, and not the direct effects of climate warming (Wagner and Adrian, 2009). Contrary to their expectations, Moss et al. (2003) found that an increase in temperatures of 3 °C above ambient conditions did not result in an increase in cyanobacteria in mesocosm experiments, perhaps because the mesocosms allowed only for the direct, and not indirect, effects of lake warming on cyanobacterial dominance. More work is clearly needed to determine the relative importance of the indirect versus direct effects of increased temperatures on cyanobacteria in freshwater systems.

3.2. *Buoyancy*

Many species of planktonic cyanobacteria produce gas vesicles, which provide buoyancy and allow access to well-lit surface waters (Walsby, 1994). This buoyancy can be offset with ballast arising from photosynthetic carbohydrate production and other cell constituents (Utkilen et al., 1985). The regulation of buoyancy, which allows migration in stratified lakes between illuminated surface waters and nutrient-rich bottom waters (Ganf and Oliver, 1982), occurs as cells accumulate carbohydrates when exposed to light and respire these products of photosynthesis in the dark (Kromkamp and Walsby, 1990). Under prolonged irradiance, gas vesicles may collapse under turgor pressure (Kinsman et al., 1991).

As described above, changes in climate, such as increased temperatures, prolonged droughts and longer water residence times (De Stasio et al., 1996), are predicted to promote cyanobacterial bloom establishment by increasing the strength and duration of stratification (Boyd and Doney, 2002; Paerl and Huisman, 2008). Furthermore, increased nutrient loading from storm events can synergistically interact with climate-driven effects to increase stratification, further strengthening the competitive advantage of buoyancy-regulating cyanobacteria (Jones et al., 2005). Rinke et al. (2010) demonstrated that the increased phytoplankton biomass resulting from eutrophic conditions increased light attenuation and surface temperatures relative to oligotrophic conditions, thereby strengthening stratification. Thus, buoyant cyanobacteria can themselves modify their environment to promote further blooms by increasing water temperatures and stratification (Kumagai et al., 2000; Rinke et al., 2010).

The buoyancy strategies of cyanobacteria, which are a function of gas vesicle volume, the rate of change in dense cellular constituents, and colony size, play a significant role in their ability to dominate their habitats. *Microcystis* sp. can form large colonies that float rapidly to the surface, but as with *Anabaena* sp., these colonies can be mixed through the surface mixed layer with wind (Bormans et al., 1999; Brookes et al., 1999, 2002; Ibelings et al., 1991). Hence, these two cyanobacterial genera may be well adapted to a regime with stronger stratification and a reduced mixing depth. *Microcystis* sp. and *Anabaena* sp.'s fast flotation velocity (Walsby et al., 1991) allows them to efficiently track the near-surface mixed layer (Humphries and Lyne, 1988), as demonstrated by Ibelings et al. (1991) in the Dutch lake Vinkeveen. If there is increased stratification and reduced turbulence, then *Microcystis* sp. colonies will be larger and their buoyancy will be enhanced during vertical migration cycles (O'Brien et al., 2004). Another cyanobacterium, *Planktothrix rubescens*, maintains its vertical position in part because its small filaments have a low sinking or floating velocity (Walsby, 2005), and also because the tight coupling between carbohydrate accumulation and gas vesicle-mediated buoyancy maintains filaments close to the depth supporting neutral buoyancy (Walsby et al., 2004). Jacquet et al. (2005) suggested that the recent increase of *P. rubescens* in pre-alpine lakes undergoing re-oligotrophication (Ernst et al., 2009) may be because the cyanobacterium can take advantage of the earlier onset of stratification caused by increased temperatures.

