Selecting Harvest Regulations for Recreational Fisheries: Opportunities for Research/Management Cooperation

By Brett M. Johnson and Patrick J. Martinez

ABSTRACT
The need for harvest regulations to manage sportfisheries is widely recognized, but regulations are not always selected and applied scientifically with an assessment of the ecological implications of manipulating harvest. Regulations directed at protecting top predator fishes may have undesirable consequences for other fishes in the system. A strategy is developed for selecting harvest regulations that considers both direct effects of regulations on the target population and indirect effects on other trophic levels. The result is a set of regulation options that achieve angler and management goals while reducing unexpected or adverse responses within the fish community. This approach requires fishery researchers and managers to work closely together to be effective, and, thus, the regulation selection process offers an excellent opportunity for research and management cooperation.

PERCEPTIONS of the need for fishing regulations in the United States have changed substantially during the past 300 years. A period of increasing restrictions began with the first colonists, who believed that some gear and season restrictions were necessary (Redmond 1986). This period continued until the 1940s, when well-known fishing experiments on Norris Reservoir, Tennessee (Eschmeyer 1945), and Escanaba Lake, Wisconsin (Oehmcke and Waggoner 1956), failed to show detrimental effects to the fish populations. These studies strongly influenced fishery managers' thinking about the need for fishing regulations until the early 1960s (Redmond 1986).

During this period of liberalization, many fishery biologists believed that fishing regulations needlessly reduced harvest and resulted in less than maximum use of the resource's potential yield. As fishery science matured, along with the arrival of modern field methods, managers could detect mounting evidence of overexploitation in recreational fisheries. Beginning in the 1970s, length and bag limits became more widely applied to reduce exploitation rates to sustainable levels (Redmond 1986).

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Today, harvest regulations are becoming an increasingly important tool in the management of recreational fisheries. In a recent survey of 58 nonfederal U.S. fishery management agencies (Mather et al. 1995, this issue), regulation of harvest ranked as the number-one management issue of concern. Increasing sophistication among anglers and their equipment, combined with fixed or declining aquatic resources, suggest that the role of harvest regulations in fishery management will only increase in the future (Noble and Jones 1993).

The American Fisheries Society's Resource Policy Committee drafted a position statement urging a scientific basis for selecting sportfishing regulations (Goeman et al. 1995). We concur with the position statement and suggest that attitudes about fishing regulations must enter a new phase—one in which regulations are applied scientifically with an understanding of the ecological implications of manipulating harvest. We offer a strategy for selecting harvest regulations consistent with this goal and suggest that research-management cooperation is needed to achieve a more responsible approach to the use of sportfishing regulations.

Regulations and the single-stock paradigm

Fishery management has traditionally been a population-level endeavor. While predator-prey relations have figured prominently in the management of southeastern U.S. ponds and reservoirs (Swingle 1950; Noble 1986) and the Great Lakes

(Stewart et al. 1981), the single-stock paradigm is firmly entrenched in fishery science. The pioneering work of Schaefer (1954), Beverton and Holt (1957), and Ricker (1958) provided the backbone for today's fishery science, and this single-species approach prevails in the management of most marine and freshwater, commercial and recreational fisheries (Hilborn and Walters 1992).

The basis for most fishery management efforts, especially for the application of harvest regulations, is that stocks can be managed to "optimize" harvest by manipulating their demographic parameters such as recruitment, growth, and survival (the inputs and outputs, Ricker 1958). The target population's biological characteristics also constrain the kinds of management strategies that will be effective. Deferring harvest to older ages to increase the average size of the catch can be offset by natural mortality (Fig. 1). Thus, an analysis of the competing effects of growth and mortality is central to selecting appropriate size regulations. Clearly, it has been and continues to be a useful framework, but there are limitations.

Traditional single-species models were not designed to predict effects of management strategies across trophic levels (which we term "indirect effects"); therefore, users cannot predict the sustainability of a given harvest strategy at the population or ecosystem level. Many regulation evaluations have reported unforeseen compensatory declines of individual growth rates in target populations in response to the higher survival afforded by harvest restrictions (Hickman and Congdon 1974; Kempinger and Carline 1978; Brousseau and Armstrong 1987). Density-dependent reductions in predator growth can result from competition for habitat or food. Reduced predator growth rates often imply ecologically significant changes in prey populations. Besides considering the implications for sportfish food supply, investigations into the indirect effects of harvest regulations on prey community structure and biodiversity have been rare.

Because anglers can be such effective predators (Magnuson 1991; Kitchell and Carpenter 1993), it follows that harvest regulations are a powerful management tool and that their efficacy can extend beyond manipulating target populations to manipulating whole ecosystems. Yet only a few examples exist where sportfishing regulations were used to accomplish community, food web, or ecosystem goals (e.g., Forney 1980; Ney 1990; Kitchell 1992).

This shortcoming of current approaches combined with heightened public interest in the conservation of biodiversity and growing recognition of the necessity of ecosystem management will likely motivate fishery managers to adopt a broader ecological perspective of the management goals for harvest regulations than the traditional single-stock or "target-species" approach. While we believe population-level assessment and analyses will always be essential fishery biology tools, linking populations into broader levels of ecological organization is necessary to make fishery management more comprehensive and predictive. This broader view is not simply for political expedience but for the sustainability of our sportfishery resources.

