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Ecological Problems With Iowa's Invasive and Introduced Fishes

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Since the time of European settlement, at least 59 non-indigenous fish species have been introduced, reached, or moved within Iowa waters. At least 28 nonnative fish species have been introduced into, or reported from Iowa waters since settlement. Of that number, 10 are established at this time through natural reproduction. In addition, many species of native fishes have been translocated within the state, and we provide documentation for 31 of these species. Two translocated species, gizzard shad (*Dorosoma cepedianum*) and yellow bass (*Morone mississippiensis*), have had adverse impacts on Iowa's aquatic ecosystems. While many introductions are thought to be benign, problems with non-indigenous fishes include displacement of native fish species, alterations of aquatic habitats, reduction in total aquatic biodiversity, and lowering of water quality. We review the history of Iowa's non-indigenous fishes, document the timing and location of introductions when possible, and discuss problems caused by Iowa's current non-indigenous species as well as species likely to cause ecological problems in the near future.

Fishes highlighted include: common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), bighead carp (*Hybophthalmichthys nobilis*), black carp (*Mylopharyngodon piceus*), silver carp (*Hypophthalmichthys molitrix*), white perch (*Morone americana*), western mosquitofish (*Gambusia affinis*), rudd (*Scardinius erythrophthalmus*), yellow bass, spotted bass (*Micropterus punctulatus*), ruffe (*Gymnocephalus cernuus*), round goby (*Neogobius melanostomus*), and gizzard shad. We also discuss ecological consequences of stocking game fish and hybrids as well as threats from aquaculture, aquarium hobbyists, and anglers. Because eliminating an established nonnative fish is almost impossible, we urge all parties to work to prevent future release and establishment of non-indigenous fishes in Iowa and the United States.

INDEX DESCRIPTORS: Iowa fishes, biodiversity, non-indigenous fishes, nonnative fishes, exotic fishes, non-indigenous species, introduced species, exotic species, common carp, grass carp, bighead carp, black carp, silver carp, rudd, gizzard shad, yellow bass, mosquitofish, spotted bass, white perch, round goby, ruffe, *Cyprinus carpio, Ctenopharyngodon idella, Hybophthalmichthys nobilis, Dorosoma cepedianum, Scardinius erythrophthalmus, Gambusia affinis, Morone mississippiensis, Mylopharyngodon piceus, Hypophthalmichthys molitrix, Morone americana, Micropterus punctulatus, Gymnocephalus cernuus, Neogobius melanostomus.*

The settlement of Euro-Americans in what is now Iowa began a process of ecological alteration. Like so many times throughout the world, people imported and moved fishes to enhance recreational opportunities and food acquisition or to affect ecosystem alteration that was perceived as desirable. Several of these fishes would change Iowa's aquatic environments permanently and irrevocably. To understand the history and impacts of fish introductions in Iowa, we will first summarize the history and ecology of fish introductions in the United States before focusing on Iowa.

Fuller et al. (1999) described a non-indigenous species as a form introduced into an area or ecosystem "outside its historic or natural geographic range"; this includes both foreign (i.e., exotic or nonnative) and transplanted (or "translocated") species. Also called "alien species," "introduced species," "nonnative species," or non-indigenous species, these fishes are forms whose occurrence in a region is the result of human activities that have aided their dispersal across geographical barriers or have created favorable conditions for their establishment. Terminology describing non-indigenous species is varied and complex. We will use the term "invasive exotic" as described by Cox (1999), who makes a distinction between exotic or non-indigenous species (those that only become established) and invasive exotics (those exotic species that pose a threat to the integrity of native ecosystems), and this terminology in our paper is similar to terminology used in Executive Order 13112, Invasive Species, by former President William J. Clinton on 3 February, 1999 (Clinton 1999). For ecologists, it is the rapid spread of the invasive exotics that causes the most concern, and we will primarily focus on the ecological damage done by some of Iowa's invasive exotic fishes and the types of ecological damage that have been documented for these species. We use the term "translocated" to distinguish fishes that were moved within or close to their geo-political range, usually for purposes of stocking game fishes, from "non-indigenous" fishes introduced from outside their native range. For instance, a fish, native to Iowa rivers that drain into the Upper Mississippi River, that was moved to an inland lake within the Missouri River drainage of Iowa would be considered translocated. Also, we will note fishes with recent range expansions into Iowa, but tentatively not label them as non-indigenous because they were native to neighboring states and spread to Iowa on their own. The taxonomy in this paper follows that of Robbins et al. (1991).

Early History of Non-indigenous Introductions in the United States

Release of non-indigenous fishes in the United States began as early as the 1600s with the introduction of the goldfish (*Carassius auratus*) (Crossman 1991), and by the late 1800s, non-indigenous fish introductions were also accompanied by translocation of native fishes to new locations (Carlander 1954, Courtenay 1979, Courtenay 1990, Crossman 1991). With reference to history, Crossman (1991) stated that there were two major periods of fish introductions in North America, the late 1800s and the time following the 1950s.

This resulted in 35 exotic fishes established in North America by 1980 with an additional 68 species by 1991 (Crossman 1991). In the continental U.S. alone, Courtenay et al. (1984) documented 41 established exotic species by 1984, with an additional 63 exoric fishes present in rhe U.S. without an established population. Further, Courtenay and Taylor (1984) described 168 additional native fish species that had been translocated from one area to a new location. By 1993, there were 69 non-indigenous fish species with breeding populations in the U.S. (Courtenay 1993). These data do not represent the thousands of species of aquarium fishes imported into the U.S., which, in 1991, represented almost 200 million individuals a year (Crossman 1991).

Current Status of U.S. Introductions

Nico and Fuller (1999) and Fuller et al. (1999) provided the most current information on distribution of non-indigenous fishes in the U.S. noting that 316 native fishes have been introduced outside their normal geographic range by humans, 185 species have been introduced from foreign countries, and 35 species are hybrids. Of this group, 71 (38%) are established in the wild as reproducing populations. The numbers of introduced species cited by Nico and Fuller (1999) and Fuller et al. (1999) are somewhat higher than those of past researchers because they included all fish introduced into the U.S. since the 1800s whether established or not, and they also count stocked fish as being introduced, even if it was moved within its normal geographic range (i.e., translocated).

Means By Which Non-indigenous Fishes Have Been Introduced

How have non-indigenous species been introduced into the wild? Apart from aquarium fishes sometimes released by their owners, many non-indigenous species were deliberately introduced or translocated because of a real or perceived benefit to humans such as edibility, sporting qualities, aesthetic qualities, or ability to control mosquitoes or aquatic weeds (Moyle 1986, Nico and Fuller 1999). Within this contexr, nonnative fishes in aquaculture confinements present a large potential for new introductions (Courtenay 1993). Courtenay (1993) also documented cases where endangered fishes were introduced into new areas in the hopes of establishing additional viable populations. In addition, non-indigenous fishes have been accidentally introduced into the U.S. through ballast water of ships, through construction of canals and aqueducts, or as discarded baitfish (Moyle 1986, Courtenay 1993, Cox 1999, Nico and Fuller 1999, Kolar and Lodge 2000).

Not all introduced species become established, and not all that do become established become problematic (Taylor et al. 1984, Williamson and Fitter 1996, Cox 1999). Moyle (1986) added that fishes that survive and increase have one or more of the following characteristics: 1) they are hardy enough to survive transport and thrive in disturbed environments, 2) they are aggressive and eliminate native species by competition and predation, 3) their niche is distinct enough from the native fishes that either little interaction with the native fishes occurs or the native fishes are unable to avoid the new competition and predation, 4) they achieve a high degree of reproductive success (i.e., "fitness"), 5) they are preadapted to local conditions, and/or 6) they are able to disperse to and colonize new areas quickly. Stauffer (1984) added that the ability to acclimate to a wide range of environmental conditions is important for the establishment of some non-indigenous species, and he also nored that many exhibit some form of parental care. However, established, nonnative species exhibit a variety of behavioral adaptations such as spawning habits, degree of parental care, adult size, and foraging habits (Moyle 1986). Therefore, it is difficult to identify a single set of characteristics that allow one to predict if an introduced species will be successful, and, most likely, it is a combination of adaptations that promote the reproduction and dispersal of these species.

Stauffer (1984) also proposed that evolution in a competitive environment could preadapr an exotic fish to become established and increase in range. Such a species would, therefore, be a "K" strategist, slower to reproduce and mature because of relatively intense competition, within their native range; however, in their new environment with few competitors, they would be relatively "r-selected," quicker to reproduce and mature with comparably easy access to resources, compared with the local fish fauna.

While direct human involvement is cited as the reason for fish introductions in most cases, a more recent anthropogenic phenomenon, global warming, may eventually cause distributional changes in native fishes (Mandrak 1989, Kolar and Lodge 2000, Sutherst 2000). If fish adapted to warmer waters move northward, they may come into contact with populations to which they were previously separated. While fish distributions have undoubtedly been influenced by past climate changes, anthropogenic warming could be a factor in the near future.

Ecological Problems Caused by Invasive Exotic Fishes

While some introduced and translocated fishes do not persist, and while some introduced fishes become reproductively established but apparently cause little known alteration or damage to the ecosystem, invasive exotics cause several types of problems to our aquatic ecosystems. Invasive species can cause displacement, interference, and/or decline of native aquatic species (e.g., Miller et al. 1989, Power 1990, Hindar et al. 1991, Hilborn 1992, Cox 1999), they occasionally hybridize with native species (e.g., Ferguson 1989, Dowling and Childs 1992, Cox 1999), and they can adversely affect the water quality and habitats of the aquatic ecosystem (e.g., Taylor et al. 1984, Moyle et al. 1986, Cox 1999). Indeed, non-indigenous organisms are partially implicated in the demise of at least half of the extinct U.S. fishes, and they are considered a threat to endangered and threatened fishes (Miller et al. 1989, Williams and Nowak 1993). In general, invasive exotic fishes lead to a decline in fish biodiversity (Moyle and Leidy 1992, Rahel 2000). Disruption from introduced fish, however, may not just be confined to fish ecosystems (Zaret and Paine 1973, Hecnar and M'Closkey 1997, Malakoff 1999, Kolar and Lodge 2000). The classic ecological concept of "the ripple effect" applies: a perturbation in one segment of an ecosystem can have ramifications throughout the entire ecosystem.

Summarizing Iowa's Non-indigenous Fish Species

To what extent have non-indigenous fishes been introduced into Iowa, and what has been the impact of these introductions? While many would recognize the common carp (*Cyprinus carpio*) as an introduced species and have some understanding of the negative impacts of this species, few would know that other non-indigenous fish species have either been introduced into Iowa deliberately or accidentally, that several have reached Iowa on their own, that many species native to Iowa have been translocated to areas within their historic range, and that the potential negative impacts of these introductions are significant. To document these introductions and the impact of the introductions, we conducted an extensive review of the published literature on introduced fishes and on Iowa fishes. In addition, some fish introductions are recorded in published or unpublished records of state agencies, and we reviewed many of the biennial reports of the Iowa fish commissioner for records of fish stocking efforts. While not every record of a fish introduction/stocking in Iowa was examined, we looked at many. In some cases, detailed written records of fish introductions do not appear to exist, and we made the best effort possible to determine what actually occurred.

Key sources of information on Iowa's introduced fishes include the biennial reports of the Iowa fish commissioners to the Iowa General Assembly from 1876 through 1967 (e.g., Evans et al. 1876, Shaw 1878, and Speaker 1965), species accounts and other information in the various editions of *Iowa Fish and Fishing* [especially Harlan and Speaker (1956) and Harlan et al. (1987)], and published summaries of fish faunas of states adjacent to Iowa: Missouri (Pflieger 1997), Nebraska (Morris et al. 1972, Bouc 1987), South Dakota (Bailey and Allum 1962), Minnesota (Eddy and Underhill 1974, Phillips et al. 1982), Wisconsin (Becker 1983, Lyons et al. 2000), and Illinois (Smith 1979, Burr et al. 1996, Laird and Page 1996).

We also utilized information on introduced fishes available on the worldwide web with sites maintained by the U.S. Geological Survey (*http://nas.er.usgs.gov/fishes/fishes.htm*) and the U.S. Fish and Wildlife Service (*http://invasives.fws.gov/*). The recent summary by Fuller et al. (1999) provided the basis from which we began our work on introduced fishes in Iowa.

In some cases, detailed written records of fish introductions do not appear to exist, and we made the best effort possible to determine what actually occurred through interviews with personnel from the Iowa Department of Natural Resources (IDNR) and other fisheries researchers. These same individuals also provided us with the most current information on distribution of non-indigenous fishes in Iowa. Based on our review, we attempted to identify Iowa's non-indigenous species, document fish translocations, describe some of the known effects of these introduced species, and document the need to prevent further negative ecological impacts from non-indigenous fishes.

IOWA'S NON-INDIGENOUS AND NATIVE TRANSLOCATED FISHES

Summary of Iowa's Non-Indigenous Fishes

The most recent summary of non-indigenous fish in the United States is that of Fuller et al. (1999). They list 37 species of non-indigenous fish that are either established or that have been introduced into Iowa. Their total includes 26 nonnative fish species and eleven species that are native to the state but that have been translocated by some means to nonnative areas of the state. These translocations include the bowfin (*Amia calva*), spotfin shiner (*Cyprinella spiloptera*), golden shiner (*Notemigonus crysoleucas*), channel catfish (*Ictalurus punctatus*), northern pike (*Esox lucius*), muskellunge (*Exox masquinongy*), yellow bass (*Morone mississippiensis*), pumpkinseed (*Lepomis gibbosus*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*), and walleye (*Stizostedion vitreum*).

Tables 1 and 2 summarize the best information that we have found on Iowa's non-indigenous and translocated fishes. Table 1 includes summary information for the 28 fish species that are not native to Iowa but have either been introduced to the state or have been introduced in other states and have spread to Iowa. We accept 25 of the 26 nonnative fishes identified for Iowa by Fuller et al. (1999) but do not accept their record for chain pickerel. We feel that the information on esocid distributions in Iowa presented in Crossman (1978) should take precedence over the information in Lee et al. (1980 et seq.) used by Fuller et al. (1999). Crossman (1978) shows that chain pickerel were not introduced to Iowa; he does, however, show that the native grass pickerel has been introduced to the eastern part of the state. Based on new information, we also add the threadfin shad (*Dorosoma petenense*), white catfish (*Ameiurus cattus*), and redtail catfish (*Phractocephalus hemioliopterus*) to Iowa's nonnative fishes (Table 1).

