

*Managing Fish Predators and Competitors:***Deciding When Intervention Is Effective and Appropriate**

By Raymond C. P. Beamesderfer

ABSTRACT

Fisheries management agencies increasingly are being asked to weigh tradeoffs between game, non-game, native, and nonnative species management. Oregon recently has been considering a variety of interspecific intervention activities aimed at protecting and rebuilding depleted native fishes or improving native game fish production by managing potential predators and competitors. Activities range from reduced harvest restrictions on fish predators and competitors to more aggressive removal programs. Chemical treatment and predator hazing also have been considered for potential benefits to more desirable fish populations. This paper describes a systematic decision-making process to determine for any given case if: (1) predation or competition is likely to be important, (2) potential predators or competitors can be affected by changes in harvest or other management actions, and (3) biological benefits outweigh costs and social/political considerations. This process is applied to several of Oregon's problems to help identify examples where intervention might prove effective and appropriate.

In one of fate's ironies, my recent work for a state fish and wildlife agency would appear to have caused me to abandon ideals that I formerly embraced as a fisheries student. As have most fish biologists, I spent significant time in institutions of higher learning developing a set of environmental ethics before reaching my current position in fisheries management. Two of my favorite professors at the University of California (UC)-Davis, Peter Moyle and Hiram Li, are among the foremost experts on western North American native fishes and fish ecology (see, for instance, Li and Moyle 1993). My favorite professors and the UC-Davis fish biology program taught me to passionately defend native nongame fishes and to be critical of game fish management at the expense of native fishes. However, my first "real" job was on the Columbia River northern pikeminnow (*Ptychocheilus oregonensis*) management program where people are paid bounties to catch and kill the

native, nongame, northern pikeminnow. This work has given me reason to carefully weigh some of my previous notions.

With widespread and prolonged declines in habitat and native fish species, fisheries management agencies increasingly are faced with difficult tradeoffs among game, non-game, native, and nonnative species management. Nonnative species, including many game fishes, are widespread and often threaten declining native species (Courtenay and Stauffer 1984; Moyle 1997; Nico and Fuller 1999). The pikeminnow management program is one example in which management agencies attempt to manipulate one species for the benefit of another (Beamesderfer et al. 1996; Friesen and Ward 1999). Management agencies have a long history of attempting to regulate undesirable fish species with limited success (Wiley and Wydoski 1993; Meronek et al. 1996). Oregon recently has been considering a variety of activities aimed at protecting and rebuilding depleted native

fishes and improving game fish production. Activities range from reduced harvest restrictions on fish predators and competitors to more aggressive removal programs including chemical treatment.

This paper presents observations and conclusions that have resulted from my attempts to reconcile my education and my professional activities. How do we decide when to intervene in reducing one species for the benefit of another? When do we have some hope of reducing predation or competition between an "undesirable" species and a preferred type? Where should we drop fishing limits, pay bounties, or break out the rotenone? This article describes a systems approach for considering whether or not to intervene based on evaluations of the significance of fish predation or competition, the potential for effective intervention, and the social and political acceptability of the proposed action.

A systems approach to considering intervention

Is it significant, can it be affected, and is it acceptable? These three questions form the basis for a

Raymond C. P. Beamesderfer is a fishery management biologist in the Columbia River Program of the Oregon Department of Fish and Wildlife, 17330 Southeast Evelyn Street, Clackamas, OR 97015; ray.beamesderfer@state.or.us.



systematic decision-making process for implementing management actions on one species for the benefit of another. Is species A significantly reducing the abundance of species B directly by predation or indirectly by competition for a limited resource? Can you affect the predator or competitor enough to provide benefits to the desired species? Is intervention socially, politically, and legally acceptable? I suggest that the answer must be yes to all three of these questions for intervention to be effective and appropriate.

If any one answer to the three questions is negative, there's probably no point in proceeding further. No benefit will accrue if there's no interaction. Even if there is a problem, we may be stuck with it if there is no feasible means of affecting the problem. Likewise if there is a problem and we know how to deal with it, a variety of constraints may preclude us from doing so.

