Walleye and Northern Pike: Boost or Bane to Northwest Fisheries?

By Thomas E. McMahon and David H. Bennett

ABSTRACT

Introductions of nonnative walleye (*Stizostedion vitreum*) and northern pike (*Esox lucius*) have created popular recreational fisheries in many Northwestern waters. Rising demand for expanded angling opportunities for these species, especially walleye, has been met with growing concern about long-term risks associated with the introduction of a top predator. Proposed introductions are often controversial because of potential prey depletions, reductions in salmonid populations, and long-range movements of the species from the point of release. We urge a cautious approach to future introductions of these species in the northwestern United States and outline some approaches for evaluating risks and benefits. Stricter risk assessment procedures for species introductions have been adopted by many states, but illegal introductions of both species are a continuing problem. Greater efforts are needed to educate the public about the risks of illegal transplants, and stronger statutes are necessary to discourage this activity.

The popularity of nonnative walleye (*Stizostedion vitreum*) and northern pike (*Esox lucius*) as sport fishes has mushroomed in recent years in the northwestern United States (Conover 1986). The walleye fishery in Lake Roosevelt, Washington, provides 200,000 angler-hours of fishing annually at catch rates of 0.5 fish/h with fish in the 2-kg to 5-kg size range commonly caught (Hallock and Fletcher 1991). Northern pike in Coeur d'Alene Lake, Idaho, exhibit the highest growth rates of the species in North America, and catches of fish >12 kg are common (Rich 1993). These and other trophy fisheries have received national publicity in angling magazines and television programs, thus fueling interest for similar angling opportunities elsewhere in the region. Proposed introductions are often controversial due to perceived risk to the region's prized salmonid fisheries (Conover 1986). Managing such top predators can be troublesome because potential top-down effects have been shown to significantly alter entire fish communities, even in large waterbodies (Colby et al. 1987; Knight and Vondracek 1993). Colonization of new waters beyond the point of release is an additional concern. Some western states prohibit stocking of walleye into certain waters (Idaho Department of Fish and Game [IDFG] 1982; Colby and Hunter 1989). However, demand for angling opportunities continues to mount, especially for walleye, and Idaho (IDFG 1982) and Montana (Colby and Hunter 1989) have conducted environmental assessments to guide stocking policies. Unfortunately, while state agencies have initiated detailed environmental reviews to evaluate risks and benefits of proposed introductions, illegal introductions of both species may be rising (Vashro 1990, 1995).

Throughout North America the use of species introductions as a management tool has come under increased scrutiny (Moyle et al. 1986; Spencer et al. 1991; Bain 1993). Walleye and northern pike management in the Northwest illustrates that weighing potential recreational and economic benefits derived from introductions against potential long-term ecosystem effects is fraught with complex biological and social considerations. In this article, we review the current distribution of walleye and northern pike in the region and summarize case studies describing how local systems have responded to pike and walleye introductions. Our aim is to outline approaches for evaluating risks and benefits of proposed introductions and for curtailing illegal ones.

Thomas E. McMahon is an associate professor in the Biology Department, Fish and Wildlife Program, Montana State University, Bozeman, MT 59717-0346; ubitm@msu.oscs.montana.edu. David H. Bennett is a professor in the Fish and Wildlife Resources Department, University of Idaho, Moscow, ID 83844-1136; dbennett@uidaho.edu.

Current Distribution

Walleye and northern pike were first introduced to the Northwest in the 1940s and 1950s (Brown 1971; Beamesderfer and Nigro 1989) and now occur throughout the Columbia and upper Missouri River basins (Figure 1). Their range continues to expand as they colonize and are introduced into additional waterbodies.

Walleye

One of the more significant walleye introductions in the region was to the upper Columbia River system (Figure 1). Although the history of its introduction is unclear, a popular

sport fishery was established by the 1960s in Lake Roosevelt, Washington (Hallock and Fletcher 1991). Walleye are now widespread throughout the lower Columbia River basin, and sport fisheries have developed in several reservoirs and tailwaters (Hallock and Fletcher 1991; Tinus and Beamesderfer 1994). However, concern about predation on salmonid smolts in the Columbia River (Rieman et al. 1991) has led to a policy of no further introductions of walleye into Oregon (A. Smith, Oregon Department of Fish and Wildlife, personal communication). Washington is currently developing a walleye management policy (Doug Fletcher, Washington Department of Fisheries, personal communication). Walleye were stocked into several southern Idaho reservoirs beginning in 1974 (IDFG 1982), but because of concern about anadromous salmonids, walleye introductions are prohibited in the Snake River drainage (IDFG 1982).

Walleye were first reported in Wyoming in 1961 at Seminoe Reservoir, the uppermost reservoir on the North Platte River (Figure 1). During high water in subsequent years, walleye were flushed downstream and colonized all seven North Platte River reservoirs throughout a range of 450 river kilometers (Figure 1; McMillan 1984). Walleye also have been stocked into other reservoirs in the Missouri River drainage (Marwitz and Hubert 1995).