Ten of the 28 nonnative species we identify are considered established in Iowa waters, either through natural reproduction or through maintenance stocking by the IDNR (Tables 1 and 3). Fuller et al. (1999) identify three foreign (exotic), nonnative fishes in Iowa as established through natural reproduction [goldfish, common carp, and brown trout (*Salmo trutta*)]. To this group, we add the following two species that are either known, or suspected, to have naturally reproducing populations in Iowa or its reaches of the Missouri or Upper Mississippi rivers: grass carp (*Ctenopharyngodon idella*), and bighead carp (*Hypophthalmichthys nobilis*). In addition, natural reproduction has been documented in five nonnative Iowa species that are either hybrids or native to other regions of North America: rainbow trout (*Oncorhynchus mykiss*), western mosquitofish (*Gambusia affinis*), redear sunfish (*Lepomis microlophus*), spotted bass (*Micropterus punctulatus*), and sauger × walleye hybrid (saugeye) (*Stizostedion canadense* × *S. vitreum*).

Table 2 includes information for 31 native species known to have been translocated within the state of Iowa. Our addition of 20 native translocated Iowa fishes to the 11 species identified by Fuller et al. (1991) is due primarily to our more detailed review of the literature specific to Iowa fishes, especially the summaries of fishes transported throughout Iowa as part of fish rescue operations as described in the biennial reports of the Iowa fish commissioners (e.g., Shaw 1880, Lincoln 1902). Combining the nonnative introductions and translocations of native fishes, we have documented 59 non-indigenous fish species in Iowa.

During the process of summarizing Iowa's non-indigenous fishes, the issue of "translocation" proved troublesome. That is, Fuller et al. (1999) show several Iowa species as introduced to nonnative areas of the state that are presumed to be native to the entire state, including channel catfish and largemouth bass. We agree that the within-state movement of a species to a drainage basin outside of its historic or natural geographic range constitutes introduction of a non-indigenous species. We question, however, whether the stocking of a species into a waterbody *within* its native range constitutes a non-indigenous introduction (i.e., translocation). Although we followed this convention used by Fuller et al. (1999), we suggest that the issue of identifying truly non-indigenous transplants or translocations in Iowa is problematic for the following reasons.

(1) "Fish rescue operations," the transport of native game and nongame fishes from backwaters of the Iowa reach of the Upper Mississippi River and distribution to other waters in the state, had been underway for approximately 15 years prior to the first statewide fish surveys conducted by Meek (1892, 1893, 1894). Thus, the native distribution of many species in the state cannot be known. This transfer of native fishes from one area of the state to another was conducted to promote sport fishing and provide food fish (Table 2), and Carlander (1954), Conover (1987), and Menzel (1987) described the history of these Iowa fish transfers. Conducted in Iowa from the 1870s to the 1950s, "fish rescue" operations involved summertime removal of game fish stranded in backwaters of the Upper Mississippi River after spring floods. These fish were then transferred, usually by rail car, to inland rivers and lakes. As an example, Bailey and Harrison (1945) felt that this was how yellow bass (*Morone mississippiensis*) were introduced into Clear Lake prior to 1932. This practice came to a halt in the 1950s after construction of fish hatcheries where desired species could be raised under controlled conditions prior to release. Undoubtedly, the fish species noted in Table 2 as translocated through fish rescue operations represent a conservative estimate of species potentially translocated by this activity.

(2) Approximately half of Iowa's 139 presumable native fish species occur in the Upper Mississippi River (Menzel 1987, Pitlo et al. 1995). Thus, the "fish rescue" operations would have provided a means of moving a large proportion of Iowa's fish species to streams, rivers, and lakes in drainages both within and outside of their native range through the many "mixed shipments" of fishes. Because de-

Table 1. Summary of exotic (nonnative fishes introduced into Iowa[1]

Species	Location(s) of Initial Introduction or Record(s)	Approximate Year of Initial Introduction or Record	Current Distribution in Iowa	Status in Iowa[2]
American shad *Alosa sapidissima*	Introduced to Des Moines River at Des Moines	1874–1976 (Evans et al. 1876, Shaw 1878)	Not reported for state (see Harlan et al. 1987)	NR
Threadfin Shad *Dorosoma petenense*	Introduced to Prairie Rose Lake, Shelby Co.	circa 1680 (M. Conover, pers. comm.)	Missouri River (Pegg and Pierce 1996)	NR
Goldfish *Carassius auratus*	Introduced statewide	1887 (Carlton 1888)	Mississippi, Missouri, Cedar, Des Moines, and NE Iowa rivers; scattered locations elsewhere (Harlan et al. 1987)	E
Common Carp *Cyprinus carpio*	Introduced statewide	1885 (Aldrich 1886)	Statewide (Harlan et al. 1987)	E
Grass Carp *Ctenopharyngodon idella*	Statewide	1973 (Harlan et al. 1987)	Statewide (Harlan et al. 1987)	E?
Bighead Carp *Hypophthalmichthys nobilis*	Reported from lower Des Moines River	1990 (Pitlo et al. 1995)	Mississippi, Missouri and lower reaches of major interior rivers (Pitlo et al. 1995, IDNR 2001, and J. Schwartz and L. Miller, IDNR, pers. comm.)	E?
Tench *Tinca tinca*	Introduction to Des Moines River at Ottumwa, Wapello Co.	1891 or 1892 (Griggs 1893, Baughman 1947)	Not reported for state (see Harlan et al. 1987)	NR
Piranha Unidentified species	Cedar River of Linn Co. Other sightings	1983 (Anonymous 1983)	Not reported for state (see Harlan et al. 1987). Occasional reports from other waters (e.g., Aulwes 1999)	NR
White Catfish *Ameiurus cattus*	Reported from Upper Mississippi River, Pool 16	before 1980 (Rasmussen 1979)	Upper Mississippi River, Pool 16 (Pitlo et al. 1995)	R
Redtail Catfish *Phractocephalus hemioliopterus*	Reported from Upper Mississippi River, Pool 9 and Cedar River near Vinton	1999 (Aulwes 1999)	Unknown	R
Tiger Muskellunge *Esox masquinongy* × *E. lucius*	Introduced to selected lakes and reservoirs	1965 (Harlan et al. 1987)	Selected lakes and reservoirs (Harlan et al. 1987)	R, S
Rainbow Smelt *Osmeru mordax*	Reported from Missouri River	1975 (Harlan et al. 1987)	Missouri River (Harlan et al. 1987)	R
Lake Whitefish *Coregonus clupeaformis*	Introductions to Clear Lake, Cerro Gordo Co., Spirit and Okoboji lakes, Dickinson Co., Maquoketa River, Delaware Co.	1876 (Shaw 1878)	Not reported for state (see Harlan et al. 1987)	NR
Coho Salmon *Onchorhynchus kitsutch*	Introduction to West Lake Okoboji, Dickinson Co.	1970 (Jim Christianson, IDNR, pers. comm.)	Not reported for state (see Harlan et al. 1987)	NR
Rainbow Trout *Onchorhynchus mykiss*	Introduced statewide	1874 (Evans et al. 1876)	Coldwater streams in NE Iowa (Harlan et al. 1987)	E, S
Chinook Salmon *Oncorhynchus tshawytscha*	Introduction; location unknown	1875 (Baird 1876 cited in Fuller et al. 1999)	Not reported for state (see Harlan et al. 1987)	NR
Atlantic Salmon *Salmo salar*	Introduced statewide	1875 (Evans et al. 1876)	Not reported for state (see Harlan et al. 1987)	NR

Table 1. Continued.[1]

Species	Location(s) of Initial Introduction or Record(s)	Approximate Year of Initial Introduction or Record	Current Distribution in Iowa	Status in Iowa[2]
Brown Trout *Salmo trutta*	Introduced to West Okoboji Lake (Dickinson Co.) and Five Island Lake (Palo Alto Co.)	1885 (Aldrich 1886, MacCrimmon et al. 1970)	Coldwater streams in NE Iowa (Harlan et al. 1987)	E, S
Lake Trout *Salvelinus namaycush*	Introduced ro approximately 40 lakes, rivers, and streams statewide	1876 (Shaw 1878)	Not reported for state (see Harlan et al. 1987)	NR
Arctic Grayling *Thymallus arcticus*	Introduced to Maquoketa R. Coon Cr.(?), and Yellow R.; also in Village and Clear creeks near Lansing (Allamakee Co.)	Before 1900 (Bowers 1901 *in* Fuller et al. 1999) 1902 or 1903 (Lincoln 1904)	Not reported for state (see Harlan et al. 1987)	NR
Western Mosquitofish *Gambusia affinis*	Reported from upper Mississippi River, Pool 19, Lee Co.	1979 (Harlan et al. 1987)	Upper Mississippi River and lower Iowa River (Harlan et al. 1987, N. Bernstein and M. Bowler, personal communications)	E
White Perch *Morone americana*	Reported from Missouri River and nearby Iowa waters.	1980 (Hergengrader 1980, Fuller et al. 1999)	Missouri River (Pegg and Pierce 1996)	R
Striped Bass *Morone saxatilis*	Introduced into Rathbun Reservoir (Appanoose Co.)	1971 (Harlan et al. 1987)	Not reported for state (see Harlan et al. 1987)	NR
Striped Bass × White bass hybrid (wiper) *M. saxatilis* × *M. chrysops*	Introduced into Saylorville Reservoir (Polk Co.)	1981 (Harlan et al. 1987)	Saylorville Reservoir and Des Moines River; Upper Mississippi River, Pool 14 (Harlan et al. 1987)	R, S
Redear Sunfish *Lepomis microlophus*	Introduced into selected southern Iowa lakes	Early 1960s (Speaker 1965, Harlan et al. 1987)	Selected southern Iowa lakes (Harlan et al. 1987)	E
Spotted Bass *Micropterus punctulatus*	Introduced into White Breast Creek (Marion Co.) and Middle Raccoon River (Guthrie Co.)	1963 (Speaker 1965, Harlan et al. 1987)	Lake MacBride, Coralville Reservoir, and Iowa River, Johnson Co. (Harlan et al. 1987)	E
Sauger × Walleye hybrid *Stizostedion canadense* × *S. vitreum*	Twelvemile Lake, Union Co. and Lake Icaria, Adams Co.	1986 (Hill 1996)	Rock Creek and Saylorville lakes, Missouri R., Twelvemile Lake, Union Co. and Lake Icaria, Adams Co. (M. Conover, IDNR, pers. comm.)	E?
Tilapia Unidentified species	Introduced to Lake LaVerne, Ames, Story Co.	1968, 1969 (Carlander 1978)	Not reported for state (see Harlan et al. 1987)	NR

[1]Additional sources: Baird (1876), Baird (1878), Harlan and Speaker (1956), Conover (1987), Menzel (1987), Lucas (2000).
[2]E = established; one or more natural breeding populations known to exist
E? = reported for state, possibly established; existence of a breeding population not confirmed.
R = reported from one or more localities; no evidence of establishment
S = stocked
NR = not reported

Table 2. Native fishes known to have been translocated within Iowa.[1]

Species		Waterbodies/Areas with Either Current or Historical Translocated Populations
Paddlefish	*Polyodon spathula*	Possibly introduced to Okoboji lakes in Dickinson Co. (Menzel 1987)
Bowfin	*Amia calva*	Introduced to Spirit and Okoboji lakes, Dickinson Co. (Lee et al. 1980 et seq., Harlan et al. 1987, Menzel 1987); introduced to Missouri River drainage of Iowa (Cross et al. 1986)
American Eel[2]	*Anguilla rostrata*	Possibly introduced to Spirit Lake, Dickinson Co. (Harlan and Speaker 1956; Menzel 1987); stocked nearly statewide in 1870s and 1880s (Shaw 1878; Harlan and Speaker 1956)
Gizzard Shad	*Dorosoma cepedianum*	Stocked into Iowa's flood control reservoirs (Coralville, Rathbun, Red Rock and Saylorville reservoirs) (Harlan et al. 1987); also inadvertently introduced into Prairie Rose L., Shelby Co. (M. Conover, pers. comm.)
Spotfin Shiner	*Cyprinella spiloptera*	Introduced to Chariton R. drainage; drainages of Missouri R. tributaries in western Iowa (Lee et al. 1980 et seq.; Harlan and Speaker 1956; Harlan et al. 1987)
Emerald Shiner	*Notropis atherinoides*	Introduced to Rathbun Reservoir (Appanoose Co.) as forage (Harlan et al. 1987)
Spottail Shiner	*Notropis hudsonius*	Reported from Lake Manawa (Pottawattamie Co.), introduced to Rathbun Reservoir (Appanoose Co.) (Harlan et al. 1987)
Golden Shiner	*Notemigonus crysoleucas*	Introduced to southern Iowa lakes (Harlan et al. 1987)
Fathead Minnow	*Pimephales promelas*	Native to entire state; introduced to Clear L. (Cerro Gordo Co.) (Bailey and Harrison 1945)
Black Bullhead	*Ameiurus melas*	Native to entire state; distributed widely in ponds, lakes and reservoirs (Harlan et al. 1987); introduced to Clear L. (Cerro Gordo Co.) (Bailey and Harrison 1945)
Brown Bullhead	*Ameiurus nebulosus*	Introduced into Missouri River drainage of southwest Iowa (Cross et al. 1986)
Blue Catfish	*Ictalurus furcatus*	Possibly introduced to Okoboji lakes (Menzel 1987); stocked in Big Creek L., Polk Co. (Harlan et al. 1987)
Channel Catfish	*Ictalurus punctatus*	Native to entire state; widely stocked in ponds, lakes and reservoirs (Harlan et al. 1987)
Flathead Catfish	*Pylodictis olivaris*	Okoboji lakes, Dickinson Co. (Larrabee 1926); Big Creek L., Polk Co. (M. Conover, pers. comm.)
Grass Pickerel	*Esox americanus*	Transplanted to Linn Co. in 1999 at Indian Creek Nature Center (P. Sleeper, IDNR, pers. comm.); also shown as "introduced" in northeastern Iowa by Crossman (1978)
Northern Pike	*Esox lucius*	Stocked in several man-made lakes (Harlan et al. 1987)
Muskellunge	*Esox masquinongy*[3]	Stocked in several waterbodies, including Clear L. (Cerro Gordo Co.), Big Spirit and West Okoboji lakes (Dickinson Co.); also Big Creek L. (Polk Co.), and Rathbun Reservoir (Appanoose Co.) (Harlan et al. 1987)
Central Mudminnow	*Umbra limi*	Disjunct population in Clay County (Missouri R. drainage). Possibly due to fish rescue operations?
Brook Trout	*Salvelinus fontinalis*	Stocked in coldwater streams of northeastern Iowa (Harlan and Speaker 1956, Harlan et al. 1987)
White Bass	*Morone chrysops*	Clear L., Cerro Gordo Co. (Bailey and Harrison 1945), possibly other natural lakes in north-central and northwestern Iowa (Harlan and Speaker 1956)
Yellow Bass	*Morone mississippiensis*	Clear L., Cerro Gordo Co. (Bailey and Harrison 1945); also, lakes and reservoirs of southern and western Iowa (Lee et al. 1980 et seq.) including Lake Manawa, Pottawattamie Co., (Harlan et al. 1987), Rathbun Reservoir, Appanoose Co. (M. Conover, IDNR, pers. comm.) and Lake Icaria, Adams Co. (Fuller et al. 1999), introduced into Missouri River drainage of Iowa (Cross et al. 1986)
Rock Bass	*Ambloplites rupestris*	Introduced at two locations, including Upper Iowa River, during 1892–1893 biennial period (Griggs 1893); mentioned as distributed via fish rescue operations to 15 locations statewide in 1901 including Des Moines R. at Ottumwa and Humboldt, Boone R. at Webster City, and Nodaway R. at Corning (Lincoln 1902)
Pumpkinseed	*Lepomis gibbosus*	Introduced into Missouri River drainage of Iowa (Cross et al. 1986); possibly introduced to lakes in the Missouri River drainage of southwestern Iowa as part of fish rescue operations (see distribution in Harlan et al. 1987)