Motile or buoyant species may also be able to combine light harvesting near the surface with uptake of nutrients in the hypolimnion. According to Bormans et al. (1999), there is little evidence that buoyant cyanobacteria are capable of exploiting these spatially separated resources. However, Wagner and Adrian (2009) argue that in relatively shallow lakes, such as Lake Müggelsee (maximum depth = 8 m), cyanobacterial migration is sufficient to allow access to the hypolimnion where nutrient concentrations are elevated. Ganf and Oliver (1982) also found that *M. aeruginosa* and *Anabaena spiroides* were able to migrate 12 m to access light and nutrients, despite substantial density barriers. Hence, fast-migrating genera (e.g., *Microcystis*, *Anabaena*) may benefit from the climate-induced strengthening of stratification by gaining a competitive advantage over other non-migrating or slow-migrating phytoplankton. While increased stratification is predicted to favour buoyancy-regulating cyanobacteria in comparison to non-buoyant algae in most environmental conditions (Huisman et al., 2004), Wagner and Adrian (2009) found that certain thresholds needed to be exceeded for bloom-forming cyanobacteria (especially *Aphanizomenon*, *Anabaena*, and *Microcystis* sp.) to dominate: stratification periods in Lake Müggelsee needed to be longer than 3 weeks and exhibit a Schmidt stability index exceeding 44 g cm^{-2} within a critical total phosphorus (TP) range of 70–215 μg L^{-1} (Wagner and Adrian, 2009).

The short-term buoyancy response to light, where carbohydrate is accumulated and respired, is nested within a longer-term response that is a function of both the cyanobacterium's previous nutrient and light history (Brookes and Ganf, 2001) and these resources' effects on gas vesicle production and cell metabolism. The rate of gas vesicle production relative to growth, which dilutes the gas vesicle pool per cell, can decrease as nitrogen becomes limiting (Brookes and Ganf, 2001; Klemer, 1978; Klemer et al., 1982). Konopka et al. (1987) showed that gas vesicle volume increased in phosphate-limited *Aphanizomenon flos-aquae* but that the filaments remained non-buoyant while P-limitation persisted. Similarly, Brookes et al. (2000) observed considerably fewer gas vesicles in P-limited *M. aeruginosa* cells relative to P-replete cells.

In contrast to the reduction in buoyancy that accompanies gas vesicle dilution in nitrogen-limited cultures, nitrogen-replete *M. aeruginosa* colonies can show persistent buoyancy (Brookes and Ganf, 2001). There are several examples in which a proportion of cyanobacterial cells maintained at high light failed to lose buoyancy (Walsby et al., 1989), for which excess nutrients was invoked as the mechanism maintaining persistent buoyancy (Brookes et al., 1999). Eutrophic conditions in freshwater ecosystems, which are expected to occur more frequently in regions that will experience increased nutrient loading and changed hydrology, could lead to 'over-buoyancy' and surface accumulations of cyanobacteria.

Gas vesicle strength is related to the depth of the water body in which the cyanobacteria are found. For example, *P. rubescens* from Lake Zurich (maximum depth = 143 m) has narrower and stronger gas vesicles than found in any other freshwater cyanobacteria (Bright and Walsby, 1999), which may have evolved to withstand the high hydrostatic pressures experienced during deep winter mixing. Thus, deep mixing may select for species with strong gas vesicles able to withstand deep mixing without collapsing. Modifications to the mixing regime that may occur if winters become milder and turnover less frequent (Gerten and Adrian, 2002) could potentially open up new habitat for species with weaker gas vesicles that were previously outcompeted. Similarly, if lakes experience dramatic decreases in water levels under future scenarios of modified hydrology and drought, cyanobacteria with weaker gas vesicles may proliferate.

Decreasing water temperatures in the autumn is a central factor in the loss of buoyancy and resultant sinking of many cyanobacteria to the sediments (Visser et al., 2005). The temperature at which *Microcystis* sp. colonies have been observed to lose buoyancy has been shown to range from 12 to 18 °C (Visser et al., 1995 and references therein). The loss of buoyancy as water temperatures decrease is not due to the weakening and collapse of gas vesicles, but rather to the accumulation of carbohydrate ballast, caused by a difference in temperature sensitivity between respiration and photosynthesis (Thomas and Walsby, 1986). Warmer waters in autumn may delay the sinking of cyanobacteria that have formed blooms, but it is likely to be a strongly strain-dependent effect, as demonstrated by the wide range of temperatures that triggered *Microcystis* sp. sinking (Visser et al., 1995). Experiments with *M. aeruginosa* in water that was warmed from 15 °C to 20 and 28 °C demonstrated that buoyancy became constitutive at higher temperatures, with cells remaining buoyant throughout the light period (Kromkamp et al., 1988). Hence, lake warming may result in additional buoyancy that sustains prolonged blooms.