In Montana, 40 million walleye fry are stocked annually into approximately 60 waterbodies. Stocking occurs primarily in large prairie reservoirs east of the Continental Divide, where natural reproduction is often limited (Colby and Hunter 1989). Walleye introductions are prohibited west of the Continental Divide because of the important native and nonnative salmonid populations (Colby and Hunter 1989). However, illegal introductions of walleye have resulted in self-sustaining populations in several reservoirs in western Montana, most recently in Noxon Rapids Reservoir on the Clark Fork of the Columbia River and Canyon Ferry Reservoir near the headwaters of the Missouri River (Figure 1; Vashro 1995).

Northern Pike

Northern pike were illegally stocked into Coeur d'Alene Lake, Idaho, in the early 1970s (Rich 1993) and have spread to several lowland lakes in northern Idaho. In Wyoming, northern pike occur only at Keyhole Reservoir (Figure 1), where they were illegally stocked in the 1960s. Once established, annual stocking and length limits were instituted to reduce carp (*Cyprinus carpio*) populations and diversify angling opportunities (B. McDowell, Wyoming Game and Fish Department [WGFD], personal communication).

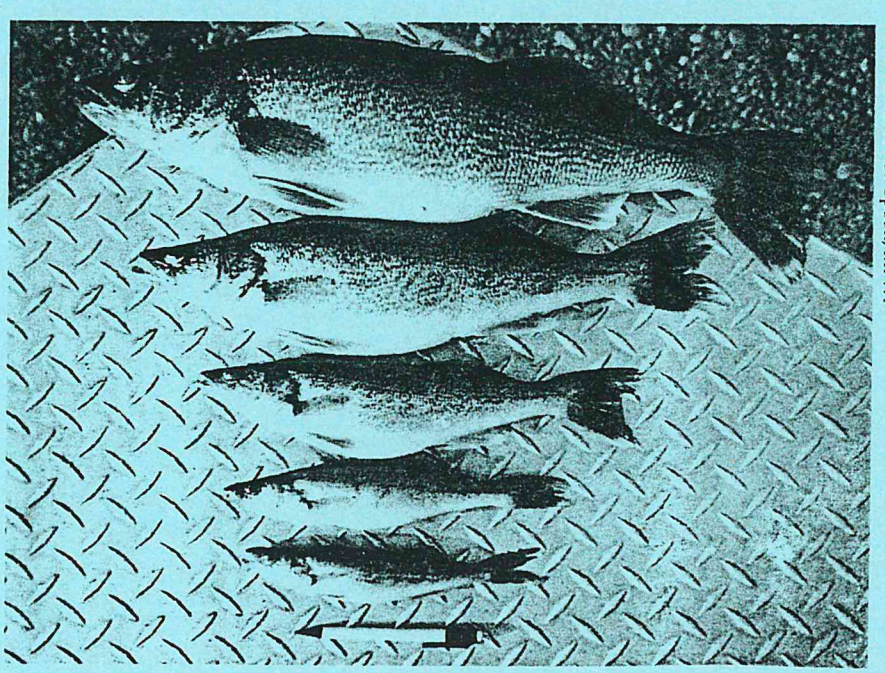
Although native to Montana only in the Saskatchewan River drainage, northern pike are now found statewide in sloughs, backwaters, and other clear waters with abundant aquatic vegetation (Figure 1; DosSantos 1991). Northern pike support popular sport fisheries in the lower Flathead and Bitterroot rivers (Jones 1990; DosSantos 1991), and unplanned introductions and invasions of northern pike are a recurring problem. Of 111 waters in northwest Montana that contain illegally introduced fish, 62 contain northern pike (J. Vashro; Montana Fish, Wildlife, and Parks [MFWP]; personal communication).

No known stockings of northern pike have been made in the state of Washington, but colonization from Montana rivers has been recorded. In Washington and British Columbia, pike are viewed as a threat to declining stocks of salmonids because of predation and possible transmission of exotic parasites (J. Hammond, British Columbia Ministry of Fish and Wildlife, personal communication). Northern pike have not been introduced into Oregon, but some probably occur in weedy sloughs of the Columbia River as migrants from upstream. The state's current policy is to eradicate pike when found (A. Smith, Oregon Department of Fish and Wildlife, personal communication).