Rules of thumb for evaluating interaction problems

There are three approaches for investigating species interaction problems: empirical, mechanistic, and inferential. The ideal method is an empirical approach where one species is added or removed and the other species is monitored for a response. For instance, if we want to know if seals and sea lions reduce salmon returns, we could reduce seal and sea lion numbers and see if we get more salmon. Similarly, if we want to know if zebra mussel (*Dreissena polymorpha*) introduction harms native fishes, we could monitor fish populations before and after mussel introduction. However, many fish populations naturally ebb and flow in response to a variety of factors and so a valid experimental design requires a control to distinguish a response from background noise and replicates for the test and control groups to provide statistically valid conclusions (Green 1979). Good empirical studies are rare, although there have been some excellent case histories where native populations were monitored following a species

introduction (Zaret and Paine 1973; Brown and Moyle 1991).

In the mechanistic approach, the relationship is broken into its components, each is evaluated, and then results are added back together. To demonstrate competition, for instance, you must show that both species use the same resource, use by one species precludes use by the other species, the resource is in limited supply, and resource abundance regulates the affected species. For competition, it is generally easy to show common use of a resource but limitation and regulation are extremely difficult to demonstrate. A general problem with mechanistic studies also comes in identifying all the appropriate links between cause and effect. Key relationships or interactions are easily overlooked. Mechanistic studies of complex systems can be likened to trying to put a car engine together when you've never seen one before, you don't have instructions, and you're not even sure you have all the parts.

The inferential alternative involves drawing useful generalizations from case studies and general ecological principles and then applying those principles to similar cases. Rules of thumb developed from such generalizations can help infer where problems are likely to occur, narrow the list of problems, and prioritize which problems warrant further action. In the proposed decision system, the rules of thumb provide the answers to the three questions.

Rule of thumb #1: Interaction problems are often a symptom of an underlying habitat alteration problem. This rule of thumb is illustrated

by pikeminnow predation on salmon smolts in the Columbia and Willamette rivers (Figure 1). Juvenile salmonids are a significant diet item for pikeminnow from the Columbia River (Poe et al. 1991; Zimmerman 1999). Columbia River pikeminnow are estimated to be eating perhaps 16 million salmon and steelhead smolts (*Oncorhynchus* spp.) per year or about 8% of the run (Beamesderfer et al. 1996; Zimmerman and Ward 1999). Rewards or bounties have been paid for pikeminnow from the Columbia River since 1990 and over 1 million pikeminnow have been removed. Pikeminnow harvest is estimated to have resulted in increases in salmon returns of as many as 1 million adults over the lifespan of the removed pikeminnows. In contrast, pikeminnow in the Willamette River eat few smolts although large numbers of salmonids migrate through the system (Buchanan et al. 1981). Pikeminnow predation is a problem in the Columbia and not in the Willamette because the dams have disrupted prey and predator behavior in the Columbia. Predation is low in areas such as the mainstem Willamette where smolts migrate normally: offshore, during turbid high flow events, high in the water column where they avoid the bottom- and shoreline-oriented pikeminnow (Brown and Moyle 1981). Intervention is often considered as a substitute for habitat problems which seem to be too expensive or politically difficult to address directly. Overexploitation sometimes acts similar to habitat alteration in that problems attributed to interactions

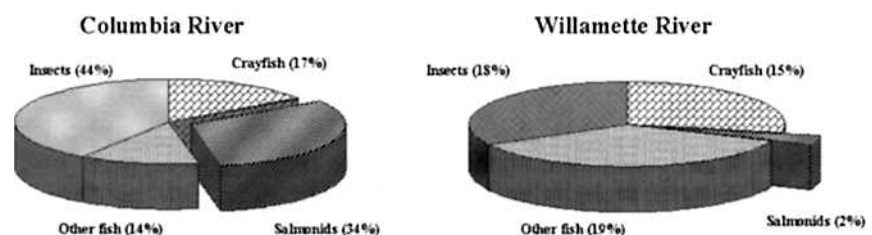


Figure 1. Frequency of occurrence of diet items of northern pikeminnow from the Columbia and Willamette rivers (Buchanan et al. 1981; Poe et al. 1991).