The high degree of variability in catchment hydrology, nutrient loading and hydrodynamics that lakes will experience makes it difficult to predict how the buoyancy of different cyanobacterial groups will be impacted by climate change. However, general conclusions can be made. Increased stratification will favour the fast-migrating buoyant cyanobacteria. As nutrient loading and stratification increase, there will tend to be a shift towards buoyant species that can access both the well-lit surface waters and hypolimnetic nutrient pool. High nocturnal temperatures will act to maintain a shallower surface mixed layer, causing cells to not mix as deeply during night, which will enable them greater access to light during day. These changes may shift the balance between competing cyanobacteria. For example, in Lake Ijsselmeer, The Netherlands, *Microcystis* is commonly the dominant cyanobacterial genus unless summers are exceptionally warm and stable, at which point *P. agardhii* dominates because of shallow mixing over extended periods (Ibelings, 1992). Higher water temperatures persisting into autumn may mean that the loss of buoyancy and mass-sedimentation of cyanobacterial populations that normally occurs will be delayed.

3.3. *Luxury phosphorus uptake and storage*

In many freshwater systems, phosphorus (P) is a limiting nutrient (Schindler, 1974, 1977; Schindler et al., 2008). Cyanobacteria, however, have been shown to overcome this limitation by at least two mechanisms: they produce phosphatases, enzymes that hydrolyse phosphate from organic solutes that then can be taken up (Coleman, 1992) and they have the ability to sequester luxury P intracellularly (reviewed in Healey, 1982). Luxury P uptake into storage can increase the P cell quota from 0.2 to 0.4 % of ash-free dry mass to $\geq$3% of ash-free dry mass, almost 8–16 times the minimum quota (Reynolds, 2006). As a result, cyanobacteria can theoretically double three to four times without having to uptake any additional P (Reynolds, 2006), which provides a large competitive advantage in P-limiting environments.

Different cyanobacterial genera vary in their ability to access organic P with phosphatases and to store luxury P. Whitton et al. (1991) found significant differences among 50 cyanobacterial strains (10 genera) in their ability to access P from various organic molecules. For example, the Rivulariaceae tested (*Calothrix, Dichothrix*, and *Gloeotrichia*) produced significantly higher P yields than filamentous non-Rivulariaceae (*Anabaena*, *Fischerella*, *Lyngbya*, and *Tolypothrix*) from most organic molecules. *Gloeotrichia*, in particular, exhibited significantly higher extracellular phosphomonoesterase (PMEase) activity than any other genus tested (Whitton et al., 1991). Similar differences in luxury P storage ability may exist among cyanobacteria, which could favour certain taxa over others during periods of P deficiency. For example, *Anacystis* may be less able to take up luxury P than *Anabaena*, *Plectonema*, or *Synechococcus* (Healey, 1982).

Paradoxically, cyanobacteria are able to dominate in both low and high P conditions. In low nutrient conditions, cyanobacteria's high affinity for P allows them to outcompete other phytoplankton (e.g., Posselt et al., 2009). Increased P results in higher concentrations of phytoplankton biomass, which is the best predictor for cyanobacterial dominance in lakes (Downing et al., 2001). Cyanobacteria benefit indirectly from high phytoplankton conditions, potentially because of the low light and CO_2 concentrations that result from high levels of production (reviewed in Hyenstrand et al., 1998). Cyanobacteria are superior competitors for light (but with noted differences among taxa, see Section 3.6), and can create higher turbidity per unit P than any other phytoplankton group, thereby excluding their competitors (Scheffer et al., 1997). At low CO_2 levels, cyanobacteria can become dominant because they generally have better CO_2 uptake kinetics than other phytoplankton (Shapiro, 1997). As a result, cyanobacteria can reduce CO_2 concentrations to levels that allow them to persist but exclude other phytoplankton (Shapiro, 1997). Finally, when phytoplankton are high, buoyant cyanobacteria can shade out competitors by forming surface scums (see Sections 3.2 and 3.6 on buoyancy and photoacclimation, respectively), further strengthening their dominance at high P conditions.

