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Unauthorized Fish Introductions: Fisheries Management of the People, for the People, or by the People?

FRANK J. RAHEL

Department of Zoology and Physiology, Biological Sciences Building, Room 428
Department 3166, University of Wyoming
1000 East University Avenue, Laramie, Wyoming 82071, USA

Abstract.—Although agency-authorized stocking of sport and forage fishes was the most common reason for fish introductions in the past, unauthorized introductions are now a major reason for the spread of nonnative fishes. Of 62 unauthorized fish introductions documented in Wyoming during 1973–2002, half (50%) involved the deliberate and illegal release of species by the public. These illegal introductions involved 23 taxa and included sport fish, baitfish, and aquaria fish. Colonization events involving the unwanted movement of fishes into new water bodies constituted 34% of unauthorized introductions and involved 13 species. Inadvertent introductions whereby species were introduced unknowingly, often as contaminants in authorized fish stockings, constituted 8% of unauthorized introductions. The remaining 8% of unauthorized introductions involved cases where the source of the nonnative fish was unknown. Options for reducing the number of unauthorized introductions include educating the public about the negative consequences of unplanned fish introductions and enacting legislation that restricts the public's access to species deemed undesirable if released into local water bodies. Because control or eradication of nonnative fishes is expensive, logistically difficult, and sometimes controversial, it will be feasible in only a limited number of situations. In most cases, we will have to accept unauthorized introductions as potentially leading to permanent additions to the regional fish fauna.

Introduction

There is a long history of fish introductions by management agencies in the United States. The U.S. Fish Commission was created in 1871, and its mission was to increase fishery resources through hatchery propagation and stocking of fishes (Nielsen 1999). Many states organized game and fish commissions during the latter part of the 19th century, and the first task of these organizations usually involved stocking fish. For example, Michigan established a Board of Fish Commissioners in 1873 and instructed it "to increase the product of the fisheries," primarily through fish culture and stocking (Clark et al. 1981). Even prior to statehood, the territory of Wyoming established a Board of Fish Commissioners in 1882 and charged it to "in the most economical and practical manner, procure and distribute fish in the public waters of this territory and adopt such other measures as shall in their judgment best promote the increase and preservation of food fish" (Barkwell 1883). Also contributing to the growing emphasis on fish stocking was the American Fish Culturists' Association (now the American Fisheries Society) formed in 1870 by a group of private fish culturists interested in promoting hatchery production as a cure for declining fish populations.

Through the development of culture techniques and transportation technology, these organizations fostered an era of widespread fish stocking across the United States. By the late 1800s, striped bass *Morone saxatilis* had been shipped from New Jersey and become established in California, rainbow trout *Oncorhynchus mykiss* from the western United States had become established in many eastern states, and European species such as brown trout *Salmo trutta* and common carp *Cyprinus carpio* were becoming naturalized throughout North America (Nielsen 1999). The 20th century saw an acceleration of introductions as fishery management agencies responded to the public's demand for a diversity of angling opportunities and as reservoirs provided new habitats with

few native sport fishes (Moyle and Light 1996). The result of these agency-sanctioned introductions was an increased homogenization of fish faunas across the United States with a suite of cosmopolitan game species and associated prey species dominating fish assemblages in many areas (Rahel 2000).

The era of unbridled fish introductions by natural resource management agencies is over. Increasingly, introductions of new species are being evaluated for their ecological impact as well as their utilitarian value to humans (Wingate 1992; French 1993). Although such evaluations have not always happened in the past, they are becoming an engrained part of management agency practices. As a result, it is increasingly difficult for management agencies to introduce species that are not native to a region (Townsend and Winterbourn 1992; Rahel 1997; Ferber 2001) or, in some cases, even to continue stocking hatchery strains that have been part of the historic management of a fishery (Philipp et al. 1993).

In contrast to the situation with authorized introductions, no review of ecological effects occurs with unauthorized fish introductions. Unauthorized introductions occur through many methods including illegal plants by anglers, bait bucket releases, escapes from the aquaculture or aquarium trade industries, and inadvertent releases such as from ballast water exchange or contamination of authorized fish plants with other species (Benson 1999; Litvak and Mandrak 1999). Such introductions constitute a growing problem for fisheries managers.

The purpose of this paper is to discuss the changing nature of fish introductions and examine the role of the public in spreading nonnative species. In particular, I compare the nature of authorized versus unauthorized fish introductions with a focus on the state of Wyoming. Like many other states in the western United States, Wyoming has experienced numerous fish species introductions (Baxter and Stone 1995; Rahel 2000) and provides a good case study of how management agencies and the public have influenced the dispersal of nonnative fishes across the aquatic landscape.