Effects of Introductions

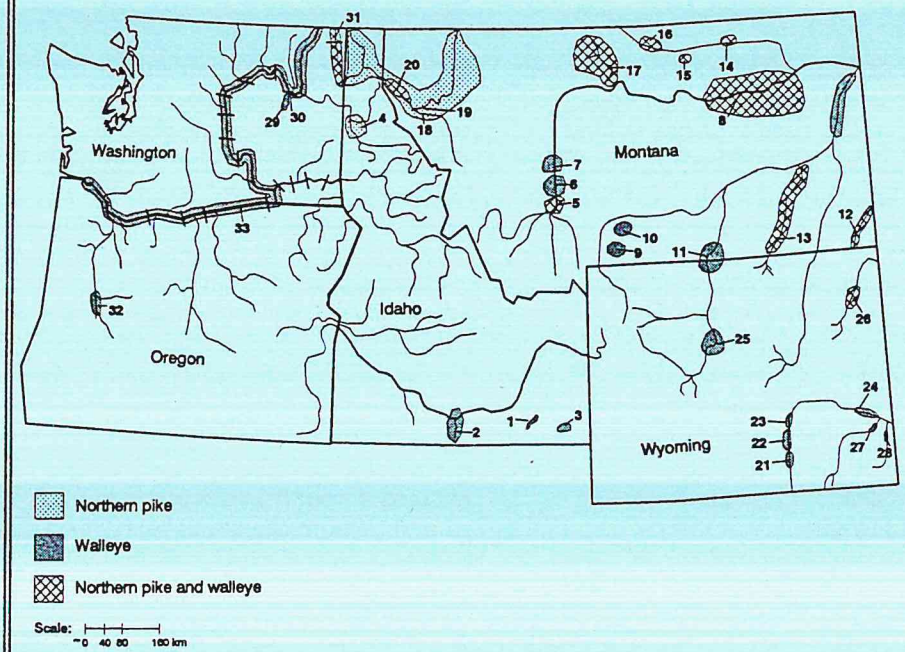
Walleye

The effects of walleye introductions and range expansion in the Northwest are complex and varied. Fisheries scientists have frequently observed prey depletions, reduced salmonid populations, and large shifts in fish community composition (Colby and Hunter 1989). Seminoe



Dave Yerk and Ron Spoon, MFWP

Illegal introduction of walleye into Canyon Ferry Reservoir, Montana, has resulted in a reproducing population, which managers expect will harm existing fisheries.



State	Location	Drainage	Species	Source
Idaho	1. Oneida Lake	Snake River	Walleye	P
	2. Salmon Falls Reservoir	Snake River	Walleye	P
	3. Mud Lake	Snake River	Walleye	P
	4. Coeur d'Alene Lake	Spokane River	Northern Pike	IL
Montana	5. Canyon Ferry Reservoir	Missouri River	Walleye	IL
	6. Hauser Reservoir	Missouri River	Walleye	IN
	7. Holter Reservoir	Missouri River	Walleye	IN
	8. Fort Peck Reservoir	Missouri River	Walleye	P
			Northern Pike	P
	9. Dailey Reservoir	Yellowstone River	Walleye	P
	10. Cooney Reservoir	Yellowstone River	Walleye	P
	11. Bighorn Lake	Bighorn River	Walleye	P
	12. Little Missouri River		Walleye	IN
			Northern Pike	IN
	13. Tongue River Reservoir	Tongue River	Walleye	P
			Northern Pike	P
	14. Nelson Reservoir	Milk River	Walleye	P
			Northern Pike	P
	15. Beaver Creek Reservoir	Bighorn River	Walleye	P
			Northern Pike	IL
	16. Fresno Reservoir	Milk River	Walleye	P
			Northern Pike	P
	17. Tiber Reservoir	Marias River	Walleye	P
			Northern Pike	P
	18. Bitterroot River		Northern Pike	IL/IN
	19. Flathead River		Northern Pike	IL/IN
	20. Noxon Rapids Reservoir	Clark Fork River	Walleye	IL
			Northern Pike	IN
Wyoming	21. Seminoe Reservoir	North Platte River	Walleye	IN
	22. Pathfinder Reservoir	North Platte River	Walleye	IN
	23. Alcova Reservoir	North Platte River	Walleye	IN
	24. Glendo Reservoir	North Platte River	Walleye	P
	25. Boysen Reservoir	Wind River	Walleye	P
	26. Keyhole Reservoir	Belle Fourche River	Walleye	P
			Northern Pike	IL
	27. Grayrocks Reservoir	Laramie River	Walleye	P
	28. Hawk Springs	Horse Creek	Walleye	P
Washington	29. Banks Lake	Columbia River	Walleye	P
	30. Lake Roosevelt	Columbia River	Walleye	IN
	31. Box Canyon Reservoir	Pend Oreille River	Walleye	P
			Northern Pike	IN
Oregon	32. Willamette River		Walleye	IN
	33. John Day Reservoir	Columbia River	Walleye	IN

Figure 1 shows the range of nonnative walleye and northern pike, which has expanded greatly in northwestern states during the past 40 years. This map illustrates major waterbodies having known nonnative populations of northern pike and walleye, with the source of a population defined as an invasion (IN), legal plant (P), or illegal introduction (IL). Species locations, indicated by shading, are enlarged for emphasis. Bars indicate locations of major dams on the Columbia River, Oregon and Washington.

Reservoir, Wyoming, provides one of the more complete studies of changes in predator-prey interactions after walleye introduction (McMillan 1984). Seminoe was managed primarily as a put-grow-and-take rainbow trout (*Oncorhynchus mykiss*) and a wild brown trout (*Salmo trutta*) fishery. The walleye population grew rapidly after its initial sighting in 1961, and caused sharp declines in native minnows (*Hybognathus* spp.), darters (*Etheostoma* spp.), crayfish (*Orconectes obscurus*), and suckers (*Catostomus* spp.) by 1968. A popular fishery for walleye developed, with walleye averaging 45 cm long in 1973. As prey species declined in the early 1970s, predation on rainbow trout intensified. Walleye stomach samples indicated that most of the 500,000 fingerling trout stocked annually in the spring were eaten within a few weeks after planting (McMillan 1984). Managers tried dispersed stocking of fingerlings to increase trout survival, but the lack of alternate forage, combined with a growing walleye population, made success of this strategy short-lived. Walleye growth, condition, and abundance declined; cannibalism increased; and recruitment failed as food supplies were overexploited. From 1973 to 1978, the percentage of walleye > 40 cm dropped from 52% to 9% of the population (McMillan 1984). The near-simultaneous collapse of walleye and trout populations led to sharp reductions in angler effort and harvest. Gizzard shad (*Dorosoma cepedianum*) and emerald shiner (*Notropis atherinoides*) were then stocked to bolster the prey base. The combination of an alternate forage base, decreased size of walleye, and especially the stocking of large trout 200 to 340 mm long that were less vulnerable to walleye predation led to