As described above, the hydrology of low-latitude and continental mid-latitude regions will be characterised by oscillating periods of drought and flooding by the end of the 21st century. When the associated effects of warmer temperatures are also taken into account, we expect that low-latitude and continental mid-latitude inland waters will experience greater thermal stratification, lower water levels during drought periods, less ice cover, and pulsed nutrient loads (Jeppesen et al., 2007; Parry et al., 2007). During long periods of stratification, P limitation in the epilimnion will increase while the hypolimnion may experience anoxia and consequently increased P concentrations due to internal recycling from the sediments (Nürnberg, 1984, 1988; Nürnberg et al., 1986). Cyanobacteria may be able to overcome the epilimnetic P limitation during stratification due to their internal nutrient storage (Istvánovics et al., 1993; Pettersson et al., 1993), while phytoplankton without luxury P uptake may not be able to persist during low nutrient periods. For example, *Gloeotrichia echinulata* is able to outcompete other phytoplankton in nutrient-limited conditions because it absorbs additional P in the sediments so as to not require any additional P uptake for its own metabolism or reproduction after it recruits into the water column (Istvánovics et al., 1993). *G. echinulata*'s P uptake and storage may explain why the cyanobacterium is able to dominate nutrient-limited lakes across the northeastern U.S. (Carey et al., 2008). Despite lower precipitation overall in low to mid-latitudes, high-intensity episodic storm events are predicted to increase in these regions (Parry et al., 2007). Because of their anticipated increased severity (Parry et al., 2007), these storms may be more effective at triggering mixing, which could result in the release of large concentrations of hypolimnetic P to the epilimnion (Søndergaard et al., 2003). The release of hypolimnetic P during mixing events caused by storms may also be coupled with large external loads of P entering lakes through surface runoff (Jeppesen et al., 2007). During these periods of increased nutrient loading due to storms, we expect that the high levels of P will lead to higher primary production and may favour cyanobacteria, as seen with anthropogenic eutrophication. We predict that small cyanobacteria with large surface area to volume ratios and high nutrient uptake rates may especially benefit (Finkel et al., 2009). Finally, lower water levels during drought periods and less ice cover may also promote cyanobacteria because lower lake levels may concentrate and increase nutrient concentrations, and longer ice-free periods extend the cyanobacterial growing season (Peeters et al., 2007).

In temperate and high-latitude regions, which are predicted to experience increased mean precipitation and the greatest increase in precipitation intensity, cyanobacteria may also dominate. Jeppesen et al. (2007) found that in Danish lakes, the higher external P loads caused by runoff would be greater than the predicted water volume increase, resulting in net higher nutrient concentrations in aquatic ecosystems. The increased precipitation intensity in winter will increase flows, erosion, and nutrient delivery in the spring while lower flows in the summer will compound the stratification and drought conditions described above (Jeppesen et al., 2007). These three drivers- increased nutrient concentrations, greater erosion and discharge due to high precipitation intensity, and summer drought- are all predicted to favour cyanobacteria with rapid nutrient uptake and P luxury storage.

3.4. *Nitrogen-fixation*

Nitrogen-fixation (N-fixation) is a physiological adaptation of some species of cyanobacteria that can provide them with a competitive advantage when available sources of N in the water column are strongly depleted (Oliver and Ganf, 2000; Wood et al., 2010). Dissolved inorganic forms of N, primarily nitrate and ammonium, are preferentially assimilated by phytoplankton, although dissolved organic N has occasionally been shown to constitute an additional component of N nutrition for some cyanobacteria (Berman, 1997). Utilisation of gaseous N_2 via N-fixation is energetically expensive because of its requirement to both break the triple bond linking N_2 molecules during the formation of ammonium and to maintain the nitrogenase enzyme essential to catalyse the reaction. However, energetic investments in N-fixation and maintenance of heterocysts in freshwater N-fixing cyanobacteria may be offset by the competitive advantage provided to them in severely N-deficient environments (Oliver and Ganf, 2000). In freshwater environments, N-fixation is generally accomplished by heterocysts, specialised cells that prevent the incursion of oxygen from surrounding water and neighbouring vegetative cells, which would otherwise inactivate the activity of nitrogenase. Heterocystous cyanobacteria occur in pelagic freshwater and brackish environments but rarely in the ocean (Paerl, 1996).