The Changing Role of Management Agencies and the Public in Fish Introductions

Agency-authorized introductions of sport and forage fishes have been the most common reason for fish introductions in the past. Fuller et al. (1999) analyzed 536 fish introductions across the United States (regardless of whether the species became established or not) and found that 44% involved sport or forage species. Data summarized by Benson (1999: Table 1.4) indicated that 38% of the 423 intentional releases of fishes in the United States involved sport or forage species. Of the 214 intentional fish species introductions in North America tabulated by Crossman and Cudmore (1999), 57% involved sport or forage species. Of 901 introductions that resulted in establishment of a fish species in a new state outside its home range within the 48 coterminous United States, Rahel (2000) found that 61% were attributable to stocking of sport or forage species (Figure 1). And in California, 47% of the 58 introduced and established fish taxa were the result of deliberate stocking by fishery management agencies (Dill and Cordone 1997a). Thus, at the scale of states or countries, authorized introduction of sport fishes or associated forage fishes by management agencies was the dominant factor behind past stocking efforts.

Although the above studies provide a broad overview of the magnitude of authorized introductions, they do not indicate how the sources of fish introductions may have changed over time. This is because most summaries of species introductions in North America integrate events that occurred from the 1870s to the present. When the relative abundance of authorized and unauthorized fish species introductions is followed through time, an interesting pattern emerges: the proportion of agency-authorized introductions has declined recently (Figure 2). This decline likely has two causes. First, the large number of introductions in the early decades of

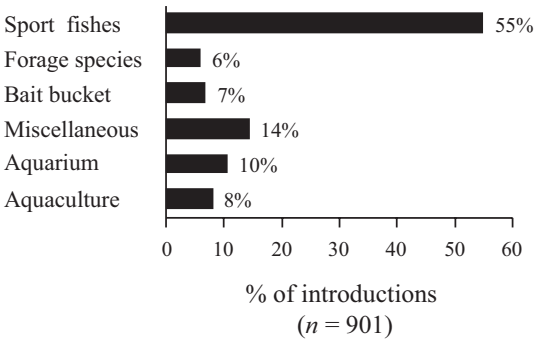

Figure 1. The percentage of 901 introduction events in the 48 coterminous United States attributable to various sources. An introduction event represents the establishment of a breeding population of a nonnative species in a state. Data from Rahel (2000).

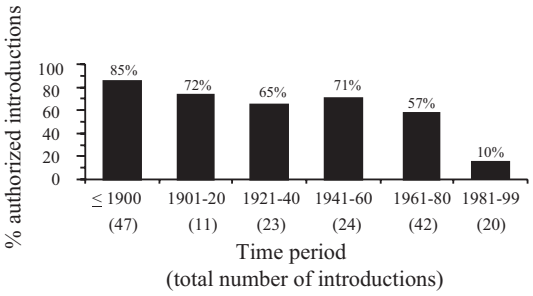

Figure 2. The percentage of introduction events that were authorized by fishery management agencies during the 19th and 20th centuries in six states and the North American Great Lakes. For each time period, the total number of introduction events across all regions and the proportion that were authorized is presented. Data sources: Great Lakes (Mills et al. 1993); California (Dill and Cordone 1997b); Connecticut (Whitworth 1996); Illinois (Laird and Page 1996); Missouri (Pflieger 1997); Tennessee (Etnier and Starnes 1993); Wyoming (Baxter and Stone 1995).

the 20th century satisfied much of the public's demand for a diversity of fishing opportunities. In a sense, many of the species that could be introduced have been introduced, at least at the regional level. Second, state and federal fisheries biologists have become more aware of the harmful effects of nonnative species and thus agency-authorized introduction of species outside their native or naturalized ranges is no longer a common practice (Townsend and Winterbourn 1992; Rahel 1997; Jackson et al. 2004; this volume). A slowing of the rate of authorized introductions is good from an ecological perspective because it reduces the likelihood of the "Frankenstein effect" whereby severe, unanticipated negative effects result from a well-intentioned species introduction (Moyle et al. 1987).

Unfortunately, the decline in authorized introductions is being offset by a large number of unauthorized fish introductions. This is particularly true at the local scale where nonnative fish species originally stocked by management agencies are now being moved to new water bodies within the region (Radomski and Goeman 1995). For example, more than 200 illegal fish stockings have been documented in Montana over the past two decades (Vashro 1995). McMahon and Bennet (1996) described many illegal introductions of walleye *Sander vitreus* and northern pike *Esox lucius* in the Pacific Northwest where these piscivores can have a serious impact on salmonid populations. As a result of such unauthorized introductions, fish species are expanding into water bodies not anticipated by fisheries managers.

Sources of Unauthorized Fish Introductions

Sources of unauthorized introductions fall into four categories based on the intent of the people involved and the nature of the introduction process (Table 1). The first category I have termed "illegal introductions." These occur when individuals knowingly release a species directly into a water body. Although individuals involved in illegal introductions are aware of their actions, their motivations are diverse. Some are motivated by a disdain for government regulation and may even resort to forms of ecological terrorism such as reintroducing nonnative fishes after they have been removed by chemical rehabilitation. In other cases, people may decide to establish a desired fish species in a favorite fishing area without soliciting the approval of fisheries biologists. And some people may believe they are being compassionate by releasing excess baitfish or unwanted pet fish into the wild rather than killing them.