Table 2. Continued.[1]

Species		Waterbodies/Areas with Either Current or Historical Translocated Populations
Warmouth	*Lepomis gulosus*	Introduced to several southern Iowa lakes in Missouri River drainage (see Harlan et al. 1987) possibly through fish rescue operations; also stocked in several natural lakes prior to 1900 (see Griggs 1893)
Bluegill	*Lepomis macrochirus*	Widely stocked in ponds, lakes, and reservoirs (Harlan et al. 1987); possibly introduced into Missouri River drainage of Iowa (Cross et al. 1986)
Smallmouth Bass	*Micropterus dolomieu*	Possibly introduced to Big Spirit and West Okoboji lakes (see Larrabee 1926, Johnson 1941, Eddy and Underhill 1974,and Robbins and Mac-Crimmon 1974)
Largemouth Bass	*Micropterus salmoides*	Native to entire state; widely stocked into ponds, lakes and reservoirs (Harlan et al. 1987)
White Crappie	*Pomoxis annularis*	Native to entire state; widely stocked into ponds, lakes and reservoirs (Harlan et al. 1987)
Black Crappie	*Pomoxis nigromaculatus*	Widely stocked into ponds, lakes and reservoirs (Harlan et al. 1987; introduced into Missouri River drainage of Iowa (Cross et al. 1986)
Yellow Perch	*Perca flavescens*	Records of introductions from 1900–1920 cited by Fuller et al. (1999); introduced to Clear L. (Cerro Gordo Co.) (Bailey and Harrison 1945); also found in lakes and reservoirs in the Missouri River drainage of southern Iowa (Harlan et al. 1987)
Walleye	*Stizostedion vitreum*	Possibly introduced into Missouri River drainage of Iowa (Cross et al. 1986); Iowa distribution greatly expanded through stocking in larger lakes (Harlan et al. 1987)

[1]Bailey and Harrison (1945), Lee et al. (1980 et seq.), Cross et al. (1986), Harlan et al. (1987), Menzel (1987), Fuller et al. (1999), and personal communications.
[2]Some eels were brought from out-of-state (Table 3).
[3]Rare in Mississippi River in early fish surveys; few records in state prior to 1945.

tailed records of the species rescued and translocated into Iowa waters were not kept (or at least have not survived), we have no way to determine, or to even reasonably approximate, the actual number of species translocated.

(3) Several species in the Missouri River drainage of northwest Iowa are more typical of the Upper Mississippi River drainage of central and eastern Iowa, thus suggesting the possibility of nonnative introductions. The presence of these fishes in northwest Iowa, however, has been attributed to several possible Missouri/Mississippi interdrainage connections in the upper reaches of the Big Sioux and Little Sioux river basins (Missouri drainage) and the Minnesota and Des Moines river basins (Mississippi River drainage) during high water conditions. Species that may have used either the Big Sioux/Minnesota or Little Sioux/Des Moines connections include paddlefish (*Polyodon spathula*), longnose gar (*Lepisosteus osseus*), bowfin, skipjack herring (*Alosa chrysochloris*), central mudminnow (*Umbra limi*), northern pike, golden shiner, emerald shiner (*Notropis atherinoides*), spottail shiner (*Notropis hudsonius*), American eel (*Anguilla rostrata*), white bass (*Morone chrysops*), smallmouth bass (*Micropterus dolomieu*), pumpkinseed, walleye, and yellow perch (see Bailey and Allum 1962, Cross et al. 1986, Menzel 1987). While not discounting entirely the influence of early Iowa fish rescue operations, Bailey and Allum (1962) felt that the primary routes of dispersal of these fishes to the Missouri drainage involved these interdrainage connections.

Certainly, some Iowa species of fish, primarily game species, were translocated early in the state's history by humans and became established in waterbodies beyond their native distribution. For example, Bailey and Harrison (1945) attribute the presence of white bass and yellow bass in Clear Lake (Cerro Gordo Co.) to either targeted stocking or to inadvertent introduction through fish rescue operations. They imply that these two species were not present in this natural glacial lake prior to these introductions. They also mention regular stocking of walleyes, largemouth bass, white crappie (*Pomoxis annularis*), yellow perch as well as occasional stockings of smallmouth bass, black bullhead (*Ameiurus melas*), channel catfish, northern pike, and bluegill (*Lepomis macrochirus*) during the period 1894 to 1943, and they note that several nongame fishes were stocked into the lake during this period including golden shiners and fathead minnows (*Pimephales promelas*). They do not, however, indicate, nor were they likely able to determine, whether these species occurred naturally in this lake. Thus, the determination of whether these introductions involve truly non-indigenous species cannot be made.

The inclusive approach to identifying "non-indigenous species" used by Fuller et al. (1999) and in this paper suggests that all stocking activities represent the introduction of a non-indigenous species. The identification of all Iowa waterbodies that may have been stocked with such non-indigenous fishes during 125 years of fisheries management, however, is not only difficult to determine (for reasons given above) but is also beyond the scope of this paper. And whether, for example, the introduction of channel catfish into a human-made lake within a river basin where the species is native constitutes an "introduction" or "translocation" in the context of "non-indigenous" species is a topic for future debate.

Previous summaries of Iowa fishes (e.g., Bailey 1951, 1956, Harlan and Speaker 1956, Menzel 1981, and Harlan et al. 1987) have focused on nonnative species established in the state through either natural reproduction or intentional stocking. In previous summaries, no detailed attempt was made to account for non-indigenous fishes that were introduced to state waters but failed to become established, and relatively little attention was given to native fishes translocated to nonnative areas of the state. Our review shows that at least 12

Table 3. Comparison of summaries of nonnative fishes in Iowa through natural reproduction and/or maintenance stocking from 1951 through present.

Species		Bailey (1951, 1956)	Menzel (1981)[1]	Harlan et al. (1987)	Phillips and Gengerke 1999	Current (2001)
Goldfish	*Carassius auratus*	X	X	X	X	X
Common Carp	*Cyprinus carpio*	X	X	X	X	X
Grass Carp	*Ctenopharyngodon idella*		X	X	X	X
Bighead Carp	*Hypophthalmichthys nobilis*				X	X
Tiger Muskellunge	*Esox masquinongy* × *E. lucius*			X	X	X
Rainbow Smelt	*Osmerus mordax*[2]			X	X	X
Rainbow Trout	*Oncorhynchus mykiss*	X	X	X	X	X
Brown Trout	*Salmo trutta*	X	X	X	X	X
Western Mosquitofish	*Gambusia affinis*		X	X		X
Striped Bass	*Morone saxatilis*[3]		X			
Wiper	*M. saxatilis* × *M. chrysops*			X	X	X
Redear Sunfish	*Lepomis microlophus*		X	X	X	X
Spotted Bass	*Micropterus punctulatus*		X	X	X	X
Saugeye	*Stizostedion canadense* × *S. vitreum*				X	X
Total number of species:		4	9	11	12	13

[1]Did not include hybrid fishes (tiger muskellunge and wiper).
[2]Seasonal occurrence only in Missouri River; no evidence of natural reproduction
[3]Established through stocking at time of Menzel (1981); however, no longer stocked in Iowa waters; now considered "not reported" for the state (see Harlan et al. 1987).

nonnative fish species were introduced to Iowa waters during the late 1800s and early 1900s, but only four of these species were noted as "established" in Iowa waters as of 1950: goldfish, common carp, rainbow trout, and brown trout (Bailey 1951, 1956). All four species had been present in Iowa waters since before 1900. Goldfish and common carp had long been well-established through natural reproduction. Rainbow trout and brown trout, however, were established primarily through stocking, although some natural reproduction by both species had been documented in the 1950s (Harlan and Speaker 1956). A recent summary from the IDNR Fisheries Bureau shows that the number of Iowa coldwater streams supporting natural reproduction of rainbow trout and brown trout (and the native brook trout (*Salvelinus fontinalis*)) has increased considerably over the last 50 years (Moeller 1999).

Three decades later, Menzel (1981), although not including hybrid sport fishes being stocked at the time, concluded that there were now at least 9 fish species established in Iowa either intentionally or accidentally. To the previous four "exotic" species he added grass carp, striped bass, redear sunfish, spotted bass and the western mosquitofish. Harlan et al. (1987) added two hybrid fishes [tiger muskellunge (*Esox masquinongy* × *E. lucius*) and wiper (*Morone saxatilis* × *M. chrysops*)] as well as the rainbow smelt (*Osmerus mordax*) to Menzel's (1981) list of nonnative species. They also noted that the attempt to develop a recreational fishery for striped bass ended in 1980 and that this species probably no longer occurred in Iowa waters. Phillips and Gengerke (1999) added two species to the list of established nonnative fishes in Iowa: bighead carp and saugeye. They did not, however, list the western mosquitofish. Thus, with our addition of the western mosquitofish, the current total of nonnative fish species either established in Iowa through natural reproduction and/or maintenance stocking is 13 (Table 3).

New Species of Concern in Iowa

New non-indigenous species to the state, like the bighead carp, have probably established reproducing populations (Table 1), and others may soon enter state waters. In addition, if the round goby (*Neogobius melanostomus*) successfully invades the Upper Mississippi River basin from the U.S. Great Lakes, it may soon appear in Iowa where it will probably negatively impact native fishes (Jude et al. 1992, Charlebois et al. 1997).

Iowa is also threatened by invasion of the ruffe (*Gymnocephalus cernuus*) and the white perch (*Morone americana*), which are also in the Great Lakes (Phillips and Gengerke 1999), and the silver carp (*Hypophthalmichthys molitrix*) and rudd (*Scardinius erythrophthalmus*) are additional species that may one day appear in Iowa (IDNR 2001). As we note later, the white perch may already be in western Iowa waters along the Missouri River.

Influence of Iowa's Climate on Nonnative Introductions

Iowa's geographical location in the temperate latitudes with typically cold winters has undoubtedly limited the ability of many introduced fish to establish populations in the state. In an overview and history of fish introductions, Courtenay (1993) estimated that 51% of the exotic fishes established in the U.S. originally came from the aquarium and hobby industries, but most of these fishes appear to be established in the coastal regions of the U.S., such as the warm waters of Florida (Courtenay 1997, Courtenay and Stauffer 1990). Temperate regions of the U.S., such as Iowa, tend to have many fewer exotic species (Fuller et al. 1999). The only hobby fish established in Iowa is the goldfish. This native of Asia was possibly released into U.S. waters as a forage fish for game fishes or a baitfish, but possibly also introduced from aquaria and ornamental ponds (Mills et al. 1993). In Iowa, this species was first introduced in the late 1880s as an ornamental species (Carlton 1888, Harlan and Speaker 1956). The lack of tropical ornamental fish in Iowa is no doubt a result of relatively severe winters that hinder survival of cold-intolerant aquarium fishes released to Iowa waters. Similarly, the predominance of warm water habitats in the state's streams, rivers, and lakes has prevented the establishment of the wide variety of cool-water and coldwater species, both native and nonnative, introduced across Iowa from the mid-1870s to the early 1900s.

However, there are increasing reports of southern, warmer-water species being captured in Iowa. For example, a spotted gar (*Lepisosteus oculatus*) was recently caught in the Upper Mississippi River (M. Bowler, pers. comm.), and freckled madtoms (*Noturus nocturnus*), first reported in 1984 in southeastern Iowa (Paragamian 1986), are also being captured in the Upper Mississippi River (M. Bowler, pers. comm.) (Table 4). While it is unknown if such range expansions are due to global warming, movement of southern species north should be monitored to determine if this is a trend.

Significance of Large Rivers to Nonnative Introductions

Moyle (1986) pointed out that large rivers are more susceptible to establishment of introduced species, and Iowa is bordered by two major rivers that are also connected to each other: the Missouri and the Upper Mississippi rivers (Fig. 1). Additionally, large rivers like the Wisconsin, Illinois, and Ohio all flow into the Upper Mississippi River after receiving tributaries from a large region, and several Upper Mississippi River tributaries connect to the Great Lakes. Therefore, a fish species introduced into the Great Lakes, a drainage between the Appalachian and Rocky mountains, or a drainage between northern Minnesota, parts of Canada, and the Gulf of Mexico could eventually reach Iowa's border and become established in one of the state's many tributaries of the Missouri and/or Upper Mississippi rivers (Fig. 1). From those tributaries, the exotic species could conceivably spread into the entire state.