Non-heterocystous strategies of N-fixation are best known in the marine cyanobacteria *Trichodesmium* sp. (Berman-Frank et al., 2003) but can also occur in freshwater and brackish cyanobacteria by temporal separation of N-fixation. For example, nitrogenase activity at night in some species of *Lyngbya* can be separated from the oxygen-producing photosynthetic activity that would otherwise inactivate nitrogenase during the day (Stal et al., 2010). Species of *Lyngbya* are known to form toxic blooms in marine or brackish-water environments and some species (e.g., *Lyngbya wollei*) also form large benthic mats that can be dislodged and form surface blooms in lake environments, often in association with storm-driven mixing (Bridgeman and Penamon, 2010).

Like many other physiological processes specific to cyanobacteria, there are several hypotheses about how increases in water temperature will affect rates of N-fixation *in vivo* (e.g., Miyamato et al., 1979). In a warmer climate, enzymatically-controlled processes such as N-fixation might be expected to increase at a rate approximating cyanobacterial growth rate responses to temperature (i.e., a Q_{10} of ≥ 1.8; Reynolds, 2006). Staal et al. (2003) showed that Q_{10} values for N-fixation of heterocystous strains of *Nodularia spumigena* and *Anabaena* sp., inferred from nitrogenase activity rates, were indeed >1.8 and commonly close to 2.0 in the light. They found for 21 different heterocystous species that rates of N-fixation in the light were 2.5–4 times higher in the light than in the dark, and that there was substantially greater temperature dependence of N-fixation in the light (Staal et al., 2003). Further work is required to understand if, and the extent to which, temperature dependence of N-fixation may enhance the competitiveness of this group of cyanobacteria in a warmer climate. There are also a number of indirect effects of temperature on N-fixation. For example, an increase in water temperature will reduce the solubility of oxygen and nitrogen in water, and may result in adaptation of the heterocyst by decreasing cell wall thickness and permeability (Staal et al., 2003). This response has been hypothesised to reduce the competitiveness of heterocystous over non-heterocystous cyanobacteria, but is probably unlikely to supplant the dominance of heterocystous N-fixing cyanobacteria in freshwater and brackish environments.

The availability of dissolved inorganic N is critical to the occurrence of N-fixation, both for heterocystous (e.g., *Anabaena*, *Aphanizomenon*, and *Planktothrix*) and non-heterocystous genera (e.g., *Lyngbya*). Heterocysts have been shown to differentiate rapidly *in vivo* as nitrate concentrations decrease below ~30 μg L^{-1} (Agawin et al., 2007) and their proliferation has also been shown to precede the rapid increase in vegetative cells associated with blooms, when the relative abundance of heterocysts can decrease rapidly (Wood et al., 2010). Changes in N loading therefore need to be considered when assessing changes in N-fixation under a future climate. Nitrogen loading from lake catchments may potentially either increase or decrease with climate change, driven primarily by geographic heterogeneity of rainfall and temperature-induced changes in soil and vegetation dynamics (Jeppesen et al., 2007), but it will also be strongly influenced by human activities relating to changes in land use and intensification in cultivated catchments (Jeppesen et al., 2011). In this context it is relevant to consider that human activities have already profoundly altered the global N cycle through massive escalation of N-fixation and application of synthetic N fertilisers for both crop production for human food and pasture production to support greater numbers of domesticated animals (Vitousek et al., 1997). Increases in N loading are not only specific to cultivated catchments, however, because with more than twice the amount of reactive N circulating in the biosphere due to human activities, atmospheric N deposition has alleviated N-limitation of phytoplankton in lakes that would otherwise be largely unaffected by human activities (Elser et al., 2010). Greater availability of inorganic N species arising from increases in atmospheric and terrestrial inputs and storm-driven N loading to freshwater systems could reduce the occurrence of N-fixation.