The second category I have termed "colonization" (Table 1). Usually this involves species that were stocked legally into a water body or commercial holding facility but then managed to escape and colonize other water bodies. Often the escape is associated with

Table 1. Categories of unauthorized fish species introductions.

Category	Characteristics of such introductions
Illegal	Perpetrators knowingly introduce a species into a waterway. Motivation may involve ecological terrorism, desire to create a new fishery, or compassion for bait or pet fish.
Colonization	Nonnative species spread to new habitats where their presence was not intended. This spread is not due to the direct transport by humans but may be facilitated by human actions such as removal of migration barriers or water conveyance among drainages.
Inadvertent	Perpetrators are not aware they are introducing a fish species into a water body. Often referred to as accidental introductions.
Unknown	Not enough information is available to assign the introduction event to one of the above categories.

high flow events that may cause water to overspill a dam or wash out holding ponds. Such was the case for the establishment of bighead carp *Hypophthalmichthys nobilis* in the southeastern United States (Fuller et al. 1999). Colonization also can occur when natural migration barriers are eliminated or when formerly isolated basins are connected via canals. For example, the Welland Canal allowed fish such as the sea lamprey *Petromyzon marinus* to circumvent the migration barrier imposed by Niagara Falls and thus gain entry into the upper Great Lakes (Mills et al. 1993). Creation of the Chicago sanitary canal system provided a migration corridor between the Mississippi River drainage and Lake Michigan that has allowed the exchange of 15 species formerly confined to just one of the basins (Kolar and Lodge 2000).

The third category involves "inadvertent" introductions. Typically these are the direct result of human actions, but the people involved are usually not aware they are introducing an unwanted species. A common situation is when a fish species is introduced as a contaminant during an authorized stocking of another species. Many unauthorized introductions of green sunfish *Lepomis cyanellus* across the United States were the result of authorized introductions of bluegills *L. macrochirus* or largemouth bass *Micropterus salmoides* using fish stocks contaminated with green sunfish (Benson 1999). Inadvertent introductions can also be the result of ballast water releases such as those that resulted in establishment of round goby *Neogobius melanostomus* in the North American Great Lakes (Mills et al. 1993).

The fourth category involves situations where the cause of an introduction is "unknown." In reality, the cause of many introductions is not known with certainty, but fisheries biologists are often able to surmise the likely cause based on their knowledge of the local angling community, the stocking history of the water body, and the locations of nearby populations that could serve as a source of colonists.

Evaluating Sources of Unauthorized Fish Introductions

How important are these different pathways for unauthorized fish introductions? To answer this question, I examined 62 unauthorized fish introductions that occurred in Wyoming during 1973–2002. Most of these introduction events were documented by Wyoming Game and Fish Department biologists or by university researchers. Major sources of data were annual fisheries progress reports published by the Wyoming Game and Fish Department, personal communications with regional fish biologists, and graduate student theses or dissertations at the University of Wyoming. Whether or not introduction leads to establishment of a fish species was not considered in this analysis because my objective was to characterize the reasons behind unauthorized introductions, not the ecological characteristics that influence establishment of new species.

Half (50%) of unauthorized introductions involved illegal stocking by the public (Table 2). These involved 23 fish taxa, and no single species dominated this category. Illegal stocked fish included sport fish (walleye and yellow perch *Perca flavescens*), baitfish (white sucker *Catostomus commersonii* and several cyprinid species) and aquaria fish (goldfish). The next highest category of unauthorized introductions involved colonization by 13 species into new waters (34%). Brook trout and rainbow trout were among the most common colonizers. Neither of these species is native to Wyoming and both have detrimental effects on native cutthroat trout *Oncorhynchus clarkii*. Much management effort had been devoted to removing these species from streams with native cutthroat trout and then building migration barriers to prevent recolonization from downstream populations (Thompson and Rahel 1996). Unfortunately, brook trout *Salvelinus fontinalis* and brown trout have been able to move past these migrations barriers in some cases (Thompson and Rahel 1998). Walleye also colonized several water bodies and caused major disruptions to existing fisheries (see discussion below in Creating Beachheads for Invasions).

Inadvertent introductions were relatively rare (8%) and involved four species. Freshwater drum *Aplodinotus grunniens* was thought to have been introduced during authorized stocking of channel catfish into two reservoirs. Walleye were introduced during a stocking of smallmouth bass. Brook stickleback *Culaea inconstans* were believed to have become established in the upper reaches of the North Platte River system after they were stocked in a headwater reservoir along with a shipment of bait minnows. Finescale dace *Phoxinus neogaeus* were contained in a shipment of emerald shiners *Notropis atherinoides* legally stocked into a Wyoming reservoir as a forage species. Although inadvertent introductions are relatively uncommon, this is the category over which management agencies have the most control. Closer inspection of stocking allotments and reliance on cultured sources rather than wild caught fish would reduce the likelihood of introducing unwanted species during fish stocking. The remaining 8% of unauthorized in-

Table 2. Sources of 62 unauthorized fish introductions in Wyoming (1973–2002). Categories are described in Table 1.