As an example, the connection between the Upper Mississippi River and the Great Lakes, via the Chicago Sanitary & Ship Canal and Illinois River, has allowed several exotic fishes from the Great Lakes to find their way to the Mississippi River drainage. This route, as yet, has not resulted in exotic fishes reaching Iowa waters, although recent records for round goby in the upper Illinois River (Keppner and Theriot 1997, Steingraeber and Guilfoyle 1997) suggest this possibility. In addition, the active aquaculture industry in several states within the lower Mississippi River basin and this industry's experiments with nonnative fishes for pest control has served as a source of several exotic fishes, such as the bighead carp, that have moved upriver to inhabit the Upper Mississippi River basin. Further, the experimental stockings of game and forage fish in the large, mainstem reservoirs on the Missouri River in the Dakotas have provided populations of fish that could disperse downriver to the state of Iowa, and these stockings have allowed populations of rainbow smelt to inhabit, on a seasonal (winter/spring) basis, the Iowa reach of the Missouri River.

Of the 10 currently, established nonnative fishes (Table 1), only the western mosquitofish and the bighead carp have reached the state and established populations on their own power (Table 4). In addition, a spotted gar (*Lepisosteus oculatus*) was recently reported from Iowa waters in Pool 13 of the Upper Mississippi River (M. Bowler, pers. comm.), thus suggesting than an additional fish species has moved into Iowa waters without direct assistance from humans. This is the first confirmed Iowa record for spotted gar. Aulwes (1999) also noted several recent Iowa records of mature redtail catfish (*Phractocephalus hemioliopterus*) being caught in both the Upper Mississippi and Cedar rivers. How redtail catfish, noted from a single U.S. record in Florida by Fuller et al. (1999), reached Iowa is unknown.

Intentional Introductions of Non-indigenous Fishes in Iowa

State-sponsored introductions

While several of Iowa's non-indigenous fishes have reached Iowa waters via river connecrions, most of the exotic fish with populations established in Iowa today, either through natural reproduction or routine stocking, have resulted from intentional introductions by the state fishery agency. With the exception of goldfish, common carp, and grass carp, the motivation for intentional introduction of nonnative fish species to Iowa waters has been enhancement of the state's recreational fishery.

State-sponsored introductions of game fishes continue today with introductions targeted toward Iowa's larger lakes and reservoirs (Table 2), and the distribution of some of these fishes appears confined to these larger bodies of water. For example, Harlan and Speaker (1956) reported only two or three records of the muskellunge, which they felt had been transported into the state, but Harlan et al. (1987) noted the stocking of muskellunge fry into Iowa's major lakes and reservoirs after 1960. Conover (1987) also noted various management techniques used to favor production of game fishes over fishes that either have less appeal to anglers or that compete with game fishes. Such management included introduction of forage fish like the spottail shiner and emerald shiner to reservoirs, and it is likely that the gizzard shad (*Dorosoma cepedianum*) was inadvertently introduced to an Iowa lake (Prairie Rose Lake, Shelby Co.) for this reason.

It is difficult to document all of the intentional introductions done within the state. The early (pre-1900) efforts to manage Iowa's fish populations were focused, in part, on introduction of popular sport and food fishes from throughout the United States. Although a wide variety of species were introduced, salmonid fishes, either those native to the U.S. or previously stocked into U.S. waters by other state or federal agencies, were the preferred species for introduction into Iowa waters during this period. Beginning in the middle 1870s, these introductions are summarized, with varying levels of detail, in the biennial reports of the state fish commissioners (e.g., Evans et al. 1876). In reviewing just the records from 1874 to 1887 (Evans et al. 1876, Shaw 1878, Shaw 1880), a conservative estimate of the fishes introduced into the state numbers in the millions of individuals of many species.

Introductions by citizens

Not all intentional introductions, however, have resulted from activities of government agencies. Private citizens and sporting groups have stocked game fish into ponds and have released what they felt were desirable species into rivers (Avise et al. 1997). For example, the second author recalls taking the tiger muskellunge from a farm pond in Montgomery County, Iowa in 1968, well before the state of Iowa began widespread introduction of this hybrid to its waters. He later learned that a local fisherman had purchased and placed four tiger muskellunge into the farm pond. Nor are escapes or releases from aquaculture facilities or release of aquaria fish the fault of governmental natural resource deparrments. Currently, Iowa Code Section 481A.47 prohibits the introduction of nonnative fish into the state unless the person applies for and receives a permit from the IDNR, and Section 481A.83 prohibits a person from stocking any public water of the state with fish without permission from the IDNR.

IMPACTS OF IOWA'S NON-INDIGENOUS AND TRANSLOCATED FISHES

Non-indigenous and Translocated Fishes in Iowa without Documented Ecological Impacts

For many of Iowa's introduced fishes, no impact is known. This apparent lack of impact, however, may largely be an artifact of inattention. At this time, we conditionally classify the following species as either nonnative introductions or native translocations that are either well established or commonly found within the state, but

Table 4. Exotic and native North American fishes either introduced to, or native to, areas outside of Iowa, believed to have reached the state via hydrologic connections.

Species		Year and Origin of U.S. Introductions Affecting Iowa	Current Distribution and Status in Iowa	First Year Reported in Iowa
Spotted Gar	*Lepisosteus oculatus*	Naturally-occurring populations in Mississippi R. downriver from state (Pflieger 1997)	Reported in 2000 from Pool 13 of the Upper Mississippi R. near Bellevue, IA; no evidence of natural reproduction	2000 (M. Bowler, pers. comm.)
Threadfin Shad	*Dorosoma petenense*	Naturally-occurring populations in Missouri and Mississippi rivers downriver from state (Pflieger 1997)	Reported from Missouri River; no evidence of natural reproduction	1996 (Pegg and Pierce 1996)
Bighead Carp	*Hypophthalmichthys nobilis*	1972 in Arkansas (Cremer and Smitherman 1980)	Reported from Mississippi, Missouri and lower reaches of major interior rivers; presume natural reproduction	1990 (Pitlo et al. 1995)
Freckled Madtom	*Noturus nocturnus*	Naturally-occurring populations in Missouri and Illinois downriver from state (Paragamian 1986)	Reported from English River, Washington Co. (Paragamian 1986) and tailwater of Lock and Dam 12 on the Upper Mississippi River (M. Bowler, pers. comm.).	1984 (Paragamian 1986)
White Perch	*Morone americana*	1964 in Nebraska (Hergengrader and Bliss 1971)	Reported from Missouri River; no evidence of natural reproduction	1980 (Hergenrader 1980; Pegg and Pierce 1996)
Rainbow Smelt	*Osmerus mordax*	1971 in South Dakota (Bouc 1987; Mayden et al. 1987)	Reported from Missouri River (seasonal population only); no evidence of natural reproduction	1975 (Harlan et al. 1987)
Western Mosquitofish	*Gambusia affinis*	Naturally-occurring populations in Missouri downriver from state (Pflieger 1997)	Reported from Mississippi River and lower Iowa River; established populations.	1979 (Harlan et al. 1987)

Fig. 1. Relationship of Iowa's rivers to the Mississippi and Missouri river drainages.

for which we do not know of major impacts to Iowa's ecosystem. Translocated native fishes in this group include muskellunge, central mudminnow (*Umbra limi*), emerald shiner, golden shiner, spottail shiner, blue catfish (*Ictalurus furcatus*), American eel, white bass, and northern rock bass (*Ambloplites rupestris*). Nonnatives include rainbow trout, brown trout, rainbow smelt, tiger muskellunge, goldfish, wiper (striped bass × white bass hybrid), and redear sunfish.

For instance, the goldfish is distributed in a variety of locations across the state, likely reflecting intentional releases from aquaria or garden ponds, but early fish commissioners also distributed large numbers of this species. For example, during the decade of the 1890s, state fish commissioners fulfilled at least 475 requests for goldfish from Iowa citizens (Soper 1892, Griggs 1893, Delevan 1895, Delevan 1900). Pitlo et al. (1995) reported goldfish from several pools of the Upper Mississippi River, but only the more down-river pools (17 through 19) supported substantial populations. Hesse et al. (1982) reported goldfish for the Missouri River along Harrison County. Historically, goldfish were considered scarce (Harlan and Speaker 1956), and this characterization holds true today for most state waters. Harlan et al. (1987) showed a total of nine records for the 1975–1985 survey period with eight of the records from the Iowa-Cedar River basin. Post-1985 surveys conducted by IDNR continue to demonstrate the sporadic occurrence of this species, with recent records only from Big Creek in Henry County, Johnson Run near Shenandoah in Page County, and North Cedar Creek near Bussey in Marion County. While goldfish appear to be scarce in most of Iowa, Day et al. (1996) presented data that question whether small populations of goldfish can be considered benign. Therefore, although the goldfish is relatively scarce in Iowa, some of the same impacts that will be discussed for the common carp and the grass carp are applicable to the goldfish (Richardson et al. 1995). The goldfish may never become numerous due to competition with native fishes and other introduced fishes (Laird and Page 1996).

At this time, it is too soon to determine what the impacts will be, if any, but these species should be monitored for signs of impact. In addition, we do not know of ecological impacts of many game fish species, which are routinely stocked from fish hatcheries. Several studies point to impacts from hatchery fish (e.g., Hilborn 1992), and even fishes like rainbow trout and brown trout with supposed low impacts to native species have documented impacts (Fausch and White 1981, Waters 1983, Fausch 1988, Dumont et al. 1988, Dowling and Childs 1992, Krueger and May 1991, Clark and Rose 1997). Further, the stocking of hybrid game fish (e.g., tiger muskellunge and the saugeye) also has not been analyzed as to potential ecological impacts. For instance, it has recently been reported that the saugeye is breeding back into native sauger (*Stizostedion canadense*) populations in the Iowa reach of the Missouri River (M. Conover, pers. comm.).

We believe that the regular addition of large numbers of predatory, non-indigenous or indigenous fishes impacts Iowa's aquatic ecosystems (Taylor et al. 1984, Hecnar and M'Closkey 1997, Cox 1999, Nico and Fuller 1999, Rahel 2000). Many Iowa lakes, however, have already been altered by over 100 years of stocking (intentional and inadvertent) as well as other fish management techniques such as stocking forage fishes for game species. Further, the addition of a small, non-game fishes like the spottail shiner could conceivably alter populations of indigenous minnows which had evolved without the introduced or translocated species present, and even a few exotics can affect an ecosystem if a disease or parasite is introduced along with the fish (i.e., Hoffman and Schubert 1984, Welcomme 1984, Kennedy and Pojmanska 1996, Bergersen and Anderson 1997).

ECOLOGICAL PROBLEMS CAUSED BY IOWA'S NON-INDIGENOUS AND TRANSLOCATED FISHES

While ecologists and conservationists are mainly concerned with ecological problems associated with the spread of invasive exotic fishes (Sheldon 1988, Simberloff 1996), governmental bodies, businesses, and the public are mainly aware of the economic impacts (Wiley 1997, Pimental et al. 2000). In this section we will emphasize the known and potential ecological impacts of several of Iowa's established, introduced fishes rather than the costs of managing invasive, non-indigenous species and their related economic impacts. Non-indigenous or translocated species known to have caused adverse impacts to Iowa's aquatic ecosystems include common carp, grass carp, gizzard shad, and yellow bass. Non-indigenous species present in state waters potentially causing severe problems include bighead carp, white perch, spotted bass, and western mosquitofish. We list species in both groups in their approximate order of real or potential impact in Iowa waters.

Non-indigenous and Translocated Species in Iowa Known to Cause Ecological Problems

Of the non-indigenous fishes known to have caused significant ecological impact in Iowa, the common carp and grass carp are the most widespread, and each species as a history of ecological impact that is well-documented in the literature. Translocations of gizzard shad and yellow bass have caused significant but localized problems in the state.

Common Carp

The common carp is a native of Asia, where it serves as an important food source. From Asia, it was brought into Germany and the rest of Europe centuries ago where it was also considered an important food item as well as a game fish. Common carp prefer moderately warm waters, can grow as large as 22.7 kg with 11.3–13.6 kg common, are long-lived, and are highly fecund (Gengerke 1987). The common carp is omnivorous with diet studies showing a predominance of animal matter (especially aquatic insects) compared to plant material (Moen 1953, Becker 1983, Pflieger 1997). In Europe, this species was cultured in captivity to produce a variety that had fewer scales and bones, and it was originally brought to the U.S. in anticipation that this would be a desirable game and food fish (Courtenay 1979, Radonski et al. 1984). However, once released into U.S. waters, either deliberately or by accidentally escaping from breeding ponds, the species reverted to its natural state of coarse flesh with increased scales (Courtenay 1979). Most researchers feel that the common carp was introduced into the U.S. prior to 1850 in New York State (DeKay 1842, Courtenay 1979, Radonski et al.

1984); however, Nico and Fuller (1999) feel that the first verifiable record is from California in 1872 (Poppe 1880). Although it immediately thrived in the waters of the U.S., it was soon deemed undesirable as a food item or sport fish, and, therefore, the common carp quickly has become became known as an invasive exotic that is generally despised by anglers, commercial fishery workers, and aquatic and fisheries biologists (Radonski et al. 1984).

Entry/Introduction into Iowa

Common carp were introduced into Iowa waters in the early 1880s. As early as 1877, Iowa's first fish commissioner, B.F. Shaw, stated that he was considering initial distribution of the highly touted common carp (Shaw 1878). Shaw had heard and read of carp propagation, and he realized that carp were a potential source of food and were better suited for the warmer and muddier waters in portions of Iowa. He stated that "so little is known of this fish in the country," and in the second biennial report of the state fish commission he included a letter from J. A. Poppe from Sonoma, Ca., regarding pond culture of carp (Shaw 1878). Shaw (1880) also noted that: "There is, in my opinion, no fish known the introduction of which into Iowa waters promises so much and such general good as the carp." Shaw (1880) noted that, during the 1878–1879 biennium, he had not yet been successful in procuring carp from the U.S. Fish Commissioner (Spencer F. Baird) for distribution in Iowa, but he hoped that he would soon "procure enough to make a beginning."