Despite the increase in N loading from cultivation and atmospheric deposition in many catchments, there is not yet, to the best of our knowledge, any evidence that a link exists between N loading and changes in occurrence of N-fixing cyanobacteria. Several factors may offset the expected net alleviation of N-limitation by increased anthropogenic N loading. For example, within lakes there can be changes in the way that N is transformed and utilised, including observed increases in N losses due to denitrification as N loads increase in association with greater percentages of the catchment in pasture (Bruesewitz et al., 2011). Climate change is likely to increase the duration of water column stratification, which may favour N-fixing, buoyancy-regulating cyanobacteria as inorganic N-species are depleted from surface waters over extended growing seasons (Jeppesen et al., 2011). Both of these examples would promote cyanobacteria capable of N-fixation, even if nutrient loading increases with greater storm intensity. Thus, the interplay of nutrient availability and increases in water temperature will be critical to the future occurrence and proliferation of N-fixing cyanobacteria.

Considerations of how N-fixation may be altered by climate change could be assisted with models of N-fixation that explicitly include water temperature. The models that currently exist (e.g., Hense and Beckmann, 2006; Howarth et al., 1999; Levine and Lewis, 1987; Stal and Walsby, 1998) tend to be more specifically targeted to a species level and are based primarily on substrate limitation (e.g., by light and nitrogen). These models offer limited insight into the complexity of N-fixation in natural ecosystems. Most other models of cyanobacteria populations have been directed either at non N-fixing cyanobacteria (Robson and Hamilton, 2004) or have not explicitly included N-fixation (e.g., Howard et al., 1996). The complexity involved in modelling N-fixation, even at the scale of chemostats (Agawin et al., 2007), indicates that challenges remain to incorporating the major processes relevant to N-fixation in models that operate at the lake ecosystem scale, including a need for fundamental process information on N-fixation in different species of cyanobacteria at different temperatures and N concentrations.

3.5. *Akinete production and life cycle attributes*

Some taxa within the Nostocaceae, Rivulariaceae and Stigonemataceae families of cyanobacteria (which include, but are not limited to, the genera of *Anabaena*, *Cylindrospermopsis*, *Gloeotrichia*, and *Nodularia*) can produce akinetes, or thick-walled resting cells (Nichols and Adams, 1982). Akinete differentiation typically occurs during unfavourable growth conditions and is triggered by changes in light, nutrients, temperature and potentially desiccation (reviewed in Kaplan-Levy et al., 2010). Akinete metabolism is very low or undetectable, allowing the cells to survive in bottom sediments for extended periods of time until germination occurs under favourable growth conditions (Adams and Duggan, 1999). Akinete development may ensure the long-term survival of cyanobacterial populations (Whitton, 1987), as akinetes can survive temperatures up to 55 °C (Yamamoto, 1976), and are viable up to 64 and potentially >100 years after deposition (Livingstone and Jaworski, 1980; Wood et al., 2009) and after desiccation on land for six winter months (Forsell, 1998). Akinete germination can be activated by increasing light, temperatures, nutrients, or dissolved oxygen (or a combination of these factors; Kaplan-Levy et al., 2010).

Under future climate scenarios, cyanobacteria that produce akinetes may have an advantage in withstanding increasingly variable conditions. For example, cyanobacterial populations that form akinetes could be better adapted to intermittent nutrient availability that may be caused by altered precipitation regimes and changes in light intensity and quality due to increased turbidity from storm-induced erosion. In regions that will experience increased drought conditions, akinete-forming cyanobacteria can potentially persist even if water bodies dry up seasonally (Paerl et al., 2011). In general, cyanobacteria exhibit high tolerance to desiccation by producing polyhydroxy saccharides that protect cellular macromolecules from denaturation (Potts, 1994), allowing them to survive alternating drought and wet conditions.

Microcystis sp. do not form akinetes; rather, they overwinter in a vegetative state (Verspagen et al., 2005). Successful overwintering is crucial for *Microcystis* sp. because the sediment provides an inoculum for population growth in the following spring. Model simulations indicate that *Microcystis* sp. blooms may be reduced by as much as 50% if the size of the benthic inoculum is reduced (Verspagen et al., 2005). A study by Brunberg and Blomqvist (2002) on overwintering under different environmental conditions indicates that a reduction in the snow cover on ice-covered lakes would reduce overwintering *Microcystis* sp. populations. We expect that warmer temperatures may increase *Microcystis* sp. recruitment from the sediments, as has been observed for other cyanobacterial taxa (e.g., Karlsson-Elfgren et al., 2004), and may allow *Microcystis* sp. to overwinter in the water column. However, Verspagen et al. (2006) found that increasing temperatures also increase *Microcystis* sp. mortality rate, and overwintering in the water column may increase the light and temperature fluctuations cells are exposed to, decreasing their survival (Brunberg and Blomqvist, 2002). Consequently, decreasing ice cover and rising temperatures in temperate and high-latitude regions may potentially favour other, akinete-forming, cyanobacterial genera over *Microcystis*.