Taxa	Illegal	colonization	inadvertent	unknown	total
Cyprinidae					
Bonneville redside shiner *Richardsonius balteatus hydrophlox*	1	0	0	0	1
Common carp	0	0	0	1	1
Fathead minnow *Pimephales promelas*	1	1	0	0	2
Finescale dace	0	0	1	0	1
Golden shiner *Notemigonus crysoleucas*	1	0	0	0	1
Goldfish *Carassius auratus*	3	1	0	0	4
Leatherside chub *Snyderichthys copei*	0	0	0	1	1
Red shiner *Cyprinella lutrensis*	1	0	0	0	1
Sand shiner *Notropis stramineus*	0	1	0	0	1
Speckled dace *Rhinichthys osculus*	1	0	0	0	1
Utah chub *Gila atraria*	1	0	0	0	1
Catostomidae					
White sucker	2	0	0	0	2
Ictaluridae					
Black bullhead *Ameirus melas*	1	0	0	0	1
Channel catfish *Ictalurus punctatus*	1	0	0	0	1
Esocidae					
Northern pike	1	0	0	0	1
Salmonidae					
Brook trout	1	4	0	0	5
Cutthroat trout	0	1	0	0	1
Lake trout *Salvelinus namaycush*	1	1	0	0	2
Rainbow trout	1	3	0	0	4
Splake (*S. fontinalis* × *S. namaycush*)	0	1	0	0	1
Gadidae					
Burbot *Lota lota*	1	0	0	0	1
Gasterosteidae					
Brook stickleback	2	2	1	1	6
Centrarchidae					
Bluegill	0	0	0	1	1
Green sunfish	1	1	0	0	2
Largemouth bass	1	0	0	0	1
Smallmouth bass *Micropterus dolomieu*	2	1	0	0	3
White crappie *Pomoxis annularis*	1	0	0	0	1
Percidae					
Iowa darter *Etheostoma exile*	1	0	0	0	1
Walleye	2	3	1	0	6
Yellow perch	3	1	0	1	5
Sciaenidae					
Freshwater drum	0	0	2	0	2
Total for each category	31	21	5	5	62
Percent of all introductions	50%	34%	8%	8%	

troductions involved five species for which the source of the introduction was not known.

Creating Beachheads for Invasions

For most sport and forage fish species, initial introductions into a region were done by a state or federal management agency. However, once a species is present, illegal transfers by the public and colonization via natural and human-mediated waterway connections become a major pathway for future introductions. This is illustrated by the various ways that walleye have expanded their range in Wyoming. Early stocking of walleye in Wyoming was authorized by the Wyoming

Game and Fish Department, and the first successful plant occurred in 1943 in Wardell Reservoir, near the town of Cody (Simon 1946). Subsequently, authorized stockings of walleye occurred in various reservoirs east of the continental divide (Figure 3). In addition, there have been eight documented cases of unauthorized stockings of walleye in Wyoming (Figure 3). These cases include examples of the three main categories of unauthorized stocking: illegal plants by the public, colonization into new water bodies, and inadvertent stocking due to contamination of an authorized plant of another species.

Examples of illegal stocking of walleye by the public include Lake DeSmet and the Gillette Fishing Lake (Table 3). The situation in Lake DeSmet is of particular concern to fishery managers because this reservoir has historically been an important trout fishery and walleye are known to be voracious predators on salmonids (McMahon and Bennet 1996; Bradshaw 2000). The Gillette Fishing Lake is in the town of Gillette, and several walleye were captured when the lake was treated with rotenone in 2000. Because walleye had never been stocked by the Wyoming Game and Fish Department and because there were no walleye populations in the drainage that could serve as a source of colonists, illegal stocking was the most likely explanation for their presence in this lake.

The spread of walleye in the North Platte River system in Wyoming illustrates the process of colonization once a species is introduced into a drainage system. Walleye were not native in the Platte River system in Wyoming (Baxter and Stone 1995). Early management efforts resulted in a highly successful put-grow-and-take fishery based on rainbow trout, especially in Seminoe, Pathfinder, and Alcova reservoirs (McMillan 1984). In 1961, Seminoe Reservoir experienced a seminal event, the first documented catch of a walleye. The source of walleye was never identified, but the most likely pathway was drift out of the upper reaches of the North Platte River drainage in Colorado where walleye were present in some private ponds (McMillan 1984). Walleye prospered in Seminoe Reservoir but were prevented from moving downstream by the outflow dam where water passed through sub-