increased survival of planted trout. A mixed walleye and trout fishery now exists in Seminoe Reservoir (Marwitz and Hubert 1995), but the costs of managing this fishery have increased because of greater expense associated with transporting and rearing larger trout (McMillan 1984; Wiley et al. 1993).

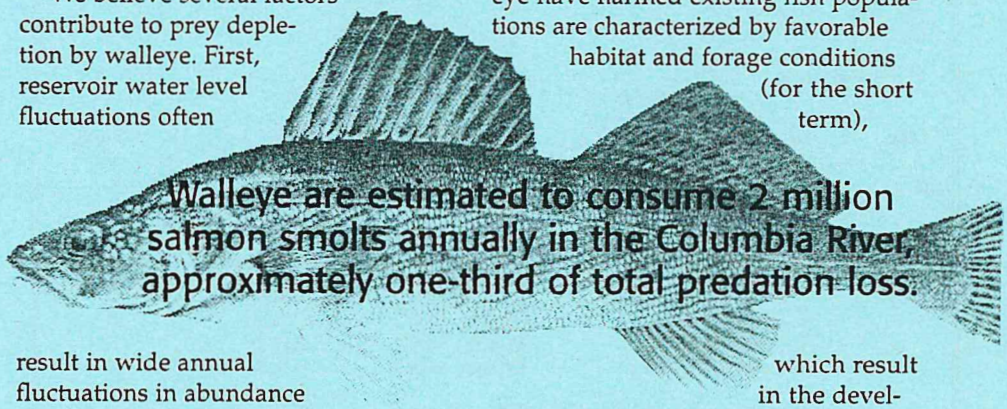
Managers have repeatedly observed creation of a "predator trap," a large number of prey-limited piscivores (Peterman and Gatto 1978), after walleye introduction in other systems. Walleye predation led managers to stock larger trout or eliminate the trout fishery in Pathfinder (McMillan 1984), Keyhole (Wichers 1981), Alcova, and Glendo (WGFD 1990) reservoirs, Wyoming, and Salmon Falls Creek Reservoir, Idaho (Partridge 1988). A survey of 15 major walleye-producing reservoirs in Montana revealed that, although 3–4 reservoirs produce good walleye fisheries with catch rates near 0.3 fish/h, most are limited by inadequate forage (Shepard 1991). Walleye appear prey-limited in most Wyoming reservoirs, with growth rate positively related to trout stocking density (Marwitz and Hubert 1995).

Managers did not anticipate negative effects of walleye on salmonid fisheries since reports of walleye preying on salmonids are not widespread in the literature (Colby and Hunter 1989). In their native range, lakes with both walleye and salmonids, such as lake trout (*Salvelinus namaycush*), are relatively rare (Johnson et al. 1977), and where they do co-occur, the species have little spatial overlap because of differing habitat requirements (MacLean and Magnuson 1977). However, the opportunity for spatial segregation is limited in many western reservoirs due to a lack of strong thermal stratification and small littoral area (Colby and Hunter 1989). Fingerling trout are particularly vulnerable to predation by walleye because stocking typically occurs in the spring, when post-spawning walleye have high forage demands, but other suitable-sized prey are often scarce (Ney and Orth 1986).

Stable walleye fisheries generally have been difficult to maintain in Northwest reservoirs even when their favored prey, yellow perch (*Perca flavescens*), is initially abundant. In Salmon Falls Creek Reservoir, Idaho, perch comprised 80% and walleye < 1% of the total numbers of sport fish caught in gill nets in 1975, shortly after walleye were introduced (Partridge 1988). But by 1987, perch and walleye percentages had reversed. Anglers caught state-record walleye in intervening years, but numbers, maximum sizes, and condition then declined. Similar reversals in yellow perch and walleye abundances have been observed in Keyhole (Wichers 1981, 1986) and Glendo reservoirs, Wyoming (WGFD 1990).

We believe several factors contribute to prey depletion by walleye. First, reservoir water level fluctuations often result in wide annual fluctuations in abundance of yellow perch and other prey fishes (Noble 1986); thus, walleye deplete the food supply in years of low forage abundance. Second, the lack of cover in many reservoirs during summer drawdown makes prey fishes highly vulnerable to walleye predation even during years of high reproduction of prey (Swenson 1977). This effect is exacerbated during successive years of poor reproductive success of prey and low water levels (Partridge 1988; WDFG 1990). Third, when recruitment of one prey species is low, alternate forage is often not available because of typically low prey diversity in western reservoirs (Wydoski and Bennett 1981).