3.6. *Photosynthesis*

In this section, we explore photosynthesis and photoacclimation in cyanobacteria and whether the direct and indirect effects of climate change may affect the competition for light between cyanobacteria and their phytoplankton competitors. Cyanobacteria are reputed to be strong competitors for light due to their accessory pigmentation and the structural organisation of their light-harvesting antenna (e.g., Osborne and Raven, 1986). Laboratory experiments demonstrated that the picoplanktonic cyanobacterium *Synechocystis* sp. attenuated light to lower levels than any other tested species and readily outcompeted other phytoplankton species when light was limiting (Passarge et al., 2006). However, Huisman et al. (1999) found that *Microcystis* sp. were not particularly strong competitors for light in a well-mixed environment, as did Reynolds (2006), who found that *Microcystis* sp. had the poorest light efficiency (by examining the steepness of the initial slope of growth vs. irradiance curves) of 19 phytoplankton species tested. The differences in light interception among different species were mostly due to morphological characteristics: slender, attenuated forms – like that of filamentous cyanobacterial species – were superior to large colonial species at harvesting light (Reynolds, 2006). Huisman et al. (1999) concluded that the observed dominance of cyanobacteria in eutrophic waters cannot be explained (solely) by competition for light.

Overall, we hypothesise that the indirect effects of climate warming (i.e., the strengthening stability of the water column) will have a bigger impact on the competition for light among cyanobacterial taxa and with other phytoplankton than the direct effect of warmer water temperatures. The ability of phytoplankton to acclimate to higher water temperatures and photosynthesise is dependent on changes in the fluidity of the thylakoid membranes, which occurs by changing the lipid composition of the membranes (Herrero and Flores, 2008). Increased temperatures as a result of climate change may affect photosynthetic electron transport in cyanobacterial photosystems, photoacclimation, and the maximum rates of photosynthesis (e.g., Post et al., 1985; Wu et al., 2009). As a result, cyanobacterial photosynthesis may not actually be affected by warmer temperatures during bloom periods or other times when photosynthetic rates are limited because temperature does not have a large effect on the overall efficiency of photosynthesis (Post et al., 1985).

By comparison, the indirect effect of stronger thermal stability on photosynthesis may alter dominance among cyanobacterial taxa and other phytoplankton. Field observations show that when mixing is strong and buoyant phytoplankton do not have a competitive advantage, *Microcystis* sp. arc outcompeted by superior competitors for light such as *P. agardhii* (see Scheffer et al., 1997) or *C. raciborskii* (O'Brien et al., 2009; Wu et al., 2009). *P. agardhii* has a higher affinity for light than *Microcystis* sp. and if its biomass is sufficiently concentrated during bloom periods, it can shade out competitors, including *Microcystis* sp. (Scheffer et al., 1997). If climate warming stimulates blooms, thereby reducing light availability in the water column, a genus such as *Planktothrix* would benefit. *Microcystis*, however, is adapted to alternating periods of mixing and quiescence and is highly buoyant, potentially favouring the genera under climate scenarios of increased water column stability. When mixing subsides, buoyant colonies can rapidly float up into the near-surface mixed layer and benefit from enhanced access to light. This short-term benefit may have long-term consequences, however, because the time spent at or near the lake surface determines the risk of photoinhibition (described below). Consequently, *Microcystis* may face a trade-off in lakes with strongly enhanced water column stability.