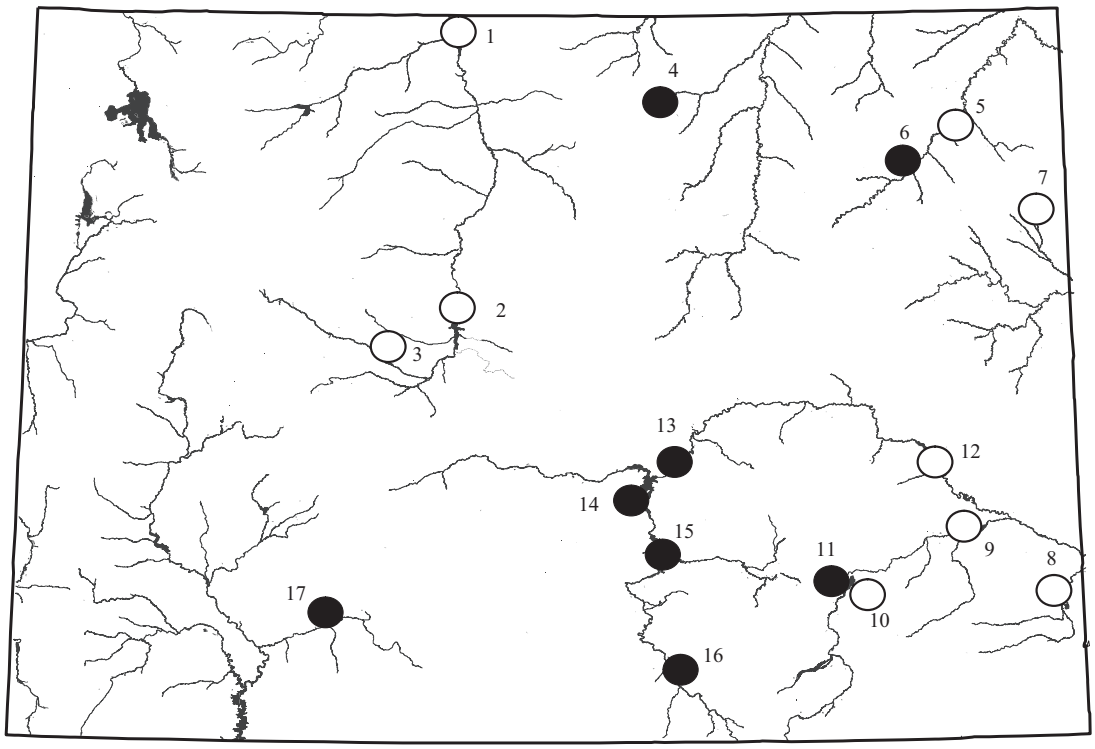

Figure 3. Locations of walleye introductions in Wyoming. Open circles represent authorized stockings by the Wyoming Game and Fish Department. Closed circles represent unauthorized stockings. Identification numbers and stocking information are described in Table 3.

Table 3. Walleye introductions in Wyoming. Authorized stockings were sanctioned by the Wyoming Game and Fish Department. Unauthorized stockings are described using the categories in Table 1. The list of introduction sites is not meant to be exhaustive but rather illustrative of the nature of walleye introductions in the state. Water bodies are numbered as in Figure 3.

Water body	Drainage	Type of introduction
1. Yellowtail Reservoir	Bighorn River	Authorized
2. Boysen Reservoir	Bighorn River	Authorized
3. Ocean Lake	Bighorn River	Authorized
4. Lake DeSmet	Powder River	Unauthorized: illegal stocking by the public
5. Keyhole Reservoir	Belle Fourche River	Authorized
6. Gillette Fishing Lake	Belle Fourche River	Unauthorized: illegal stocking by the public
7. LAK Reservoir	Cheyenne River	Authorized
8. Hawk Springs Reservoir	North Platte River	Authorized
9. Grayrocks Reservoir.	North Platte River	Authorized
10. Wheatland Reservoir 2	North Platte River	Authorized
11. Wheatland Reservoir 3	North Platte River	Unauthorized: colonized from Wheatland Reservoir 2
12. Glendo Reservoir	North Platte River	Authorized
13. Alcova Reservoir	North Platte River	Unauthorized: colonized from Pathfinder Reservoir
14. Pathfinder Reservoir	North Platte River	Unauthorized: colonized from Seminoe Reservoir
15. Seminoe Reservoir	North Platte River	Unauthorized: colonized from upstream sources
16. Saratoga Lake	North Platte River	Unauthorized: colonized from North Platte River
17. Jim Bridger Pond	Green River	Unauthorized: inadvertent as a contaminant in an authorized stocking of smallmouth bass

surface outlets to turbines used to generate electricity. However, high runoff in 1973 caused water to spill over the dam and allowed walleye to move downstream into Pathfinder Reservoir where they became established. Walleye were prevented from further movement downstream until another high water year in 1984 caused water to overflow Pathfinder Reservoir dam and allowed walleye to colonize Alcova Reservoir (Mavrakis and Yule 1998). Initially, walleye were not welcomed by anglers, especially in the blue ribbon trout fishery in the North Platte River between Seminoe and Pathfinder reservoirs where many trout anglers tossed walleyes on the bank as trash fish (McMillan 1984). The presence of walleye has dramatically changed the nature of the fishery in the North Platte River system where trout catch rates have declined as walleye catch rates have increased. To maintain a trout fishery in the face of an abundant walleye population, managers have been forced to stock larger (and thus fewer) trout and to stock when water temperatures are cool to minimize losses to walleye predation (Mavrakis and Yule 1998). Another example of colonization in the North Platte River system involved the movement of walleye into Wheatland Reservoir #3 during water transfers via the canal from Wheatland Reservoir #2 (Figure 3; Table 3) (McDowell 1984).