In his report for the 1880–1881 biennium, Shaw (1882) reported that five "carp ponds" were constructed on the state hatchery grounds near Anamosa in summer 1880 that had been stocked with "a fine lot of breeding fish." Shaw expressed confidence that these ponds would provide "quantities of this valuable fish sufficient to fully stock both public and private waters" of Iowa. In a note dated November 5, 1881, Shaw (1882) related his delight at discovering that the carp placed in one of the "carp ponds" had reproduced. He closed the section on carp in his 1882 biennial report with the following passage: "As the fish in this pond were only four or five inches long when put into the pond last spring [1881], we had hardly hoped for any young carp this season. How many may be found when a final examination of the ponds is made, we cannot tell, but that these young fish have bred is full of promise for the future good. As far as known, these are the first carp ever bred in Iowa." Shaw's writings obviously reflect the prevailing enthusiasm in the late 19th Century United States for common carp as a superior food fish and as a welcome addition to the fishery resources of the nation. In his report for the 1882–1883 biennium, Shaw (1884) described his plan for distributing common carp in Iowa: young carp would be furnished to any person in Iowa, and that for a period of five years after they breed, persons receiving carp "will plant one-third of the increase in the public waters of Iowa." Although no mention is made of carp distribution in Shaw's report for the 1882–1883 biennium (Shaw 1884), over 150 requests from Iowa citizens for common carp were met during the 1884–1885 biennium (Aldrich 1886). Subsequent reports of the Iowa fish commissioners document the applications for, and distribution of, common carp throughout the state (e.g., Carleton 1888, 1890).

Understandably, but unfortunately, neither Shaw nor other fishery workers of the day, could foresee the downside of introducing this adaptable and aggressive exotic fish species. Over the next 20 years, Shaw and subsequent state fish commissioners would distribute common carp raised at state hatcheries to hundreds individuals in Iowa.

By turn of the century, however, the honeymoon period with common carp in Iowa was beginning to close. Earlier, in the report for the 1894–1895 biennium Delevan (1895), although continuing to promote carp distribution and culture, noted problems with the taste of carp, especially those raised in mud-bottomed ponds with stagnant water. The report for the 1901–1902 biennium (Lincoln 1902) contains the first overtly negative reference to common carp in Iowa. In describing problems with illegal taking of fish (seining and dynamiting), Lincoln (1902) noted that many rivers and lakes in Iowa are "swarming with carp and buffalo to the detriment of the game and better classes of food fish." He thus suggested that state law be amended to allow, under direction of the state game warden, the taking of common carp and buffalo by spear or other means. By the end of the first decade of the 20th Century, and approximately 25 years after its introduction, the state of Iowa began attempts to remove this species from state waters. By 1909, carp populations had grown so much that the first state effort to remove was initiated at Lost Island Lake in Palo Alto County (Harlan and Speaket 1956). In his 1912 biennial report, state fish and game warden Lincoln (1912) delivered the following valediction on the culture and distribution of carp in Iowa: "These fish did not meet the expectations and were not approved as a table fish, and the culture of them ceased." He added, "It is not a question of what to do with them to rid our waters of them for they are here to stay."

A state program to remove common carp, as well as several less abundant native species [e.g., gar (*Lepisosteus* spp., bowfin, and buffalo (*Ictiobus* spp.)], began in Iowa around 1910. This program, although with different goals and methods, continues today. From the early through middle 1900s, state crews conducted annual seining, netting, or trapping of carp and other "rough fish" primarily from heavily utilized shallow natural lakes in northern Iowa but also from several human-made lakes and river impoundments. As documented in biennial reports of the state fish and game warden (Lincoln 1912, Hutton 1936, Stiles 1951), the goal of this program, variously called "obnoxious fish removal" and "rough fish control," was to remove as many rough fish as possible to allow better growth and survival of the more highly prized game fish species. This program involved donation of a portion of the fish removed to welfare agencies, and a portion of the catch was sold to defray program costs. Common carp was often the target species because they were believed responsible for the decline of aquatic vegetation, for the destruction of eggs and nests of game fish during spawning activities, and for the general deterioration of the quality of lake habitats and fisheries (Aitken 1938). In the mid-1950s, fish toxicants were first used to control common carp and other rough fish populations in Iowa's waters. The 1956 chemical renovation projects at Storm Lake and the West Fork Des Moines River at Humboldt were the first attempts to control Iowa's rough fish populations with toxicants (Stiles 1959). Although removal through seining, netting and trapping continued in the shallow natural lakes of northwest Iowa, the use of fish toxicants expanded in the early 1960s. During this decade, fish populations of several Iowa lakes and river reaches were chemically eradicated to remove abundant rough fish populations and then were quickly restocked with game fish (Powers 1961). Although initially believed successful, these efforts produced little or no long-term effects on game fish populations, especially in the river reaches. State crews continued rough fish control through under-ice seining at natural lakes until the early 1970s when this activity was transferred to commercial fishermen under contract with the state. Such contracts continue on a limited basis today (Marion Conover, pers. comm.). Since the early 1970s, the focus of rough fish removal programs has primarily been the utilization, through a commercial fishery, of the underutilized populations of common carp and other rough fish species. Secondarily, this program has provided some conrol on the ability of these populations to expand to nuisance levels. Overabundance of common carp in certain Iowa lakes remains a serious fisheries management problem. The IDNR Fisheries Bureau continues to chemically renovate lakes with nuisance-level populations of carp and other non-game fish species with special attention to eliminating shallow areas preferred by carp and to preventing carp from gaining access to the lake in the future.

Despite their widespread distribution by the late 1800s, and despite their reaching nuisance levels in Iowa's lakes and rivers during the first decade of the 20th Century, the common carp was seldom encountered during early surveys of Iowa fishes. In his late 19th Century surveys of approximately 50 Iowa streams, rivers, and lakes, Meek (1892, 1894) did not report common carp. Similarly, Call's (1892) report on fishes of the Des Moines River basin does not mention this species.

Possibly the earliest "scientific" reference to common carp from Iowa waters is that of Larrabee (1926) who noted that this species first appeared in the Okoboji lakes of northwest Iowa in approximately 1910; this is also the time when common carp were considered "obnoxious" in Iowa waters and became the target of control programs (Aitken 1938, Harlan and Speaker 1956). Larrabee (1926) also reported capture of several common carp from the Little Sioux River in 1922. The next reference is that of Jones (1928) who collected common carp in 1926 from a floodplain lake of the Cedar River (Goarcke's Lake) near Vinton in Benton County. Results of the 1932 survey of lakes, rivers and streams of northern Iowa by Carl L. Hubbs and J. Clark Salyer of the University of Michigan further suggest that, at least during the first third of the 20th Century, carp continued to be rarely seen outside of the natural lakes of northern Iowa. Common carp were taken in only nine of over 72 collections they made during July and August of that year, and eight of the nine locations were either in, or at the outlet of, natural lakes (UMMB 1936).

Although relatively few surveys of fishes were conducted during the forty years following Meek's surveys of the late 1880s and early 1890s, the relatively scarcity of records for common carp during this time suggests that the spread of this exotic fish in Iowa was gradual rather than explosive. The relatively rapid dispersal and increase in abundance of common carp in Illinois described by Forbes and Richardson (1908), however, was likely similar to the common carp's occupation of Iowa waters. Regardless, by the middle of the 20th Century, the common carp was generally accepted as one of the most widespread and abundant of Iowa's fishes with the ability to live and reproduce in a wide variety of habitats and conditions (Harlan and Speaker 1956).

Unintended Consequences of Introduction

Common carp can impact water quality and interfere with the growth and reproduction of native fishes, and these well-known impacts have long generated negative sentiments toward the species. The following are documented impacts of common carp on aquatic ecosystems of the United States: (1) increased nutrient recycling from sediments, (2) decreased macrophyte growth through increased turbidity and/or feeding, (3) increased turbidity through feeding and spawning behavior, (4) increased turbidity through wind/wave action on disturbed and macrophyte-free sediments, and (5) impacts on native fishes (Becker 1983, Taylor et al. 1984, Lubinski et al. 1986, Baker et al. 1993). The latter impacts on native fishes include removal of vegetated habitats required for growth and reproduction of native fishes, predation on eggs of native fishes, and ecological competition with similar species [e.g., carpsuckers (*Carpiodes* spp.) and buffaloes] and/or species or life stages that utilize the same food resources as the common carp. The degree to which common carp can cause adverse impacts to aquatic ecosystem is strongly related to their density (Becker 1983). Where densities of common carp remain low, few problems with either water quality or competitive interactions are likely to occur. When densities are high, however, common carp have the ability to radically alter the chemical and biological characteristics of the waterbodies they inhabit.

The primary and most-frequently documented impacts of common carp are increased turbidity and the reduction or elimination of submersed aquatic vegetation. Baker et al. (1993) summarized research showing the ability of common carp to influence turbidity and internal nutrient loading in lakes and reservoirs. They noted that common carp disturb and re-suspend bottom sediments through their feeding and spawning activities, with the consequences of increased turbidity, reduced macrophyte growth, and increased susceptibility of disturbed and macrophyte-free sediments to re-suspension by wind and wave action. They cited research demonstrating the ability of common carp and several other bottom-feeding fish species to recycle significant amounts of nutrients (especially phosphorus) from the lake bottom into the water column. They also described the ability of high densities of bottom feeding fish to increase trophic state and to delay or prevent lake recovery following reduction of external nutrient loads.

Although common carp can and have been used for control nuisance submersed aquatic plants in ponds and lakes, the resulting increase in turbidity and other negative impacts makes them undesirable as an aquatic vegetation control mechanism (Harlan et al. 1987). For example, the uprooting of aquatic vegetation by common carp removes important foods for waterfowl, reduces photosynthesis, decreases substrates for invertebrates that are essential to the ecosystem and/or prey for fishes, reduces refugia for fish fry, and can lead to phytoplankton blooms which further increase the turbidity (Courtenay 1979, Taylor et al. 1984, Lougheed et al. 1998).

Carp also tend to have a competitive advantage over native species in disturbed waters due to their tolerance of turbidity, sewage pollution, and agricultural run-off; in addition, carp-related turbidity can interfere with normal respiration and reproduction of a variety of fish species (Taylor et al. 1984). Becker (1983) summarized research suggesting competition between common carp and young largemouth bass for similar food sources, between green sunfishes (*Lepomis cyanellus*) for similar habitats and spawning areas, and between black bullheads for similar habitat, spawning areas, and food sources. Competition with ecologically similar and commercially important species such as bigmouth buffalo (*Ictiobus cyprinellus*) and carpsuckers, has been hypothesized (Laird and Page 1996).

While often perceived as the cause of increased turbidity and related changes in Iowa's aquatic ecosystems (e.g., declines in submersed aquatic vegetation and adverse impacts on native species), the spread of the common carp in the Midwest occurred simultaneously with the rise of cities and their industries as well as the development the region for agricultural. Almost immediately following European settlement, water quality impacts related to discharge of untreated or poorly treated municipal and industrial sewage were observed, and impacts from agricultural practices contributed to degraded water quality, including increased water temperatures and turbidity. Whether the common carp caused these changes, contributed to these changes, or simply benefited from them, is difficult to determine. Regardless, the effects of the common carp on any increases in water turbidities and related changes cannot definitively be separated from the effects contributed by agricultural erosion and the rise of cities and industries in the Midwest (Dymond 1955, Forbes and Richardson 1908).

Current Status

Today, the common carp is one of the most common and abundant fishes in Iowa, both in terms of geographic distribution and the diversity of aquatic habitats that it occupies. While remaining an important part of commercial fisheries and while common carp are used in the production of dietary supplements, fertilizer, and other products, this species continues to occur at nuisance levels in several of the state's publicly-owned lakes and is the focus of restoration activities at these lakes. In other waterbodies of the state, for example streams, rivers, and flood control reservoirs, the impacts caused by common carp, especially the absence of submersed aquatic vegetation and increased turbidity, have existed for several generations and are generally accepted today without excessive concern. While millions of dollars have been spent on largely ineffective programs to control and eradicate the species (Courtenay 1979, Radonski et al. 1984), the common carp has become an important part of commercial fisheries in states of the Upper Mississippi River basin (Pflieger 1997, Becker 1983, Harlan et al. 1987).

Projections for the Future

Common carp long ago invaded, and influenced, nearly every waterbody in the state. Thus, we do not feel that increases in the magnitude or frequency of problems with common carp in Iowa are likely. This species, however, will continue to present serious challenges in the management of the state's lakes for recreational fisheries and other types of water-based recreation. Important lessons have been learned in attempts to remove and control this species over the last one hundred years. These lessons include the following: (1) removal of carp and other rough fish from open river reaches, regardless of the scale of the removal/eradication effort, does not effect long-term changes in either fish populations or habitat quality; (2) any attempt to eradicate carp from a lake must also include steps to prevent re-entry of carp to the lake; (3) deep lakes with basins having steep slopes are less prone to develop nuisance-level common carp populations; and (4) anglers must be educated as to the potential consequences of using young carp for bait. These and other lessons have resulted in much-improved techniques of successfully addressing water quality and fisheries problems caused by common carp. Nonetheless, the common carp is a highly adaptable and capable invasive aquatic species, and the problems it causes will certainly continue as they have for the past century.

Grass Carp

The grass carp, or white amur, was first imported to the U.S. from eastern Asia in 1963 to fisheries experimental stations in Alabama and Arkansas to evaluate its usefulness for the control of aquatic vegetation. Although initially confined to fisheries experimental stations, both accidental and intentional releases soon occurred. In 1966, fry that were spawned at the Stuttgart, Arkansas station escaped into the White River (Raibley et al. 1995). Courtenay (1993) also noted that fish farmers in Arkansas illegally distributed grass carp to private citizens without the knowledge of law enforcement officials. This species was distributed widely across the U.S. during the 1970s and 1980s by state fisheries agencies and by private hatcheries (Raibley et al. 1995). Courtenay (1993) also noted that fish farmers in Arkansas illegally distributed grass carp to private citizens without the knowledge of law enforcement officials.