Photoacclimation is the phenotypic adjustment to changes in the availability of light, most notably up or downsize regulation of cellular pigment contents, but also in electron chain components or Calvin cycle enzymes (Falkowski and LaRoche, 1991; MacIntyre et al., 2002). The role of photoacclimation is not just to maximise the rate of photosynthetic carbon assimilation, but also to protect the cells against damage from an excess of energy (Schagerl and Mueller, 2006; Zonneveld, 1998). *Synechococcus* sp., for example, are able to grow under full sunlight but only when acclimated gradually to the extreme conditions (MacIntyre et al., 2002). Photoinhibition of photosynthesis will occur if cells are exposed to an irradiance level that is much higher than what they were acclimated to, causing light stress if irradiance is in excess to what can be used directly in photosynthesis (Powles, 1984). Under these conditions, safe dissipation of the excess excitation energy is required to protect the photosystems from long-term damage (Niyogi, 2000).

Surface bloom formation by buoyant cyanobacteria after a period of intensive mixing will dramatically increase irradiance and can cause severe photoinhibition, even in nutrient-replete cells (Ibelings, 1996; Ibelings and Maberly, 1998). The effect of photoinhibition can be extremely detrimental because cyanobacteria synthesise new gas vesicles during periods of deep mixing (and ensuing low irradiance; Konopka et al., 1987). Once mixing subsides, the now over-buoyant colonies can no longer reduce their buoyancy and will become trapped at the surface (Walsby et al., 1991). Photoinhibition sets in quickly and can induce long-lasting cellular damage (Abeliovich and Shilo, 1972; Zohary and Pais-Madeira, 1990). Ibelings et al. (1994) directly compared *M. aeruginosa* and the green alga *Scenedesmus protuberans* to high (and fluctuating) irradiance, mimicking natural light regimes in lakes. They found that buoyant *M. aeruginosa* was more sensitive to photoinhibition than its green algal competitor. Photoinhibition that is invoked promptly protects cells from potentially much more damaging effects, i.e., it is a mechanism for the long-term protection of photosystem 2 (PS2) (Oquist et al., 1992). Photoinhibition that is quickly activated may protect PS2, but during relatively short periods of high irradiance under wind-mixed conditions, *M. aeruginosa* apparently depresses its rate of photosynthesis while *S. protuberans* maintains uninhibited photosynthesis. It appears that *M. aeruginosa* is not as well adapted to fluctuating light as its eukaryotic competitors and is thus unable to benefit from the saturating irradiance levels that are temporarily available when mixing takes cells to the upper layers of the water column.

Others have also found that mixing not only prevents surface bloom formation but also arrests the growth of bloom-forming species (e.g., Reynolds et al., 1983). This re-emphasises the dependence of buoyant *Microcystis* sp. on a water column that is at least partially stable, enabling the colonies to be maintained in a shallow near-surface mixed layer where light fluctuations are reduced and where irradiance levels are usually consistently high. In a changing climate with stronger and longer periods of water column stability, the buoyancy-dependent niche of *Microcystis* sp. would be strengthened, even in relatively shallow lakes. However, if stability gets too strong and mixing subsides, *Microcystis* biomass would accumulate in surface scums, possibly causing population losses.

The combination of extreme conditions – high irradiance, depleted carbon, and elevated temperatures (Ibelings, 1996; Ibelings and Maberly, 1998) – makes it likely that scums should be considered as net loss factors for buoyant bloom-forming genera, which are costly for slow growing specialists like *Microcystis*. Finally, whether lake warming would indeed promote blooms of taxa like *Microcystis* sp. may critically depend on the degree of water column stability and lake morphometry.

4. Conclusion

Incorporating cyanobacterial physiology into bloom predictions is essential to understand how freshwater and brackish cyanobacteria will respond to climate changes. Fundamentally, cyanobacteria are an extremely diverse group with different sets of traits, and will respond to different aspects of climate change (e.g., increased stratification, altered nutrient availability). For example, *Microcystis* sp. do not fix N but have a relatively high Q_{10} (however, see discussion in this paper), while *Anabaena* sp. fix N but have a lower Q_{10}, and both genera have efficient buoyancy regulation and migration in stable water columns. We would then predict that in warmer waters *Microcystis* may be favoured, but that its competitive advantage may be compromised if N becomes limiting due to altered nutrient delivery. There will most likely also be regional differences in which cyanobacterial taxa dominate, depending on how future climate, hydrology, and nutrient loading vary geographically. Taken together, however, we believe that trade-offs in cyanobacterial physiology among species will overall promote cyanobacterial dominance over other phytoplankton in most future climate scenarios.

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