Although many western states generally avoid introducing walleye into salmonid waters (IDFG 1982), managers have not observed prey depletions and harm to salmonids in all cases. Walleye have had minimal impact on trout fisheries in some Montana reservoirs where limited spawning habitat or high flushing rates keep walleye densities low, yet recruitment is sufficient to provide a stable, albeit limited, fishery (Colby and Hunter 1989). Walleye were recently stocked into Dailey Reservoir, Montana, to thin a stunted yellow perch population and into Cooney Reservoir, Montana, to reduce abundant sucker populations. Both effects have been achieved with minimal impacts to trout fisheries (Venditti 1994; B. Shepard, MFWP, personal communication). Managers are concerned that walleye will shift to preying on trout if the current forage base declines, but walleye reproduction is limited, and stocking could be reduced if trout fisheries become affected in the future. Situations where walleye have harmed existing fish populations are characterized by favorable habitat and forage conditions (for the short term), which result in the development of large, self-sustaining walleye populations.



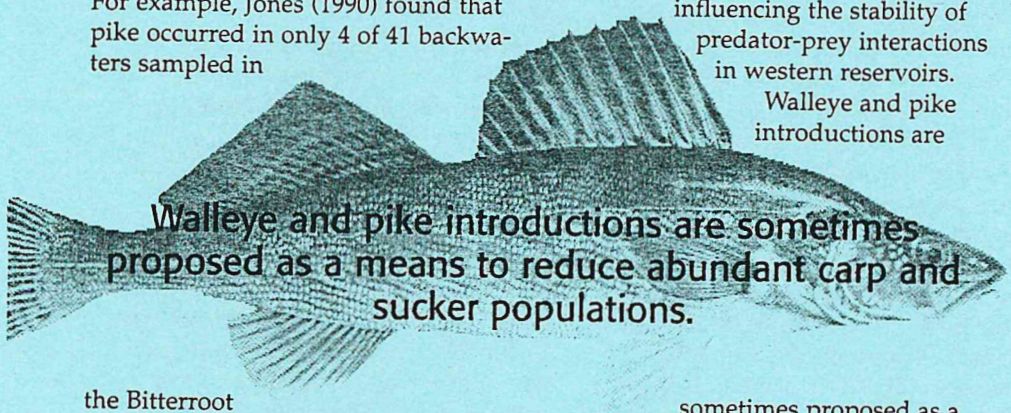
Walleye are estimated to consume 2 million salmon smolts annually in the Columbia River, approximately one-third of total predation loss.

Information is scanty on walleye-salmonid interactions in riverine systems. Walleye are often seasonally abundant in tailwaters and reservoir tributaries during spring spawning (McMillan 1984; Venditti 1994). The blue-ribbon rainbow trout and brown trout fishery in river sections above Seminoe and Pathfinder reservoirs declined after walleye were introduced, but exact causes of the decline are unknown (B. Wichers, WGFD, personal communication). Walleye are estimated to consume 2 million salmon smolts annually in the Columbia River, approximately one-third of total predation loss. Recreational and economic benefits of a walleye fishery must be balanced with this potential harm to declining salmon populations (Tinus and Beamesderfer 1994).

Northern Pike

Few studies have documented effects of northern pike introductions in the region, but like walleye, pike

piscivory has the potential to impose large-scale changes in fish communities, including species elimination (He and Kitchell 1990; Vashro 1990). Northern pike introduced into small lakes and ponds in Montana typically deplete their prey and stunt, hence the nickname "hammer handles." Generally, northern pike do not pose a serious predation threat to existing fish communities throughout much of the region because of specialized habitat requirements, resulting in limited distribution (Jones 1990; DosSantos 1991). For example, Jones (1990) found that pike occurred in only 4 of 41 backwaters sampled in the Bitterroot River, Montana. In backwaters where present, pike apparently eliminated most other fishes except the deep-bodied, spiny-rayed pumpkinseed (*Lepomis gibbosus*). Northern pike have been implicated in the decline of native westslope cutthroat trout (*O. clarki lewisi*) and bull trout (*Salvelinus confluentus*) in Upper and Lower Stillwater lakes, Montana (J. Vashro, MFWP, personal communication).



Evaluating Proposed Introductions

Relying on post-introduction case studies to evaluate potential introductions has recognized limitations but provides the best available information (Mundie and Bell-Irving 1986; Colby et al. 1987; Bain 1993). Key to evaluating the potential for harm is determining whether walleye and northern pike will establish a self-sustaining population. Applying a walleye habitat model by Bennett and McArthur (1990) is a useful first step in assessing the likelihood of establishing a self-sustaining walleye population. Comparing reproductive requirements with conditions in the proposed introduction site (e.g., McMahon 1992) using habitat suitability models developed for walleye (McMahon et al. 1984) and northern pike (Inskipp 1982) is another approach.