An example of an inadvertent introduction of walleye involved Jim Bridger Pond in the Green River drainage of western Wyoming (Table 3). In 1998, this reservoir was intentionally stocked with young smallmouth bass purchased from an out-of-state hatchery. While the fish were being stocked, it was noticed that the shipment also contained young walleye. There was concern that establishment of a walleye population in Jim Bridger Pond could serve as a source of illegal plants or colonists for other reservoirs of the Green River drainage, including Flaming Gorge Reservoir where walleye could have a devastating impact on salmonid populations. During the next several years, an intensive netting program was conducted to eliminate walleye from the reservoir. Also, plans were formulated to chemically treat the lake if walleye reproduction occurred. Fortunately, walleye did not reproduce in Jim Bridger Pond and no adults were captured in 2002 or 2003. Thus, the inadvertent introduction of walleye did not result in a population being established in this reservoir.

These examples of unauthorized walleye introductions in Wyoming illustrate how difficult it is to control the spread of a species once it has become established within a region. Fishery managers should assume that a species stocked into a water body will eventually occur in other suitable habitats within the drainage, either through illegal transfers by the public or through a process of colonization. Even well-conceived, agency-sanctioned introductions of nonnative

species can create a beachhead for invasions that will be ecologically harmful in other habitats. Claims that a nonnative species can be restricted to a particular water body or culture facility have too often been proven false in the past.

Responding to Unauthorized Introductions: Educate, Legislate, Eradicate, or Accept as Fate?

There are four ways of dealing with the problem of unauthorized fish introductions. A long-term solution is through education of the public about the negative consequences of transferring fish to new water bodies. In the nearer term, legislation that makes unauthorized stocking illegal and imposes fines can serve as a deterrent. In some situations, managers may have to resort to chemical or mechanical removal of introduced fish if they are deemed a sufficient threat to other species in the system. Finally, in many cases, unauthorized introduced species may have to be accepted as a permanent part of the biota.

Education is the ultimate solution to the problem of unauthorized introductions. Historically, the public was encouraged to participate in fish introductions, and such activities were considered to be an enhancement of nature (Dill and Cordone 1997a, 1997b; Rahel 1997). Furthermore, some state agencies still promote fish stocking as one of their most visible activities, a public relations ploy to show how license fees are helping to improve fishing. We have made progress in downplaying stocking as the major activity of fisheries management and as the magic solution to poor fishing quality (Wiley 1995), but further progress is needed (Utter 1994). A majority of the public continues to view stocking as the preferred method for enhancing fishing quality (Arlinghaus and Mehner 2003; Jackson et al. 2004).

In addition, there must be continued education about the problems caused by unauthorized fish introductions. Articles in the popular press and in fishing magazines should highlight not only the most sensational examples of illegal fish introductions such as the northern snakehead *Channa argus* (Huslin 2002), but more mundane examples that also have major impacts on native species. For example, baitfish species do not have the marquee appeal of the snakehead as the poster child for illegal stocking, but baitfish can still cause major problems when they are illegally released into a water body (Remmick 1982; Vashro 1995; Ludwig and Leitch 1996). Education can be done through national organizations such as the American Fisheries Society (Introduced Fish Section Web site http://www.afsifs.vt.edu), and the U.S. Geological Survey (nonindigenous aquatic species information resource Web site at http://nas.er.usgs.gov/fishes/). Or education can be done at the local level through news releases emphasizing the problems caused by an unauthorized introduction, by distributing informational literature (Figure 4), or by personal contact. For example, fisheries biologists should be able to suggest ways to humanely dispose of unwanted pet fish or unused baitfish as an alternative to releasing them into local waters (suggestions are given at the U.S. Geological Survey's nonindigenous aquatic species information website cited above).

Legislation prohibiting the transfer of aquatic species among water bodies is another tool in the fight against unauthorized fish introductions. Most states have laws prohibiting the release of species outside of the water body where they were initially captured (Table 4). These laws are generally published in the

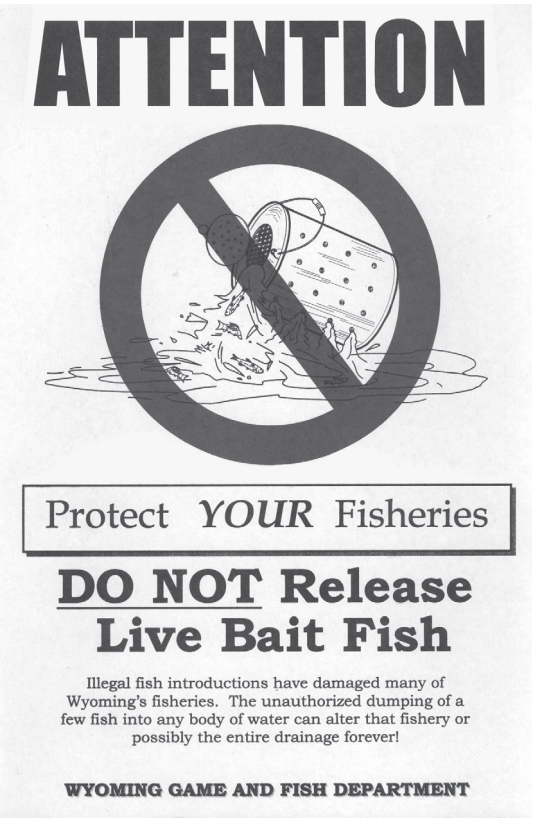

Figure 4. Copies of this sign were posted at various fishing locations in Wyoming to educate anglers about the dangers of releasing live baitfish.