FISHERIES MANAGEMENT—PERSPECTIVE

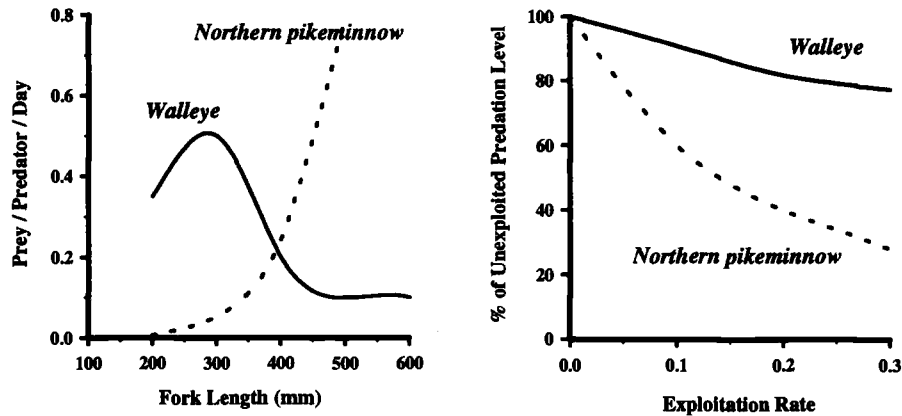


Figure 2. Predation rate on salmonids and the reduction in net predation expected with exploitation of walleye and northern pikeminnow in the Columbia River (Beamesderfer and Nigro 1989; Beamesderfer et al. 1996).

may actually result from fishing above sustainable rates.

Rule of thumb #2. Complex interactions in complex communities may compensate and cancel the benefits of intervention. A comparison of salmon predation in the Columbia (a large river mainstem) versus Tenmile Lakes (several small coastal lakes) illustrates this rule of thumb. Pikeminnow control is likely to increase salmon production in the Columbia because it is a fairly simple system from a salmon smolt's point of view, serving primarily as a migration corridor. Density-dependent regulating mechanisms for salmon are generally believed to be much more important in freshwater rearing habitats than in the ocean where survival is largely density-independent (Beamesderfer et al. 1996). Thus, if $x\%$ of smolts are saved, $x\%$ more adults generally return. However, salmon interactions with other fish species are much more complex in Tenmile Lakes. Predators in Tenmile Lakes include largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and brown bullheads (*Ameiurus nebulosus*). Coho salmon (*Oncorhynchus kisutch*) smolts pass through on their way to the ocean and coho parr also rear in the lakes. Unlike the Columbia, compensatory regulating mechanisms are still operating on coho parr. Predators eat smolts and parr but also eat and compete with each other. The net effect of all these links and feedback mechanisms

in Tenmile Lakes is extremely difficult to predict (Dambacher et al. 1999). Intervention has a much better chance of working in a simple density-independent community like the Columbia mainstem, than in a complex density-dependent community like Tenmile.

Rule of thumb #3: Intervention benefits will be small unless many or most of the problem animals can be affected. This rule of thumb explains why bounties are paid for pikeminnow from the Columbia River but not for nonnative walleye (*Stizostedion vitreum*) which also eat salmon smolts. The bigger the pikeminnow, the more smolts they eat (Figure 2). Relatively low exploitation rates of pikeminnow amortize through time to reduce survival to large piscivorous sizes, which are reached at 8–10 years of age. Fishing thus reduces the number of large smolt-eating pikeminnow. Fishing may also reduce spawner number and future pikeminnow recruitment. As a result, relatively small annual exploitation rates of only 10%–20% should reduce pikeminnow predation by half (Beamesderfer et al. 1996). Walleye are every bit as voracious a smolt predator as pikeminnow. However, walleye eat fewer smolts as they get older and so removal of walleye by angling has relatively little effect on smolt predation unless sufficient numbers can be removed to affect reproduction (Beamesderfer and Nigro 1989). Most smolts are eaten by walleye smaller than those typically