Determining the adequacy of the forage base is difficult yet vital to risk assessment since either species could deplete an abundant prey base. Prey biomass, growth and size structure, seasonal availability, and prey habitat suitability are important considerations (Kohler et al. 1986; Ney and Orth 1986; McMahon 1992). Water-level fluctuations are believed to be key variables influencing the stability of predator-prey interactions in western reservoirs. Walleye and pike introductions are sometimes proposed as a means to reduce abundant carp and sucker populations. Walleye prey on young suckers and carp when other forage is lacking (Wichers 1981; McMillan 1984), and managers have observed large declines in small suckers and carp after walleye introduction (McMillan 1984; Fredenberg and Poore 1987). Walleye can prey on fish almost half their size (Colby et al. 1979; McMillan 1984), and under heavy walleye predation, remaining sucker and carp populations shift rapidly to a size structure comprised primarily of individuals too large to be eaten (McMillan 1984; Fredenberg and Poore 1987). An abundant supply of young-of-the-year (preferably soft-rayed) fishes < 12.5 cm is needed to support an abundant walleye population (Knight and Vondracek 1993). Examples of forage depletion reinforce the need to assess the possibility of future introductions of prey, which pose their own set of risks (Wydoski and Bennett 1981; DeVries et al. 1991), to maintain good quality walleye and pike fisheries.

Compatibility of introductions with existing fisheries is another important consideration. McMillan (1984) found marked declines in condition and abundance of brown trout in Seminoe Reservoir after the expanding walleye population significantly reduced crayfish, brown trout's favored prey. Managers should estimate tradeoffs in sport-fish harvest and use. Although walleye are popular sport fish, significant reductions in angler harvest and use have been reported following their introduction (McMillan 1984). Walleye are harder to catch and, as top-level predators, are less numerous than mid-level predators such as rainbow trout, which are easier to catch and tend to support higher angler use (B. Wichers, WGFD, personal communication). The establishment of walleye and pike populations by invasion from other waters (Figure 1) illustrates that movement from introduction sites should be anticipated.

Given their expanding distribution and increasing popularity with anglers, fishery managers will continue to be called on to predict and manage effects of walleye and northern pike introductions. A case in point was the proposal to introduce walleye into the 14,250-ha Canyon Ferry Reservoir, near the headwaters of the Missouri River, site of the most popular trout and yellow perch lake fishery in Montana (Lere 1991). Walleye were proposed for introduction to expand angling opportunities and reduce nongame fishes. In response, Montana Fish, Wildlife, and Parks hosted a workshop on walleye and trout interactions, performed a preference survey of 1,831 anglers (MFWP 1992), and conducted a pre-introduction risk assessment (McMahon 1992). Based on this information, MFWP decided in 1992 not to introduce walleye into the reservoir due to high risk to the fishery, inadequacy of the forage base, and angler preference. However, walleye were illegally introduced and have increased rapidly, with fingerlings to large (737 mm), mature adults being collected in recent years (D. Yerk and R. Spoon, MFWP, personal communication).

Curtailing Illegal Introductions

As the above case illustrates, "bucket biologists" can easily circumvent

careful and thorough environmental and public pre-introduction reviews. Of the 33 major waters containing walleye and pike populations (Figure 1), 7 (21%) are known to be the result of illegal introductions. Fishery managers whom we surveyed noted that illegal introductions of walleye, northern pike, and yellow perch pose one of their more serious and perplexing management problems. Although there is little data, the number of illegal introductions may be increasing. In Montana, 50 of 210 documented cases of illegal fish introductions have occurred in the last 5 years (Vashro 1995). The problem is considered more acute now that modern angling boats equipped with livewells facilitate such transfers.

Although identifying the source of unplanned introductions is difficult (Was an introduction a deliberate effort to add a new species to the fishery? An innocent dumping of a bait bucket or livewell? A result of "contaminated" stockings by a fishery agency? An invasion from a nearby waterbody that was legally stocked?), we believe that greater enforcement efforts are needed to address the problem. Statutes related to illegal fish introductions and fish transportation should be strengthened if necessary. For example, the 1991 Montana legislature stiffened penalties (fines, suspension of fishing privileges, and liability for cost of restoring a fishery) for illegally transplanting fish, and rewards have been offered for individuals reporting such cases. Laws preventing transport of live fish from a waterbody have passed in numerous states (e.g., Utah, Idaho, Wyoming, Oregon, and western Montana) but may face considerable public opposition (H. Johnson, MFWP, personal communication).

Public education and involvement are essential. As with wildlife poaching, managers must appeal to recreationists to help locate and discourage potential violators. Montana has recruited angler organizations to help curb illegal introductions and, with their financial support, has expanded the state poaching hotline to include reports of illegal introductions. Workshops, news releases, and public meetings also could be used to inform anglers of the risks of illegal introductions. For example, the Wyoming Game and Fish Department used the discovery of walleye in Lake DeSmet, a valuable wild rainbow trout fishery, to publicize the risks of illegal introductions (B. McDowell, WGFD, personal communication). Oregon State University recently released an educational video, "Strangers in Our Waterways," that highlights hazards of illegal introductions. Portraying the costs and lost recreational opportunities from illegal introductions could be effective (Vashro 1990, 1995). In addition, fish and game regulation booklets could be used to educate anglers about risks of illegal introductions, and angler surveys could assess knowledge about the impacts of illegal introductions and gauge initial responses to proposed legislation as a basis for directing future educational efforts.