Entry/Introduction into Iowa

Grass carp were first introduced into Iowa in 1973 by the Iowa Conservation Commission (ICC) [predecessor agency to the IDNR] for the purpose of controlling nuisance aquatic vegetation in publicly-owned lakes and ponds (Harlan et al. 1987); and, with state approval, private citizens could stock them. Stocking of this species in state waters continues today.

The grass carp is an effective biological control of nuisance aquatic vegetation, and Harlan et al. (1987) thought it to have no deleterious effects on Iowa native fishes. This view appears to be shared worldwide, and the grass carp has been introduced in at least 47 nations (Shireman and Hoyer 1986, Courtenay 1993). Mitzner (1978) cited only beneficial effects of introductions of grass carp to an Iowa lake. While grass carp can reduce aquatic vegetation, most research indicates negative consequences to the introduction of grass carp to an aquatic system.

Unintended Consequences of Introduction

With many states placing this fish into their lakes and ponds to control nuisance vegetation, the movement of grass carp to U.S. streams and rivers was inevitable. As evidence of this movement, a commercial fishery has existed in the Mississippi River throughout the 1990s (Pflieger 1997). While it was initially thought that the grass carp would not be able to reproduce outside of its native rivers, fry were soon reported in the wild (Welcomme 1984, Raibley et al. 1995). Conner et al. (1980) reported the first record of grass carp from the lower Mississippi River. Reports of natural reproduction in grass carp, especially in the Mississippi and Missouri river systems, have continued (e.g., Pflieger and Grace 1987, Brown and Coon 1991, Raibley et al. 1995). Grass carp likely do not reproduce in smaller streams (IDNR 2001), and, like Missouri, records from smaller streams in Iowa likely represent escapees from lakes and ponds where they were stocked (Pflieger 1997).

Although grass carp have proved to effectively control most forms of submersed aquatic vegetation, several adverse effects have been noted in the literature including habitat alterations, changes in chemical water quality, shifts in plankton communities, and a related increase in lake productivity (Chilton II and Muoneke 1992, Bain 1993, Baker et al. 1993).

Some of these negative effects alter littoral zone habitats and aquatic food webs. For instance, elimination of aquatic macrophytes in a lake's littoral zone removes an important habitat type for small fish and for invertebrate species that serve as food sources for larval and adult fish. Although this habitat alteration would suggest adverse impacts on certain fish species, such as Centrarchids, that use littoral zone macrophytes for refugia and feeding areas, such impacts have not been conclusively demonstrated.

In addition, changes in water quality that have followed introductions of grass carp include increased turbidity, decreased levels of dissolved oxygen, and increased levels of plant nutrients. Following removal of aquatic macrophytes, phytoplankton communities of lakes have increased such that shifts occurs from clear-water/macrophyte systems to more turbid and phytoplankton-dominated systems (Leslie et al. 1983). In addition, shifts in dominant species of phytoplankton toward less desirable forms (e.g., blue-green algae) have also been noted (Richard et al. 1984).

Although the grass carp is effective at controlling some aquatic vegetation, concerns exist that it may reach high enough populations to cause ecological damage (Shireman 1984). Shireman (1984) and Taylor et al. (1984) also cited a variety of studies that indicated that some of the same negative ecosystem impacts associated with the common carp were also documented with the grass carp. Further, Russian studies determined that several game fish populations decreased in areas where grass carp were introduced, an effect seen in some U.S. studies but not others (Shireman 1984). Additionally, McNight and Hepp (1995) found that grass carp mainly consumed native aquatic vegetation in areas dominated by Eurasian watermilfoil (*Myriophyllum spicatum*), and, overall, potential plant foods of waterfowl were reduced in their study while Eurasian watermilfoil, an invasive exotic, was not affected.

There are additional studies documenting problems with grass carp introductions. Similar to common carp, negative impacts of grass carp seem to be proportional to their density. In low numbers, little impact is discerned; however, at higher densities, the ecosystem may be severely altered. Taylor et al. (1984) suggested that use of the grass carp might be of less concern in aquaculture situations that are managed as monocultures rather than in wild aquatic systems where heterogeneity of plant communities is desirable.

Current Status

The distribution of this species in Iowa closely follows the distribution of human-made lakes and ponds (Harlan et al. 1987); thus, most records for this species are from southern and western Iowa where such waterbodies are most likely to occur. Not surprisingly, recent Iowa stream records for grass carp are also from this portion of the state. Single specimens of adult grass carp have been collected by IDNR staff from Cedar Creek in Jefferson County in 1990, from Waubonsie Creek in Mills County in 1991, and from Honey Creek in Louisa County in 1998. Pitlo et al. (1995) reported grass carp as "uncommon" for most of the pools of the Iowa portion of the Upper Mississippi River, and Pegg and Pierce (1996) reported grass carp from the Iowa portion of the Missouri River.

Although naturally-teptoducing populations of grass carp appear to be established in, or at least near to, the Iowa reaches of the Upper Mississippi and Missouri rivers (Pflieger and Grace 1987, Brown and Coon 1991, Raibley et al. 1995), surveys to date have not discovered evidence of natural reproduction in Iowa's larger interior rivers (e.g., the lower Cedar, Iowa, Skunk, and Des Moines) (IDNR 2001). Based on reports of natural reproduction from adjacent states, we feel that naturally-reproducing populations of grass carp probably exist in the Iowa teaches of the Missouri and Upper Mississippi rivers and possibly in the lower reaches of interior rivers of southern Iowa.

Projections for the Future

The stocking of grass carp in ponds and man-made lakes for the control of nuisance vegetation will continue as will the potential problems with alterations of water quality, aquatic habitats, and fish populations related to the presence of this species. However, the occurrence of large populations of grass carp in Iowa's interior rivers and streams, and the potential adverse impacts that such populations could cause, is not expected. The expansion of grass carp populations in Iowa may be limited by the general absence of submersed aquatic vegetation in Iowa's present-day streams and rivers. Without this primary food source, the state's streams and rivers are likely unsuitable for growth, reproduction, and expansion of grass carp populations.

We feel, however, that the potential remains for adult grass carp that escape from lakes, ponds, and private hatcheries to adversely affect, at least in the short term (few years), riverine wetlands, and possibly upland wetlands, where proper ecosystem function and utilization by humans depends upon the presence of submersed aquatic vegetation.

An idea that has been promoted to lessen the potential impacts of grass carp introductions was to breed infertile grass carp. Chilton II and Muoneke (1992) and Courtenay (1993) described a technique of shocking grass carp eggs during artificial fertilization by heat, cold, chemical, or pressure to produce triploid offspring. While there was no guarantee of sterility of these fish, progeny of triploid individuals were thought to have a low probability of survival. Courtenay (1993) argued, however, that each fish needed to be checked to determine its ploidy prior to release, but he also suggested that this was a potentially useful technique to lessen concerns raised over releases of grass carp. Hybrid triploid carp can also be produced by crossing a bighead male and a female grass carp (Shelton and Smitherman 1984). However, Gebhard and Maughan (1986) questioned whether all fish produced by this cross were truly triploid and also noted that hybrids were not as effective at controlling aquatic vegetation as were grass carp (also Shireman 1984; Chilton II and Muoneke 1992).

Gizzard Shad

Although native to the entire state (Lee et al. 1980 et seq.), Iowa's earliest fish surveys suggest that gizzard shad were less abundant in Iowa prior to 1900 than today. This species was seldom encountered by Meek during his statewide surveys of the late 1800s (Meek 1892, 1894). Of the approximately 50 Iowa waterbodies he sampled from 1889 to 1893, gizzard shad were reported from only eight sites, with abundance at four of these sites characterized as "rare." This relative paucity of early records suggests that changes in Iowa's surface waters over the last century have favored the expansion of this species. These changes include increased turbidities, related increases in water temperatures, and the creation of several large flood control reservoirs. The general lack of records for this species in the northern half of Iowa likely reflects the preference of gizzard shad for warmer waters; they reach the northern limit of their distribution in North America in the Upper Mississippi River and Missouri River basins immediately north of Iowa (Lee et al. 1980 et seq.).

At the midpoint of the 20th Century, Harlan and Speaker (1956) indicated that the Iowa distribution of the gizzard shad was mainly in the boundary waters (Upper Mississippi, Missouri, and Big Sioux rivers) of Iowa and in the lower reaches of the state's larger interior rivers (e.g., Des Moines, Iowa/Cedar, and Nishnabotna), and in several natural lakes. Approximately 30 years later, Harlan et al. (1987) showed a similar distribution with the exception of a greater number of records and increased abundance in the southeastern quarter of the state.

Gizzard shad are now common to abundant at several sites (e.g., South Skunk River at Ames, Des Moines River at Des Moines, and the Iowa River at Amana and Iowa City) where Meek (1892) did not report the species. This increase is likely related, at least in part, to construction of four federal flood control reservoirs in Iowa since the mid-1950s (Coralville (1959), Red Rock (1968), Rathbun (1969), and Saylorville (1977)). The large lakes created by these projects provided favorable habitat for gizzard shad that allowed its numbers to increase.

Nonnative Introductions into Iowa Waters

Initially, the gizzard shad probably was transferred throughout the state as part of fish rescue operations conducted by state and federal agencies in Iowa from the 1870s to the 1950s. This species would be a likely inhabitant of the Upper Mississippi River backwaters from which fish were seined and distributed as part of "mixed shipments" to numerous waterbodies across the state. Bailey and Harrison (1945) provided a similar example for the yellow bass. Later, the gizzard shad was introduced into Iowa's four flood control reservoirs (Coralville, Rathbun, Red Rock, and Saylorville lakes) to provide forage for game fish (M. Conover, pers. comm.). Gizzard shad were inadvertently introduced into Prairie Rose Lake (Shelby Co.) in the mid-1970s in an attempt to stock the closely related threadfin shad as a temporary forage base (M. Conover, pers. comm.). The population of gizzard shad in this lake expanded to nuisance levels such that a chemical renovation of the lake's fish populations was conducted in the early 1980s.

Unintended Consequences of Introduction

Although young shad are utilized by piscivorous fish species, this fast growing species can, in the absence of predation from game fish, soon grow to a non-vulnerable size (Harlan et al. 1987, Yako et al. 1996). In such cases, populations of this prolific fish species can reach nuisance levels. Studies have shown that large populations of gizzard shad can actually hinder growth of predatory fish in some cases, and gizzard shad have been shown to compete for food with bluegills (Harlan et al. 1987), yellow perch (Shepherd and Mills 1996), and other predatory fishes (Dettmers and Stein 1996). However, this competition is not seen between gizzard shad and white crappies and black crappies (*Pomoxis nigromaculatus*) (Pope and DeVries 1994, DeVries et al. 1998, Slipke et al. 1998), and some studies verify the importance of gizzard shad in the diet of predatory fish (Stahl and Stein 1994, Madenjian et al. 1996, Michaletz 1997).

A further negative impact is that gizzard shad also can increase the nitrogen and phosphorous content of open water as they excrete nutrients ingested by feeding on organic detritus (Schaus et al. 1997). On the positive side, they are important intermediate hosts of larvae for several species of freshwater mussels (Harlan et al. 1987), and aquatic birds feed on the large numbers of gizzard shad in Iowa's reservoirs and lakes.

Control of gizzard shad in lakes is difficult because of their ability to switch between foods and avoid predators once they reach a certain size (Stein et al. 1995, Dettmers et al. 1996, Dettmers et al. 1998). Recently, the IDNR suggested draining Big Creek Lake and killing the fish that remain with a piscicide to eliminate the gizzard shad, which had become so numerous as to monopolize the plant food of the game fish (DeValois 2001). This plan was abandoned, however, after a winter kill reduced the number of gizzard shad (M. Conover, pers. comm.).

Therefore, the translocatation of gizzard shad has produced more complex ecological effects than simply providing forage for game fish, and this reinforces the need for caution in introducing even native fishes into new habitats outside their geographic range. It also points to some of the pitfalls of managing an ecosystem primarily for game fish.

Projections for the Future

Based on the ecology of this species, including its fecundity and fast growth, its nearly statewide distribution, and its ability to thrive and reach nuisance levels in Iowa waters, we feel that gizzard shad will continue to present challenges for the management of Iowa's lakes and reservoirs. Thus, while chemical renovation of lakes and/or their watersheds may provide temporary solutions, shad-related impacts to Iowa's recreational fisheries are likely to continue. The challenges of addressing problems caused by gizzard shad in Iowa waters rival those of the even more widespread, prolific, and adaptable common carp.

Yellow Bass

In Iowa, this species is native to the Upper Mississippi River and its tributaries in eastern Iowa (Lee et al. 1980 et seq.). Prior to the 1950s, this species was seldom reported from Iowa waters. Yellow bass were not reported outside of the Upper Mississippi River in the surveys of Meek (1892, 1893) and Hubbs (UMMB 1936). Both Meek and Hubbs sampled Clear Lake in Cerro Gordo County as part of their surveys; neither reported yellow bass from this lake. By the early 1940s, however, the yellow bass was well-established in Clear Lake (Bailey and Harrison 1945). A comparison of distributions of this species in Iowa between the 1950s (Harlan and Speaker 1956) and 1980s (Harlan et al. 1987) shows little change in the range of this species.

Nonnative Introductions into Iowa Waters

The yellow bass was likely included with other fish species seined from backwaters of the Upper Mississippi River and distributed as "mixed shipments" of fishes to waters statewide as part of fish rescue operations in late 1800s and early to mid-1900s. As a result of this activity, yellow bass populations were established in several Iowa lakes including Clear Lake in Cerro Gordo County (Bailey and Harrison 1945), Lake Manawa in Pottawattamie County, and several human-made lakes and water supply reservoirs in southern Iowa (Harlan et al. 1987). Over the last decade, yellow bass have unexpectedly been reported from several human-made lakes in southern Iowa, including Rathbun (Appanoose Co.), Twlevemile (Union Co.), Icaria (Adams Co.), and Anita (Cass Co.). The origin of yellow bass in these lakes is unclear but likely involves either intentional introductions by anglers or unintentional introductions by IDNR through stocking of walleye and/or channel catfish (M. Conover, comm.). Yellow bass have existed in Rathbun Lake for several years, and the possibility of this species contaminating tearing ponds of channel catfish and walleye at the Rathbun Hatchery exists. Fuller et al. (1999) noted that the recent occurrence of yellow bass in Browning Oxbow along the Missouri River in Kansas is believed due to stocking of this species in Lake Icaria in Iowa.