Table 4. Examples of laws regarding the release of live fish in various states.

State	Laws and regulations
Colorado	It is illegal for anyone other than the Department of Wildlife (DOW) or someone with an aquaculture license, stocking permit or private or commercial lake license to stock or release fish species into waters of the state. It is illegal to move fish from one water to another. Live release must take place in the water of catch unless otherwise authorized. Unless authorized in writing by the DOW for controlled and experimental purposes only, it is illegal to export, import, transport, stock, sell, acquire and possess for release any of these species: piranha; trahira; gar (all species); snakeheads or murrels; sticklebacks; walking catfish; tilapia; bighead carp; bowfins; silver carp; Indian carp; rudd. (2003 Colorado Fishing Season available from Colorado Division of Wildlife; http://wildlife.state.co.us).
Kansas	It is illegal to release any fish into public waters unless caught from that water. Kansas Fishing Regulations Summary available at www.kdwp.state.ks.us
Nebraska	It is unlawful to release in public waters of the state any fish that did not originate in that body of water. It is illegal to release your baitfish or any fish caught from a different waterbody into public waters. (2003 Nebraska Fishing Regulations available at http://www.ngpc.state.ne.us/fish/fishguide/fishguide.html).
South Dakota	A person may not transplant or introduce live fish or fish eggs into public waters or release fish, reptiles, amphibians or crustaceans not native to South Dakota into public or private waters within the state, other than aquaria, without written authorization from Game, Fish and Parks. It is illegal to bring nonnative bait into South Dakota. No person may use or possess carp, buffalo, carpsuckers, goldfish, or game fish as bait for hook and line fishing. It is illegal to sell rudd or possess them. (South Dakota 2003 Fishing Handbook available at http://www.state.sd.us/gfp).
Wyoming	It is unlawful to plant or release live fish or fish eggs without the consent and supervision of the department or its authorized personnel. This does not include fish captured by legal means and released immediately upon capture. It is illegal to transport live fish or live fish eggs from the water of capture. No live bait fish shall be transported into the State for use as live bait fish. Unused live bait fish shall not be released alive. 2002-2003 Wyoming Fish Regulations available at http://gf.state.wy.us

fishing regulations brochure given to anglers at the time a license is purchased. There also are regulations governing the collection, use, and disposal of baitfish. The trend has been to increase the regulations regarding baitfish in order to decrease the chances of unwanted species being released into new water bodies. For example, procurement of baitfish in Wyoming by the public was allowed starting in 1950. A seining-trapping permit was needed, but fish could be collected with Wyoming Game and Fish Department supervision and used anywhere in the state where use of live baitfish was legal. In the mid-1990s, an effort was made to minimize the trans-basin movement of bait fishes by requiring collectors to specify one region in which collecting was to be done and then restricting use of collected baitfish to within that region. Also, anglers purchasing bait from a commercial dealer had to retain a receipt verifying the point of purchase and were allowed to use the baitfish only in the region where they were purchased. The idea was to have more oversight regarding the baitfish used in a particular drainage by controlling which species were sold at local bait shops. However, contamination of baitfish supplies at bait shops with undesirable nonnative species continued to be a problem, and in 2000, the importation of baitfish from out of state sources was prohibited. The objective of this new regulation was to require bait dealers to sell only locally caught fish (and thus reduce the likelihood of new species being introduced into the region) and to encourage development of regional aquaculture sources of baitfish that would be free of unwanted species. In addition, only fathead minnows and golden shiners are allowed as live baitfish for statewide use. Wild-caught baitfish must be used in the area of capture as specified on the seining permit. A proposed modification would ban possession of brook sticklebacks. The objective is to force bait dealers to do a better job of screening their baitfish stocks for this new invasive species in Wyoming.

Whereas most regulations regarding unauthorized stocking of fish are enacted at the state level, some species have received attention at the national level because of the extreme harm they can cause to humans or aquatic ecosystems. Fish that are banned from

importation into the United States are walking catfish (family *Clariidae*) and snakeheads (family *Channidae*) (U.S. Office of the Federal Register 2002a). Recently, the black carp has been proposed to be added to the list of banned fish because of concern that this molluscivore would have devastating effects on native freshwater mussels and snails (Ferber 2001; U.S. Office of the Federal Register 2002b).