Conclusions

Purposeful introductions or unplanned invasions of walleye and northern pike have been a "boost" to Northwest fisheries by creating popular sport fisheries and enhancing local economies, but they also have been a "bane" due to the difficulty of sustaining an adequate prey base for these top predators, the potential for significant reduction of existing salmonid fisheries and native species, and the colonization of new waters well beyond the point of release. Managers should approach future introductions with caution. We encourage independent review of risk assessments and stocking plans to help deflect the sometimes strong public pressure fishery managers face for introducing these species

into new, sometimes inappropriate waters. More detailed monitoring studies of predator-prey interactions after introductions (e.g., Marwitz and Hubert 1995) would aid successful management. Greater efforts also are needed to stem the tide of illegal introduction. A combination of enforcement and education, as outlined, could be conducted with minimal added expense and substantial benefit to existing fisheries and native fish communities.

Acknowledgments

We thank the many individuals who provided vital information and comments: J. DosSantos, B. Hill, H. Johnson, S. Leathe, M. Lere, B. Shepard, R. Spoon, G. Thomas, J. Vashro, D. Vincent, D. Workman, D. Yerk, and A. Zale (Montana); F. Partridge and B. Rich (Idaho); A. Smith (Oregon); S. Bonar and D. Fletcher (Washington); and W. Hubert, B. McDowell, and B. Wichers (Wyoming). Reviews by W. Hubert, J. Vashro, A. Zale, and an anonymous referee were especially helpful in improving the paper. M. A. Madsen drew the distribution map.

References

Bain, M. 1993. Assessing impacts of introduced aquatic species: grass carp in large systems. Environ. Manage. 17:211–224.

Beamesderfer, R. C., and A. A. Nigro. 1989. Status, biology, and alternatives for management of walleye in John Day Reservoir: a review. Oregon Dept. Fish Wildl., Info. Rep. 89-2, Portland.

Bennett, D. H., and T. J. McArthur. 1990. Predicting success of walleye stocking programs in the United States and Canada. Fisheries 15(4):19–23.

Brown, C. J. D. 1971. Fishes of Montana. Big Sky Books, Bozeman, MT.

Colby, P., and C. Hunter. 1989. Environmental assessment of the introduction of walleye beyond their current range in Montana. Montana Department of Fish, Wildlife, and Parks, Helena.

Colby, P. J., R. E. McNicol, and R. A. Ryder. 1979. Synopsis of biological data on the walleye (*Stizostedion v. vitreum*) (Mitchill 1818). Food and Agriculture Organization (FAO) Fish. Synop. 119, Rome, Italy.

Colby, P. J., P. A. Ryan, D. H. Schupp, and S. L. Serns. 1987. Interactions in north-temperate lake fish communities. Can. J. Fish. Aquat. Sci. 44:104–128.

Conover, M. C. 1986. Stocking cool-water species to meet management needs. Pages 31–39 *in* R. H. Stroud, ed. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

DeVries, D. R., R. A. Stein, and J. G. Miner. 1991. Stocking threadfin shad: consequences for young-of-the-year fishes. Trans. Am. Fish. Soc. 120:368–381.

DosSantos, J. M. 1991. Ecology of a riverine pike population. Pages 155–159 *in* J. L. Cooper, ed. Warmwater Fisheries Symposium I. U.S. For. Serv. Gen. Tech. Rep. RM-207.

Fredenberg, W. A., and M. D. Poore. 1987. Southcentral Montana fisheries study, inventory of waters of the project area. Montana Dept. Fish, Wildl., and Parks, Job Progr. Rep. F-20-31, Billings.

Hallock, M., and D. Fletcher. 1991. A review of walleye in the lower Columbia River reservoirs. Washington Dept. Wildl. Rep. 91-9, Olympia.

He, X., and J. F. Kitchell. 1990. Direct and indirect effects of predation on a fish community: a whole-lake experiment. Trans. Am. Fish. Soc. 119:825–835.

IDFG (Idaho Department of Fish and Game). 1982. Evaluation of walleye for an expanded distribution in Idaho. IDFG, Boise.

Inskipp, P. 1982. Habitat suitability index models: northern pike. U.S. Fish Wildl. Serv. FWS-OBS-82/10.17, Washington, DC.

Johnson, M. G., J. H. Leach, C. K. Minns, and C. H. Olver. 1977. Limnological characteristics of Ontario lakes in relation to associations of walleye (*Stizostedion vitreum vitreum*), northern pike (*Esox lucius*), lake trout (*Salvelinus namaycush*), and smallmouth bass (*Micropterus dolomieui*). J. Fish. Res. Board Can. 34:1592–1601.

Jones, T. S. 1990. Floodplain distribution of fishes of the Bitterroot River, with emphasis on introduced populations of northern pike. Master's thesis. University of Montana, Missoula.

Knight, R. L., and B. Vondracek. 1993. Changes in prey fish populations in western Lake Erie, 1969–88, as related to walleye, *Stizostedion vitreum*, predation. Can. J. Fish. Aquat. Sci. 50:1289–1298.

Kohler, C. C., J. J. Ney, and W. E. Kelso. 1986. Filling the void: development of a pelagic fishery and its consequences to littoral fishes in a Virginia mainstem reservoir. Pages 166–177 *in* G. E. Hall and M. J. Van Den Avyle, eds. Reservoir fisheries management for the 80s. American Fisheries Society, Bethesda, MD.