Unintended Consequences of Introduction

In some Iowa lakes, introduced populations of yellow bass fluctuate widely, and large populations are believed detrimental to other game species, especially bluegill and largemouth bass. Declines in a lake's recreational fishery can occur, and such declines are believed to be the result of both increased competition for food resources when large populations of yellow bass present as well as the tendency for yellow bass populations to cycle between large numbers of small (stunted) individuals followed by drastic declines in the population (M. Conover, pers. comm.).

Projections for the Future

Based on its somewhat limited distribution in Iowa and on its apparent inability to thrive in Iowa's rivers and streams, we anticipate that ecological impacts caused by introduced populations of yellow bass will continue to be limited to only a few Iowa lakes. Similar to other nuisance fish species, however, established populations of yellow bass are difficult to control. Drastic measures, such as lake draining or chemical renovation are the only effective ways of eliminating nuisance populations of this species.

Non-indigenous Species in Iowa With Potential to Cause Ecological Problems

The following non-indigenous fishes are present in Iowa or its border rivers and are known or suspected of causing ecological problems where their populations are established. The bighead carp and white perch are fishes with the potential to cause serious impact to Iowa's aquatic ecosystems. The spotted bass and western mosquitofish are less likely to cause widespread problems, but they are capable of significant localized impacts to native fish communities.

Bighead Carp

Bighead carp are native to eastern China and were introduced into the U.S. in 1972 at a private Arkansas fish hatchery (Cremer and Smitherman 1980); other hatcheries received the fish at about the same time (Shelton and Smitherman 1984). Bighead carp have been promoted as a profitable food fish for aquaculture as a human food item. Studies have shown that bighead carp has many desirable characteristics for an aquaculture species including easy handling and capture, ability to eat artificial food, and rapid growth (Shelton and Smitherman 1984); and some tests indicated that humans preferred the taste of canned bighead carp over that of canned tuna (Brown 1992, Brown 1997a and b, Martin 1999).

Whether intentionally or accidentally released into the wild, bighead carp are no longer confined to fish farms (Cox 1999). Approximately 10 years following its introduction, the bighead carp began to appear in open waters of the United States, especially the Ohio and Mississippi rivers, and their appearance in the wild was attributed to escape from aquaculture facilities (Fuller et al. 1999). Tucker et al. (1996) reviewed the biology of the bighead carp as they documented recent records from the Upper Mississippi River in Illinois and Missouri, and their research indicated that the fish was established, reproducing in a variety of habitats, and spreading (i.e., becoming an invasive exotic). Additional evidence of natural reproduction and established populations of bighead carp is provided by Pflieger (1997) and Burr et al. (1996).

Entry/Introduction into Iowa and Current Status

The bighead carp has invaded Iowa's waters and was first reported in Iowa from the lower Des Moines River in 1990 and from Pool 11 of the Upper Mississippi River in 1993 (Pitlo et al. 1995). This species has continued to spread quickly in both the Upper Mississippi and Missouri rivers and their drainages (J. Schwartz and L. Miller, pers. comm.). Currently, they are numerous in the Chariton River downriver from Rathbun Reservoir in Appanoose County and in the lower Des Moines River in southeastern Iowa. Although natural reproduction of this species in Iowa waters has not yet been documented, reports of natural reproduction in wild populations of bighead carp in Illinois (Burr et al. 1996) and Missouri (Pflieger 1997) suggest that this species is also self-sustaining in Iowa waters, especially in the Iowa portions of the Missouri and Upper Mississippi rivers. In effect, it should be considered an established species.

Unintended Consequences of Introduction

It is not yet known what will be the impact of this planktonic filter feeder. Most authors hypothesize that the bighead carp will compete with native planktivores (e.g., paddlefish, bigmouth buffalo, and gizzard shad), early (planktivorous) life stages of many native fish species, as well as native freshwater mussels (Pflieger 1997, Burr et al. 1996, Laird and Page 1996, Schrank 1999). Netting studies in the Upper Mississippi River conducted by the Illinois DNR have found that bighead carp school with paddlefish. Studies have indicated, however, that bighead carp only filter feed in cages and that free-living fish tended to be more opportunistic plankton and bottom feeders (Opuszynski et al. 1991). It is also known that moving water is required to float its eggs until they hatch (Dong and Li 1994, Tucker et al. 1996).

In addition to impacts on native fishes, the planktivorous feeding habit of bighead carp may also adversely affect water quality. While bighead carp can control nuisance algal growth in small ponds, Lieberman (1996) found that they simultaneously reduced zooplankton, which, in turn, increased the turbidity as nannoplankton concentrations increased. Datta(Saha) and Jana (1998) also noted the potential for eutrophication by introductions of bighead carp.

Projections for the Future

Despite the lack of documented impacts of this relatively recent invader, the continued rapid increases in abundance and distribution of bighead carp in rivers of the Upper Mississippi and Missouri river basins, as described both anecdotally and in the literature, suggests significant potential impacts to Iowa's aquatic resources. Research to determine the distribution and status of this species in Iowa is needed, as are efforts to document any adverse ecological impacts related to its presence.

White Perch

The white perch is an anadromous species native to the Atlantic coast of North America and its associated estuaries, rivers and freshwater lakes. This species likely reached the Great Lakes via the Erie Barge Canal before 1950 when this species was first reported from this drainage. The white perch dispersed westward through the Great Lakes system and reached Lake Michigan in 1988 (Fuller et al. 1999). By 1991, white perch had moved into the upper Illinois River system, and, by 1992, it was found at the confluence of the Illinois and Upper Mississippi rivers. This species is now present throughout the state of Illinois and is almost certainly established in the state (Burr et al. 1996). Additional introduced populations were established in Nebraska in the mid-1960s when white perch were transported from New Jersey to the Valentine state fish hatchery in north-central Nebraska. While the intent was to introduce this euryhaline species to several alkaline lakes of the Nebraska Sandhills region, white perch fry were accidentally introduced into a reservoir in southeastern Nebraska with hydrologic connections to the Missouri River (Hergenrader and Bliss 1971, Hergenrader 1980). Since its introduction to Nebraska, white perch have also been reported from the Nebraska reach of the Missouri River (Bouc 1987) and in the state of Missouri (Pflieger 1997). Records from the Mississippi River in southern Missouri in the early 1990s are believed due to dispersal of white perch from Lake Michigan via the Chicago Sanitary and Ship canal to the Illinois and Mississippi rivers, although the Missouri River is seen as a potential source of these records as well (Burr et al. 1996 and Pflieger 1997).

Entry/Introduction to Iowa Waters

Since its introduction to Nebraska, white perch have also been reported from the Nebraska reach of the Missouri River (Hergenrader 1980, Bouc 1987) and in the state of Missouri (Pflieger 1997). In addition, Pegg and Pierce (1996) collected white perch from the Iowa reach of the Missouri River during their 1996 field season.

Unintended Consequences of Introduction

The variety of impacts associated with white perch introduction include consumption of large volumes of eggs of game species such as walleye, white bass, and possibly other species; possible direct predation on minnows of the genus *Notropis*; competition for food needed by game species (e.g., yellow perch) and possibly non-game species (e.g., minnows of the genus *Notropis*); and hybridization with white bass (Fuller et al. 1999). Hergengrader and Bliss (1971) reported that, following its 1964 introduction to Wagon Train Reservoir near Lincoln, Nebraska, white bass replaced the black bullhead as the reservoir's dominant fish species by the late 1960s. Both Wagon Train and Stagecoach reservoirs in southeastern Nebraska were eventually chemically renovated to remove white perch (Bouc 1987). In addition to impacts on native species, large white perch populations tend to suffer from stunting, and, thus, their contribution to recreational fisheries is limited (Hergengrader and Bliss 1971, Burr et al. 1996).

Current Status

Currently, this species is known only in Iowa from the Missouri River. White perch was not included in Harlan et al.'s (1987) summary of Iowa fishes, nor was this species identified as occurring in the Iowa reach of the Upper Mississippi River by Pitlo et al. (1995). White perch have not been reported from Pool 13 of the Upper Mississippi River despite intensive sampling of its fish populations over the last decade (Gutreuter 1997; Bowler 1998, 2000, 2001). Other than the records for the middle Missouri River by Hergengrader (1980) and Bouc (1987), the report of white perch from the Iowa reach of the Missouri River in 1996 by Pegg and Pierce (1996) is the only recent record for this species in Iowa waters.

Projections for the Future

With non-indigenous populations likely established throughout the state of Illinois (Burr et al. 1996) and with recent records from the middle Missouri River basin (Pflieger 1997), the white perch is now known from nearly all states surrounding Iowa. In addition, white perch are known to move considerable distance upstream during spawning movements. Thus, due both to their current distribution in the Midwest, and due to their ecology, this species is a likely candidate for movement into the state's waters. Surveys are needed to determine the presence of this species in western Iowa waters, beginning in floodplain lakes with hydrologic connections to the Missouri River. Of the nonnative species in Illinois, Burr et al. (1996) view species such as white perch with "greatest concern" due to their rapid dispersal, high reproductive potential, and known impacts on native fishes. In their report on the white perch in Nebraska, Hergengrader and Bliss (1971) concluded that the future prospects of white perch in the Missouri River "should be interesting." This characterization certainly holds for the prospect of this invasive exotic species colonizing Iowa waters.

Spotted Bass

This sunfish species is native to the central and lower Mississippi River drainage of the United States and, to a limited extent, has been introduced outside of its native range as a sport fish (Lee et al. 1980 et seq.). A desirable game species, spotted bass along with other black basses (*Micropterus* spp.) are widely stocked into reservoirs and lakes throughout the U.S. (Pierce and van den Avyle 1997). Introductions have been primarily in the southern one-half of the United States (Fuller et al. 1999). Due to its relatively small size, slow growth, and inability to tolerate cold water, however, the spotted bass has been distributed much less widely than either the smallmouth bass or largemouth bass (Robbins and MacCrimmon 1974).

Entry/Introduction into Iowa

The spotted bass was first introduced to Iowa in 1963 by state fisheries biologists. Spotted bass were experimentally stocked into the Middle Raccoon River (probably in Guthrie County), White Breast Creek (probably in Marion County) (Harlan et al. 1987), and Bob White Lake in Wayne County (Powers 1963, Speaker 1967). Both the Middle Raccoon River and White Breast Creek have habitat characteristics and water quality (i.e., pool/riffle sequences with warmer and more turbid water than that favored by the closely-related smallmouth bass) that would appear favorable to this environmentally tolerant black bass species. The precise location of these introductions appears to be lost; the introductions were apparently unsuccessful. In 1969 and 1970, fingerlings were stocked into Lake MacBride in Johnson County where reproducing populations of spotted bass became established and subsequently spread into the adjacent Coralville Reservoir and Iowa River (Harlan et al. 1987).

Unintended Consequences of Introduction

The most frequently documented adverse impact of spotted bass introduction is hybridization with, and potential replacement of, native smallmouth bass populations (Pflieger 1997, Fuller et al. 1999). Pflieger and Fajen (1975) noted hybridization between smallmouth bass and spotted bass when spotted bass was introduced into the habitats previously occupied by smallmouth bass only. Pierce and van den Avyle (1997) also observed hybrids when smallmouth bass were introduced into formerly isolated habitats of the Alabama spotted bass (*M. p. punctulatus*). Hybrids between these two species were fertile (Koppelman 1994), and Avise et al. (1997) described the genetic swamping and species turnover by the introduction of spotted bass into a Georgia reservoir formerly inhabited by only smallmouth bass. This introduction resulted in a population where 99% of smallmouth/spotted bass sampled were either spotted bass or hybrids.

Current Status

According to Harlan et al. (1987), the distribution of spotted bass in Iowa is currently limited to three waterbodies in Johnson County: Lake MacBride, Coralville Reservoir, and the Iowa River and tributaries immediately upstream from Coralville Reservoir. Due to its strong resemblance to the largemouth bass, however, current information on the distribution of spotted bass may underestimate its actual range in Iowa.

Projections for the Future

To our knowledge, no adverse impact of spotted bass on native Iowa fish populations, especially the hydribidzation with native smallmouth bass populations, has been documented. The existence of such an impact, however, has not been thoroughly investigated. Surveys are needed in Iowa waters that both support smallmouth bass populations and that are potentially affected by the introduction of spotted bass. One such area is the Iowa River in Hardin County. This river reach is approximately 100 miles upriver from known spotted bass populations in Coralville Reservoir and Lake MacBride and has historically supported viable populations of smallmouth bass. Also, surveys should be conducted to determine whether the initial (1963) introductions of this species into waterbodies of Guthrie, Marion, and Wayne counties were successful.

Western Mosquitofish

Two species of mosquitofish are native to the southern U.S.: the western mosquitofish (*Gambusia affinis*) and the eastern mosquitofish (*G. holbrooki*). While the second has been introduced worldwide for mosquito control, it is *G. affinis,* which is thought to be in Iowa. In addition, Pflieger (1997) noted that the western mosquitofish is more widespread and abundant in Missouri today than historically. Information from Missouri fish surveys in the 1940s, 1960s, and 1980s showed a steady movement of this species northwestward along the Missouri River and northward along the Upper Mississippi River to near the Iowa/Missouri state line. Pflieger (1997) attributed this expansion to both natural dispersal and to undocumented introductions. In Nebraska, Lynch (1988) documented the introduction, establishment, and dispersal of the western mosquitofish in the Platte and Republican rivers in the south-central portion of the state from the early 1970s to the later 1980s. He noted, however, that this species has failed to disperse appreciably in eastern Nebraska due to unspecified environmental factors.