Regulations prohibiting the use of certain fishes are useless if anglers do not abide by them. Illegal use of live bait is the third most common violation in Wyoming after fishing without a license and exceeding harvest limits. Schill and Kline (1995) estimated that 2.9% of anglers used illegal live bait in an Idaho stream. Bradshaw (1999) reported 5% of anglers used illegal live bait in a Wyoming reservoir. Interestingly, 7.5% of anglers responding to a voluntary creel box at another Wyoming reservoir indicated they used live bait (which was illegal at that reservoir), suggesting that ignorance of restrictions on live bait use may be a factor in many cases (Wyoming Game and Fish Department 1999). There is an obvious need for increased enforcement of baitfish regulations.

In some cases eradication of a nonnative fish species is deemed necessary. This is the case for species that are likely to have devastating effects on native species through predation, competition or hybridization. Removal of brook trout from streams with native cutthroat trout in the western United States is an example (Thompson and Rahel 1996). In the situation involving the inadvertent release of walleye into Jim Bridger Pond in the Green River drainage of Wyoming (Table 3), the Wyoming Game and Fish Department made contingency plans to chemically rehabilitate the reservoir if reproduction by walleye was observed. In the case of snakehead in a Maryland pond, chemical elimination was deemed necessary because of the close proximity of the pond to the Patuxent River and the highly piscivorous nature of the species (Maryland Department of Natural Resources 2003). Vashro (1995) discussed additional instances where unauthorized fish introductions necessitated chemical treatment of water bodies. But chemical treatment is expensive and commonly fails to remove all individuals (Wydoski and Wiley 1999). Also, the public is increasingly wary of rehabilitation through poisoning because of concerns about adverse effects of rotenone and antimycin on nontarget organisms, including humans (McClay 2000).

In many situations, we must simply accept as irreversible the addition of a new species to the fish assemblage of a stream, lake, or reservoir. Eradication of unwanted species is simply not feasible in large bodies of water or extensive drainage systems. Many introduced species do not have detectable effects on the existing aquatic community (Gido and Brown 1999; Trexler et al. 2000), and so there is little economic or political justification to invest the resources it would take to eliminate them. For species with negative effects, control rather than eradication is often the most practical approach. For example, mechanical removal of lake trout in Yellowstone Lake appears to be the best solution for preserving native cutthroat trout (Ruzycki et al. 2003), and there is a long history of successfully controlling sea lamprey populations in the Great Lakes through chemical treatment of selected nursery areas. But control requires an ongoing effort, something not guaranteed in perpetuity given changing sociological and political climates.

Sometimes fisheries managers have simply made the best of the situation when a new species became established. Walleye in the North Platte River system are a case in point. Although the initial response to walleye by anglers used to catching trout was not enthusiastic, the North Platte river system has evolved into an important walleye fishery (Mavrakis and Yule 1998). However, angler interest in catching trout remains high, and fishery managers have been able to maintain a respectable, albeit reduced, trout fishery by stocking fewer, larger trout and altering the timing of plants to minimize walleye predation.

Conclusions

Unauthorized fish introductions will continue to be one of the most daunting problems facing fisheries managers. The problem is more intractable than issues involving poor habitat quality or overharvest because the clandestine actions of a few can result in permanent impacts to entire aquatic ecosystems. Legislation can reduce the opportunities for illegal introductions by restricting the use of nonnative baitfish species. Ludwig and Leitch (1996) defined the probability of a bait-bucket transfer as a product of three independent event probabilities: (1) the probability of transportation across a basin boundary, (2) the probability that a bait-bucket contains a nonbaitfish species, and (3) the probability of anglers releasing baitfish alive after use. Based on empirical estimates of these probabilities for baitfish use in the upper Midwestern United States, they concluded that the single event probability of a nonbaitfish transfer was 0.01. When the total number of angler-days was considered, at least 1,000 successful bait bucket trans-

fers from the Mississippi River basin to the Hudson River basin in Minnesota, North Dakota, and South Dakota were estimated to occur each year. Restricting use of baitfish to the drainage where the fish were collected and/or prohibiting live baitfish use in certain drainages will reduce the probability that anglers will move fish across basin boundaries. Frequent inspection to encourage bait dealers to maintain uncontaminated baitfish stocks and restrictions on the species legally sold as baitfish will reduce the probability that a bait-bucket contains undesirable species. Education of the public about the harm done by unauthorized fish introductions, especially from bait-bucket releases, will reduce the probability of anglers releasing live baitfish at the end of the day.

Although legislation and education are the best hope for reducing the rate of unauthorized introductions in the long-term, fisheries biologists will still be faced with the need to eliminate introduced species that pose immediate and significant threats to aquatic ecosystems. For the foreseeable future, treatment with toxicants will remain the most effective means of eliminating unwanted species, even though this method is being met with growing concern by the public.

The issue of invasive species has moved to the forefront of natural resource management in many types of ecosystems (Mack et al. 2000). As a result, fisheries managers will find themselves allied with conservationists and natural resource managers fighting invasive species belonging to a variety of taxa. Unfortunately, it promises to be a long battle, but one that is critical to preserving existing fisheries and maintaining biological integrity in aquatic systems.

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