caught by anglers and so a walleye bounty or unlimited walleye fishing provides little salmon benefit. In most Columbia River reservoirs, small-mouth bass are similar to walleye in that most predation occurs by bass too small to be affected by fishing (Beamesderfer and Ward 1994; Zimmerman 1999).

Rule of thumb #4: Benefits will be temporary unless intervention is sustained. In 1968, Tenmile Lakes and their tributaries were chemically treated for bullheads and bluegill (Campbell and Locke 1968; Grenfell and Montgomery 1969). Treatment cost \$179,000 (in 1968 dollars) and required 755 drums (50-gallon size) of rotenone. Data on treatment benefits in Tenmile Lakes fall short of empirical scientific standards which distinguish coincidence from cause and effect but data are typical of many similar intervention efforts where sound pre-treatment or control data are lacking. Subsequent population trends are also similar to theoretical patterns and serve to illustrate this rule of thumb. A big spike in coho production immediately followed treatment and was attributed to removal of predators and competitors. Treatment may have been initially effective, in part because the Tenmile Lakes aquatic community was chemically simplified into a system where coho salmon were not subjected to complex community interactions. However, potential benefits were short-lived as warmwater fish quickly repopulated (Figure 3). In fact, record bluegill numbers followed their recovery. Thus, not only were treatment benefits short-lived for coho, but the recovery spike for warmwater fish might ultimately have depressed coho further than they would have been if we had just left the system alone.

Rule of thumb #5: The probability of success is inversely proportional to the number of special interests involved. This tongue-in-cheek rule of thumb recognizes the nonbiological constraints which can affect the potential implementation of intervention programs. These nonbiological constraints include relative costs—nobody

would be willing to pay millions of dollars for pikeminnow bounties unless it was a substitute for more costly or politically unpalatable measures. Nonbiological constraints include social conventions. Can you imagine the uproar if someone proposed a bounty program on Caspian terns (*Sterna caspia*), which have also been identified as significant salmon predators? Constraints also include politics. If Oregon removes bag limits on walleye in the Columbia River, does it do any good if Washington doesn't? And as always there are legal issues. For instance, the Marine Mammal Protection Act limits schemes we might entertain to control seals and sea lions even if we believe their predation contributes to salmon declines. Extremely complex, large-scale, or controversial actions can be difficult if not impossible to implement because of a wide array of constraints.

Application of a systems approach to fish interaction problems

Pikeminnow bounty—Columbia River. The three-step decision process combined with the five rules of thumb provide guidance on where interspecific intervention can be effective and appropriate (Table 1). For instance, the interaction with northern pikeminnow seems to be significant because millions of salmonids are being eaten each year. The interaction is not independent of habitat changes because predation has been exacerbated by dam construction and operation, but a bounty program has been implemented in lieu of more costly changes in the hydropower system. Simple interactions give intervention some chance of success. The interaction is affected because removals are adequate and sustained. The program is acceptable since northern pikeminnows are often considered to be undesirable to people, they are abundant and known to be effective predators on salmon smolts, and a modest reduction in pikeminnow numbers could substantially increase downstream survival of salmon smolts.