Entry/Introduction into Iowa

Mosquitofish probably reached Iowa on their own without stocking (Table 4). We have no knowledge that mosquitofish have been introduced to Iowa waters by humans. The occurrence of this species in southeastern Iowa was hypothesized by Bailey (1956) based upon established populations in the Upper Mississippi River and associated backwaters of eastern Missouri. The western mosquitofish was first detected in Iowa in Pool 19 of the Upper Mississippi River in Lee County during 1979 and, subsequently, in Pool 18 (Harlan et al. 1987). More recently, large numbers were found in backwaters of the lower Iowa River (Horseshoe Bend National Wildlife Refuge) in Louisa County in 1995 (Bernstein and Christiansen, unpubl. data), and several were taken from an Iowa tributary of the Upper Mississippi River (Rock Creek) in Clinton County in 1999 (M. Bowler, pers. comm.).

Unintended Consequences of Introduction

Where mosquitofish have been introduced elsewhere as biological controls for mosquito larvae, they have proven to have a limited effect. However, they are capable of surviving and reproducing in their transplanted habitats and also of dramatic range expansions (Courtenay 1993). In some areas, primarily in the arid southwestern U.S., they have become a serious environmental pest by consuming small fish as well as the larval stages of larger species (Meffe et al. 1983, Courtenay and Meffe 1989, Courtenay 1993). It is also possible that they compete with native fishes for food (Courtenay and Meffe 1989). This hardy fish also has a major advantage over most native fish in that it is a live bearer, and, therefore, survival of young is relatively high compared to egg laying fish which must find a suitable substrate for spawning. This is noteworthy because with the exception of the mosquitofish, Iowa's fish are egg layers. Also, Hurlbert et al. (1972) experimentally demonstrated the ability of *G. affinis* to prey upon rotifer, insect, and crustacean populations such that phytoplankton populations increased dramatically. Based on this evidence, they suggested that this and other fish species have the ability to influence the trophic state of the waterbodies they inhabit. There are other potential negative impacts. Mosquitofish can affect native fish populations through fin nipping during competitive interactions, and the injured fish often die of fungal infections (Lloyd 1990).

Current Status

In Iowa, the western mosquitofish is currently restricted to the backwaters of the Upper Mississippi River and the floodplain reaches of its tributaries in the southeastern quarter of the state (Harlan et al. 1987; M. Bowler, pers. comm.). The recent collection of western mosquitofish from a tributary of the Upper Mississippi River in Clinton County, however, suggest that the range of this species may be expanding northward. In addition, the establishment and dispersal of mosquitofish in Nebraska as described by Lynch (1988) suggest at least the possibility of the spread of this species in other southern Iowa waterbodies at similar latitudes.

Projections for the Future

Harlan et al. (1987) felt that Iowa winters would restrict the spread of this species (see also Eddy and Underhill 1974, Fuller et al. 1999), and, if so, the mosquitofish may not reach numbers where it will be an invasive exotic in Iowa. We are not aware of any ecological impacts of mosquitofish on Iowa fish populations or aquatic ecosystems. Nonetheless, based on the known impacts of this species, primarily predation and/or competition with ecologically similar species, and based on documented impacts on the plains topminnow (*Fundulus sciadicus*) (Whitmore 1997) and the Sonoran topminnow (*Poeciliopsis occidentalis*) (Meffe et al. 1983), we feel that the potential exists for mosquitofish to adversely affect native populations of blackstripe topminnows (*Fundulus notatus*) in lowland areas of southeastern Iowa where these species co-occur. The status of the blackstripe topminnow should be monitored in relation to changes in the abundance or distribution of the mosquitofish in southeastern Iowa.

CONSIDERATIONS FOR THE FUTURE

Non-indigenous Fishes That Could Be Found in Iowa in the Future

Although not reported from Iowa waters, several non-indigenous fishes currently occupy portions of the Mississippi and/or Missouri river basins or the hydrologically connected Great Lakes basin, and, thus, could potentially reach Iowa either through dispersal via river connections (Fig. 1) or through human activities (e.g., aquaculture and bait bucket releases). Each of these fishes is an invasive exotic species capable of establishing populations that can adversely affect native aquatic species and ecosystems. Three such species are identified in the *Plan for the Management of Aquatic Nuisance Species in Iowa* (Phillips and Gengerke 1999): ruffe, round goby, and rudd. To this list, we add the black carp (*Mylopharyngodon piceus*) and the silver carp. Brief summaries of these species follow. Unless indicated otherwise, the information for these species is taken from Fuller et al. (1999); species are listed in taxonomic order according to Robbins et al. (1991).

Silver Carp

Silver carp are native to several major Pacific drainages of eastern Asia and were originally brought to the U.S. in the early and mid-1970s to control aquatic vegetation (phytoplankton) in aquaculture ponds and, eventually, sewage lagoons. By 1980, this species had either escaped from confinements into natural waters or was deliberately introduced. The silver carp is currently known from the Upper Mississippi River in both Illinois and Missouri as well as the Missouri River in Missouri. Similar to the bighead carp, the planktivorous silver carp has the potential, in large numbers, to seriously compete with native larval fish, mussels, and species such as bigmouth buffalo and paddlefish that are planktivorous as adults. We feel that, with an ecology and point of origin in the U.S. similar to the already-established bighead carp, silver carp are good candidates to reach and become established in Iowa's border rivers and the larger reaches the state's interior rivers.

Black Carp

The black carp is also native to the Pacific drainages of eastern Asia. This species has been introduced to U.S. waters several times: first in 1970 when a shipment of grass carp from Asia to an Arkansas fish farm also contained the morphologically similar black carp; next in the early 1980s when black carp were used as a biological control in aquaculture ponds for snails that harbor intermediate trematode parasites of catfish, and third in Missouri in 1994 when at least 30 black carp and several thousand bighead carp escaped into the Osage River of Missouri when high water flooded an aquaculture facility. The first two introductions are believed to have been confined to aquaculture facilities; the 1994 introduction to the Osage River is the only known open-water introduction in the U.S. This accidental introduction reinforces the fact that escape from aquaculture facilities is almost inevitable based on past experiences (Kolar and Lodge 2000). Currently, Missouri is the only state with verified records for this species. Although there is no evidence that the escaped black carp in Missouri have become established, the spread and establishment of this molluscivore would pose a serious threat to the North American mollusks, already highly endangered in many instances.

On 2 June 2000, the U.S. Fish and Wildlife Service initiated a 60-day review and comment period to gather information and public input on the status of the Asian black carp for fish culture and any other purpose in the U.S. [such as their reported but disputed ability control zebra mussels (*Dreissena polymorpha*]. At this writing, no decision has been made. An Iowa fish farmer was recently sentenced and fined for importing black carp fish into the state along with other illegal activities (U.S. Fish and Wildlife Service 2001).

Currently, the members of the Mississippi River Cooperative Resource Association (MICRA) are working to place the black carp on the federal list of "injurious" species (S. Gritters, pers. comm.). Due to their introduction to the Missouri River drainage of Missouri, we feel that the potential exists for black carp to easily reach Iowa waters if it begins to reproduce. Their establishment in Iowa could have serious negative consequences for Iowa's depleted populations of freshwater mussels whose fragile ecological condition was noted by Arbuckle et al. (2000).

Rudd

Mills et al. (1993) and Fuller et al. (1999) have summarized the North American history of the rudd, an Eurasian fish. Although this history is only partly known, the original and disputed 1897 introduction into New York City's Central Park Lake was likely related to the popularity of rudd in Europe as a food fish, game fish (Fuller et al. 1999) and/or as an ornamental fish (Pfleiger 1997). Fuller et al. (1999) suggested that the first verifiable U.S. record for rudd is the 1916 transfer of 300 specimens from the New York City Aquarium to Lake Oconomowoc in Wisconsin. Although two successful spawnings were reported for this lake, rudd were not reported in Wisconsin from 1918 until 1988 (Becker 1983, Lyons et al. 2000). Beginning in the early 1980s, bait culture of rudd intensified, especially in Arkansas, such that bait bucket releases and interstate transport of rudd are believed to be the primary means by which this species has reached most U.S. waters. The most commonly cited threat of the rudd to native fishes is its ability to hybridize, at least under laboratory conditions, with the golden shiner (*Notemigonus crysoleucas*) (Burkhead and Williams 1991). Although reported from all states adjacent to Iowa except Minnesota, established, reproducing populations of rudd are reported only from lakes in western Nebrasksa and in southeastern South Dakota (including Lake Francis Case on the Missouri River). And although recent records of adult rudd exist for Missouri, Illinois, and Wisconsin, naturally reproducing populations have not been reported for these states (Burr et al. 1996, Laird and Page 1996, Pfleiger 1997, Lyons et al. 2000). Thus, with a somewhat limited ability to establish self-sustaining populations in waters of the Midwest, and with a projected slowing of the spread of this species due to restrictions on use as bait in some states (Fuller et al. 1999), we feel that the chances of rudd reaching and becoming established in Iowa waters are relatively low. Given the existence of naturally-reproducing populations in southeastern South Dakota and discounting bait-related introductions, the most likely natural dispersal routes into the state appear to be the Missouri or Big Sioux rivers in northwestern Iowa.

Ruffe

The ruffe is native to northern Europe and Asia and was probably introduced in ship ballast discharged into the Great Lakes in the early 1980s. It is currently found throughout Lake Superior and into Lake Huron. Studies have demonstrated that the predacious ruffe is associated with declines in native fish, including game fish such as yellow perch and walleye. Although not yet present in Lake Michigan, researchers feel that ruffe will eventually colonize all the Great Lakes. We thus feel that the most likely route of entry into the Upper Mississippi River basin would be from Lake Michigan through the Chicago Sanitary and Ship Canal to the Illinois and Upper Mississippi rivers. Once present in the Upper Mississippi River, entry of this species into Iowa waters is possible.

Round Goby

This native of Eurasia, including the Black and Caspian seas, was first collected in U.S. waters in 1990 from the St. Clair River on the Michigan-Ontario border. The origin of the round goby in U.S. waters is believed to be ship ballast. This species is now well-established in the Great Lakes, including Lake Michigan. Potential impacts of this voracious and aggressive benthic fish include direct predation on darters, sculpins, and other benthic fishes; feeding on eggs of these and other fishes; and displacement of native species from preferred spawning areas. Declines in native species, especially sculpins, have been reported where the round goby has become abundant. Similar to the ruffe, the most likely route of dispersal for the round goby into the Upper Mississippi River basin is the hydrologic connection between Lake Michigan and the upper Illinois River via the Chicago Sanitary and Ship Canal. Recent records for round goby in the upper Illinois River (Keppner and Theriot 1997, Steingraeber and Guilfoyle 1997) suggest the possibility of this troublesome exotic species invading the Illinois and Upper Mississippi basins. Attempts are underway to prevent movement of round goby through the Chicago Sanitary and Ship Canal to the upper Illinois River (Steingraeber and Guilfoyle 1997). Whether these attempts are successful, and whether this species will adapt to the water quality and aquatic habitats of the agricultural Midwest, is as yet unknown. Based on its presence in the upper Illinois River system, however, we feel that the round goby is the most likely of the so-called "ballast invaders" of the Great Lakes to eventually reach Iowa waters.

Management of Non-indigenous Fishes

Practically, it is impossible to eliminate the exotic fish species that are established in Iowa. With effort, it might be possible to slow the spread of new exotics into Iowa, but even that is next to impossible given the connectivity of Iowa's rivers to a large area of North America (Fig. 1). Further, efforts that limit stocking of game fish, even natives, within the state would meet with much resistance from sporting groups.

To quote:

The introduction of nonnative fishes, whether exotic or transplant, is an important sport fishery management tool. The responsibility for such introductions must not be taken lightly. The criterion that the fish is "valuable" is not sufficient reason to introduce an exotic species. For example, the European carp, when introduced into American waters, was considered valuable. The use of exotics in sport fisheries management must be predicated on the ability to predict reasonably the impact of the introduced exotic species on existing biota and their environs.

Certainly, there is no need for haste in making introductions of exotic species. On the contrary, there is every reason to carry out exhaustive, long-term evaluations of the proposed introductions. The fact must be kept uppermost in mind that, once accomplished, the new introduction is virtually impossible to eradicate and, thereby, an unanticipated ecological disaster is virtually impossible to rectify. (Shireman 1984)

In addition, Courtenay (1979) noted with regards to release of exotic fishes ". . .deleterious effects may not be manifested until decades following initial introduction and establishment." Introduction of non-indigenous fishes or even translocated native fish to an area will almost always produce uncertain results (Magnuson 1976, Li and Moyle 1981). However, there is some hope that future problems can be prevented or lessened by using various techniques to insure that released non-native fishes are sterile (Shelton 1986).

While we may not be able to eliminate existing exotic species, we can reduce the likelihood of future problems related to their presence. Education programs should be initiated to alert anglers of the problems of indiscriminately disposing of unused, live bait. Aquarium hobbyists should also work to educate the public about the illegal release of unwanted pet fish into rivers and lakes. We should all support the efforts of the IDNR to enforce laws preventing the introduction of fish into Iowa's waters without permission. The potential long-term ecological consequences of future introductions of exotics by the IDNR should be considered prior to release. Stocking of game fish is an important role of the IDNR, and sport fishing provides many recreational benefits. It would be desirable if stocking of native fishes were conducted with local genotypes (e.g., not move Mississippi drainage individuals into Missouri drainage waters). Also, the ecological consequences of stocking and use of hybrid game fish should be thoroughly analyzed prior to release. Finally, Iowa cannot think of exotic fish problems as being confined to the state borders. IDNR fisheries biologists and other officials should work cooperatively with other states to prevent release of non-indigenous fishes and to also work to eliminate any newly discovered non-native fish before it becomes invasive.

The recent *Plan for the Management of Aquatic Nuisance Species in Iowa* (Phillips and Gengerke 1999), funded by the IDNR, as well as the appointment of an Aquatic Nuisance Species Program Coordinator for the IDNR are good first steps to identifying threats of nonnative fishes and coordinating management efforts to control them. We would encourage public officials to support and to expand efforts to both control nonnative fishes as well as prevent the arrival of new exotics.

As Mooney and Hobbs (2000) stated, ". . .the problem of invasive species is truly a global one, which must be tackled at a global level." Because of the connectivity of Iowa's waters to the North American continent, our actions must be coordinated with those of other states. It is only with a unified effort to eliminate and/or reduce invasive fishes as well as prevent new introductions that we can be successful.

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