Lere, M. 1991. Statewide fisheries investigations, survey and inventory of cold-water lakes, Canyon Ferry, Hauser, and Holter reservoirs study. Montana Dept. Fish, Wildl., and Parks, Job Progr. Rep. F-46-R-1, Helena.

MacLean, J. H., and J. J. Magnuson. 1977. Influences on species interactions in percid communities. J. Fish. Res. Board Can. 34: 1941–1951.

Marwitz, T. D., and W. A. Hubert. 1995. Descriptions of walleye stocks in high-elevation Wyoming reservoirs. Prairie Nat. 27:101–114.

McMahon, T. E. 1992. Potential impacts of the introduction of walleye to the fishery of Canyon Ferry Reservoir and adjacent waters. Montana Dept. Fish, Wildl., and Parks, Helena.

McMahon, T. E., J. W. Terrell, and P. C. Nelson. 1984. Habitat suitability information: walleye. U.S. Fish Wildl. Serv. FWS-OBS-82/10.56, Washington, DC.

McMillan, J. 1984. Evaluation and enhancement of the trout and walleye fisheries in the North Platte River system of Wyoming with emphasis on Seminoe Reservoir. Wyoming Game and Fish Dept., Laramie.

MFWP (Montana Fish, Wildlife, and Parks). 1992. Canyon Ferry Reservoir/Missouri River fisheries management plan. MFWP, Helena.

Moyle, P. B., H. W. Li, and B. A. Barton. 1986. The Frankenstein effect: impact of introduced fishes on native fishes in North America. Pages 415–426 *in* R. H. Stroud, ed. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Mundie, J. H., and R. Bell-Irving. 1986. Predictability of the consequences of the Kemano hydroelectric proposal for natural salmon populations. Can. Water Resour. J. 11:14–25.

Ney, J. J., and D. J. Orth. 1986. Coping with future shock: matching predator stocking programs to prey abundance. Pages 81–92 *in* R. H. Stroud, ed. Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Noble, R. L. 1986. Predator-prey interactions in reservoir communities. Pages 137-143 *in* G. E. Hall and M. J. Van Den Avyle, eds. Reservoir fisheries management for the 80s. American Fisheries Society, Bethesda, MD.

Partridge, F. E. 1988. Lake and reservoir investigations, alternative fish species and strains for fishery development. Idaho Fish. Res. Rep. F-73-R-10, Boise.

Peterman, R. M., and **M. Gatto.** 1978. Estimation of functional responses of predators on juvenile salmon. J. Fish. Res. Board Can. 35:797–808.

Rich, B. A. 1993. Population dynamics, food habits, movement and habitat use of northern pike in the Coeur d'Alene River system. Master's thesis. University of Idaho, Moscow.

Rieman, B. E., R. C. Beamesderfer, S. Vigg, and **T. P. Poe.** 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Trans. Am. Fish. Soc. 120:448–458.

Shepard, B. 1991. Walleye management in Montana. *In* Walleye/trout workshop. Montana Dept. Fish, Wildl., and Parks video proceedings, Helena.

Spencer, C. N., B. R. McClelland, and **J. A. Stanford.** 1991. Shrimp stocking, salmon collapse, and eagle displacement. BioScience 41:14–21.

Swenson, W. A. 1977. Food consumption of walleye (*Stizostedion vitreum vitreum*) and sauger (*S. canadense*) in relation to food availability and physical conditions in Lake of the Woods, Minnesota, Shagawa Lake, and western Lake Superior. J. Fish. Res. Board Can. 34:1643–1654.

Tinus, E. S., and **R. C. Beamesderfer.** 1994. An update on the distribution, fisheries, and biology of walleye in the lower Columbia River. Oregon Dept. Fish Wildl., Info. Rep. 94-3, Portland.

Vashro, J. 1990. Illegal aliens. Montana Outdoors 21(4):35–37.

———. 1995. The "bucket brigade" is ruining our fisheries. Montana Outdoors 26(5):34–37.

Venditti, D. A. 1994. Diet overlap and habitat utilization of rainbow trout and juvenile walleye in Cooney Reservoir, Montana. Master's thesis. Montana State University, Bozeman.

Wichers, W. F. 1981. Fishery management investigations (fisheries problems in Keyhole Reservoir). Wyoming Game and Fish Dept., Job Progr. Rep. F-44-R-04, Cheyenne.

———. 1986. Keyhole Reservoir fisherman use and game fish harvest, 1985. Wyoming Game and Fish Dept., Fish. Div. Rep. 3085-02-8501, Cheyenne.

Wiley, R. W., R. A. Whaley, J. B. Satake, and **M. Fowden.** 1993. Assessment of stocking hatchery trout: a Wyoming perspective. N. Am. J. Fish. Manage. 13:160–170.

Wydoski, R. S., and **D. H. Bennett.** 1981. Forage species in lakes and reservoirs of the western United States. Trans. Am. Fish. Soc. 110:764–771.

WGFD (Wyoming Game and Fish Department). 1990. Annual fisheries progress report on the 1989 work schedule. WGFD, Cheyenne.