Pikeminnow bounty—Willamette River. The systems approach leads to

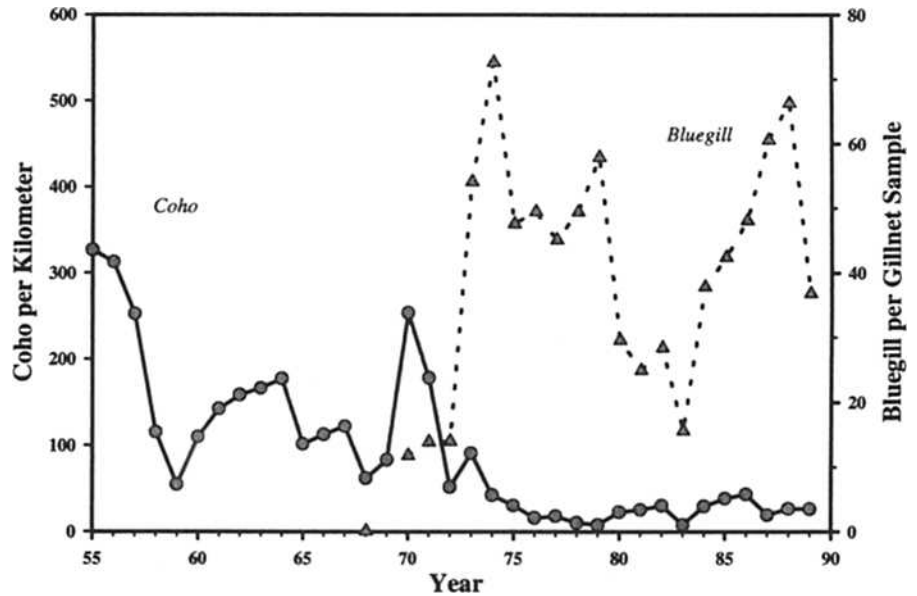


Figure 3. Relative abundance of coho salmon and bluegill before and after chemical rehabilitation of the Tenmile Lakes system in 1968 (P. Reimers, Oregon Department of Fish and Wildlife, unpublished data).

a conclusion that there's no need for a bounty program on pikeminnow in the Willamette River (Table 1). Little smolt predation occurs in the Willamette because it is a relatively unaltered system from a predator-prey behavior point of view. The interaction is not significant and we need proceed no further in the decision matrix because it takes only one hard "no" to conclude no action.

Unlimited walleye fishing—Columbia River. Removing all fishing regulations on walleye in the Columbia River is not a promising strategy (Table 1). Walleye predation is significant but fishing regulations do not remove significant numbers of walleye of predaceous size. Anglers don't catch the small walleye that are doing the damage and probably couldn't achieve a high harvest rate even with walleye bounties because of the large size of the system and low walleye density. A walleye removal program would be less acceptable than the pikeminnow program, especially to an active and vocal group of walleye anglers.

Unlimited bass fishing—Tenmile Lakes. Similarly, unlimited bass angling in Tenmile Lakes would not be expected to provide significant

benefits. Tenmile Lakes is not a simple system where a large benefit could be expected from predator removal (Dambacher et al. 1999). It is questionable whether we could even affect bass predation by increasing angler harvest rates because bass resemble walleye in that most of problem occurs in small fish not subject to fishing (Beamesderfer and Ward 1994). Acceptability issues also limit the likelihood of success. Many bass anglers practice catch and release already and wouldn't keep significantly more bass.

Chemical rehabilitation—Tenmile Lakes. The three-step decision process and rules of thumb illustrate that another chemical rehabilitation of Tenmile Lakes would not provide sustained benefits. The 1968 program could be inferred to suggest that treatment can benefit coho, and hence might suggest that other species affect coho production. Removals are definitely significant but benefits are not sustained unless treatments are repeated periodically. Further, chemical rehabilitation is much less acceptable now than it was in 1968.

Sea lion control—Willamette Falls. The last example considers sea lion control at Willamette Falls. Sea lions

FISHERIES MANAGEMENT—PERSPECTIVE

Table 1. Example applications of three-step decision process for considering the potential benefits of intervention in managing fish predators and competitors.

| Example | Significant? | | | Affected? | | | Acceptable? | Intervene? |
|---|----------------------|---------------------|----------|--------------------|------------|----------|-------------|------------|
| | Habitat independent? | Simple interaction? | Conclude | Adequate removals? | Sustained? | Conclude | | |
| Pikeminnow bounty: Columbia River | No ¹ | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Pikeminnow bounty: Willamette River | — | — | No | — | — | — | — | No |
| Unlimited walleye fishing: Columbia River | No ¹ | Yes | Yes | No | Yes | No | Unknown | No |
| Unlimited bass fishing: Tenmile Lakes | Yes | No | No | Unknown | Yes | Unknown | Unknown | No |
| Chemical rehabilitation: Tenmile Lakes | Yes | Yes ² | Yes | Yes | No | No | No | No |
| Sea lion control: Willamette Falls | No ¹ | Yes | Yes | Yes | Yes | Yes | Maybe | Maybe |

¹ Predation is exacerbated by habitat changes but predator control is a substitute for habitat restoration.

² Complex pre-control community is simplified by chemical rehabilitation.

currently eat several hundred adult spring chinook and steelhead per year at this site. Sea lions can also cause passage problems if they sit in ladder entrances. The problem is not habitat independent but no one is proposing removal of the power house, paper plants, and navigation locks at the falls. The interaction is fairly simple, so compensation would not be expected to erode the benefits of intervention. There are only a few problem animals and lethal removal methods would effectively resolve the problem. However, lethal removal of marine mammals is no longer acceptable or legal. Nonlethal methods such as gratings at ladder entrances might prove effective in keeping sea lions out of the fish ladder and would be socially and legally acceptable. This example demonstrates that there is often more than one way to address interaction problems.


Conclusions

My intention with this paper was to outline an organized process for considering interactions among fish species and to provide some guidelines for deciding when human intervention might be effective and appropriate. Examples illustrate the difficulties of implementing effective intervention

programs. The Columbia River pikeminnow bounty program is the lone exception among the examples considered where intervention is considered significant, effective, and acceptable. Although this exception refers to control of a native species, most undesirable interactions result from nonnative introductions. Clearly, efforts aimed at prevention of undesirable introductions and alien species hold greater promise than attempts to affect populations after they become established.

Interaction problems are extremely difficult to diagnose and even harder to affect. Just because one species eats another or uses the same space or food doesn't mean that the interaction is significant. Even when interactions are significant, it's a rare case where intervention will be effective. Perceived interaction problems are often a symptom of underlying habitat alteration problems. Habitat improvements are usually more appropriate than fish population manipulations where introduced species thrive in altered habitats poorly suited for the native species. Even when interactions are significant, intervention benefits are small unless most of the problem animals can be affected and the effect can be sustained. Finally, complex interactions in complex

communities may cancel the benefits of intervention or even exacerbate the problem.

Economic, political, and social issues compound consideration of any intervention effort and success often hinges on public perception rather than biology. The human component in the biological decision-making process involves cultural attitudes, perceptions, and values that have and will continue to affect fishery management decisions. Actions with marginal biological benefits are sometimes worthwhile if they affect public perception and stimulate a broader and more effective response. However, real opportunities for an impact will remain difficult to discern from false cases which look good but accomplish nothing. 

Acknowledgments

Material for this article was initially developed for presentation at a 1998 workshop on the management implications of co-occurring native and introduced fishes presented by the Oregon Department of Fish and Wildlife and the National Marine Fisheries Service. Reviews by Peter Moyle, Richard Wydoski, and Harold M. Tyus significantly improved this manuscript.

References

- Beamesderfer, R. C., and A. A. Nigro.** 1989. Status, biology, and alternatives for management of walleye in John Day Reservoir: a review. Oregon Department of Fish and Wildlife Information Report 89-2.
- Beamesderfer, R. C., and D. L. Ward.** 1994. Review of the status, biology, and alternatives for management of smallmouth bass in John Day Reservoir. Oregon Department of Fish and Wildlife Information Report 94-4.
- Beamesderfer, R. C. P., D. L. Ward, and A. A. Nigro.** 1996. Evaluation of the biological basis for a predator control program on northern squawfish (*Ptychocheilus oregonensis*) in the Columbia and Snake rivers. *Can. J. Fish. Aquat. Sci.* 53:2898–2908.
- Brown, L. R., and P. B. Moyle.** 1981. The impact of squawfish on salmonid populations: a review. *N. Am. J. Fish. Manag.* 1:104–111.
- . 1991. Changes in habitat and microhabitat partitioning within an assemblage of stream fishes in response to predation by Sacramento squawfish (*Ptychocheilus grandis*). *Can. J. Fish. Aquat. Sci.* 48:849–856.
- Buchanan, D. V., R. M. Hooton, and J. R. Moring.** 1981. Northern squawfish (*Ptychocheilus oregonensis*) predation on juvenile salmonids in sections of the Willamette River basin, Oregon. *Can. J. Fish. Aquat. Sci.* 38:360–364.
- Campbell, C. J., and F. E. Locke, eds.** 1968. Fishery Division annual report. Oregon State Game Commission, Portland.
- Courtenay, W. R., Jr., and J. R. Stauffer, Jr., eds.** 1984. Distribution, biology, and management of exotic fishes. Johns Hopkins University Press, Baltimore, MD.
- Dambacher, J. M., H. W. Li, and P. A. Rossignol.** 1999. Historical reconstruction, through qualitative modeling, of the effects of exotic fish introductions in Tenmile Lakes Oregon. Pages 219–233 in Oregon Department of Fish and Wildlife and National Marine Fisheries Service. Proceedings of a workshop on management implications of co-occurring native and introduced fishes. Available from National Marine Fisheries Service; 525 NE Oregon Street, Suite 510; Portland, OR 97232.
- Friesen, T. A., and D. L. Ward.** 1999. Management of northern pikeminnow and implications for juvenile salmonid survival in the lower Columbia and Snake rivers. *N. Am. J. Fish. Manag.* 19:406–420.
- Green, R. H.** 1979. Sampling design and statistical methods for environmental biologists. Wiley, New York.
- Grenfell, R. A., and M. Montgomery.** 1969. Don't tip the balance. Oregon State Game Commission Bulletin. January:3–6.
- Li, H. W., and P. B. Moyle.** 1993. Management of introduced fishes. Pages 287–307 in C. C. Kohler and W. A. Hubert, eds. Inland fisheries management in North America. American Fisheries Society, Bethesda, MD.
- Meronek, T. G., P. M. Bouchard, E. R. Buckner, T. M. Burri, K. K. Demmerly, D. C. Hatleli, R. A. Klumb, S. H. Schmidt, and D. W. Coble.** 1996. A review of fish control projects. *N. Am. J. Fish. Manag.* 16:63–74.
- Moyle, P. B.** 1997. The importance of historical perspective: fish introductions. *Fisheries* 22(10):14.
- Nico, L. G., and P. L. Fuller.** 1999. Spatial and temporal patterns of nonindigenous fish introductions in the United States. *Fisheries* 24(1):16–27.
- Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Prendergast.** 1991. Feeding of predaceous fishes on outmigrating juvenile salmonids in John Day Reservoir, Columbia River. *Trans. Am. Fish. Soc.* 120:405–420.
- Wiley, R. W., and R. S. Wydoski.** 1993. Management of undesirable fish species. Pages 335–354 in C. C. Kohler and W. A. Hubert, eds. Inland fisheries management in North America. American Fisheries Society, Bethesda, MD.
- Zaret, T. M., and R. T. Paine.** 1973. Species introduction in a tropical lake. *Science* 182:449–455.
- Zimmerman, M. P.** 1999. Food habits of smallmouth bass, walleyes, and northern pikeminnow in the lower Columbia River basin during outmigration of juvenile anadromous salmonids. *Trans. Am. Fish. Soc.* 128:1036–1054.
- Zimmerman, M. P., and D. L. Ward.** 1999. Index of predation on juvenile salmonids by northern pikeminnow in the lower Columbia River basin, 1994–1996. *Trans. Am. Fish. Soc.* 128:995–1007.