The regulation selection process

Ideally, managers should assess four factors when contemplating harvest regulations: angler desires, management goals, target-population biology, and potential indirect ecological effects. Obviously, angler desires must enter into the process

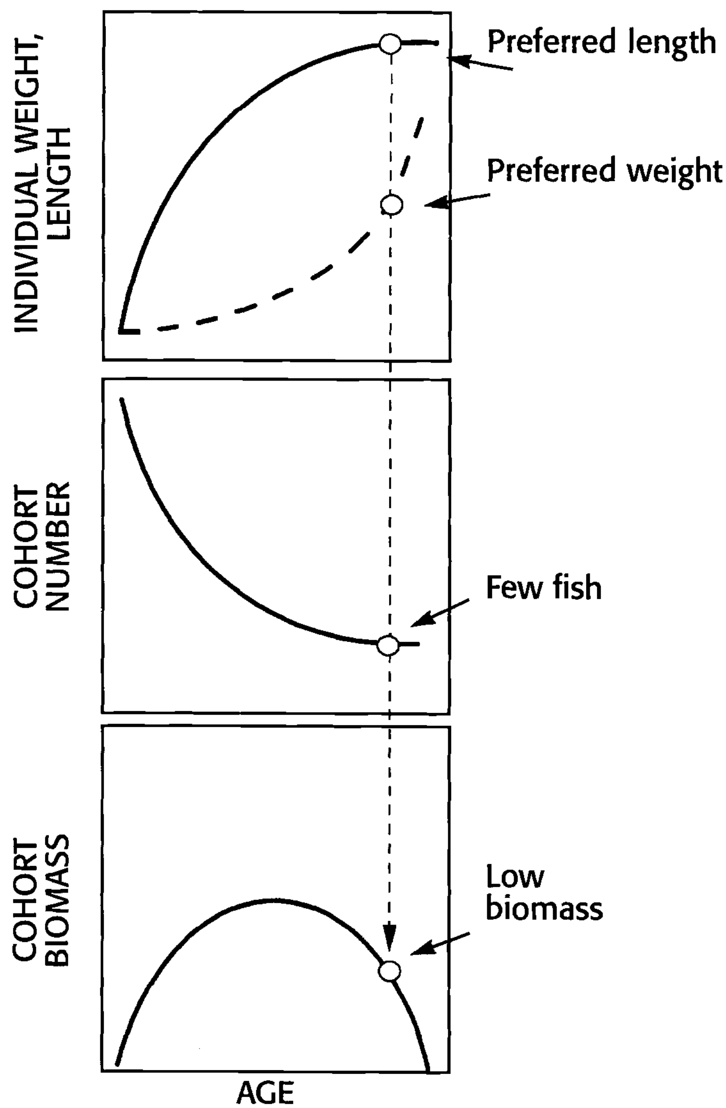
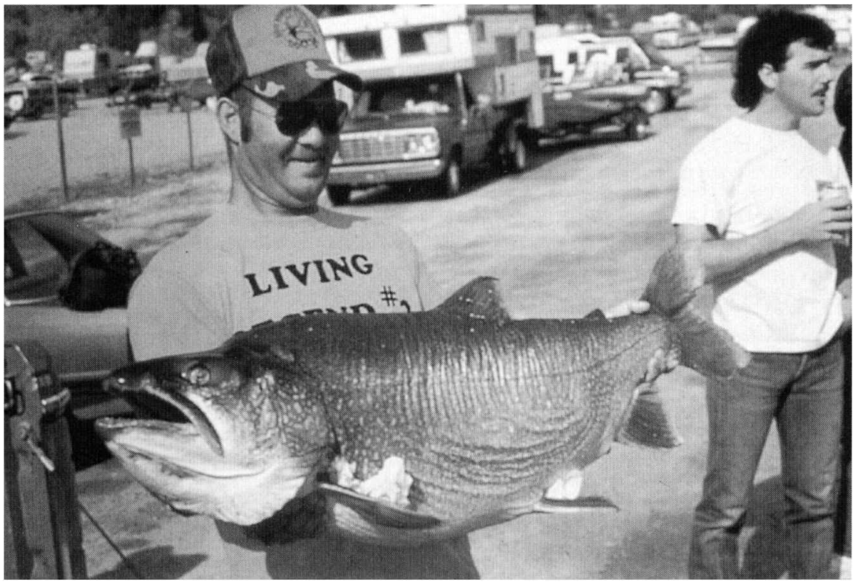


Fig. 1. Fish demographic relationships must enter into the selection of appropriate harvest regulations. Cohort biomass at a given age is the product of individual fish weight at that age and the number of fish



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The Utah state record lake trout (51 lbs 8 oz) was caught in 1988 at Flaming Gorge Reservoir.

Our approach requires fishery researchers and managers to work closely together to be effective. Managers can benefit from the new tools becoming available to researchers, and researchers can benefit by being involved with regulation "experiments" that managers routinely conduct. Finally, researchers and managers must work together to take the next step beyond predator-prey considerations in harvest regulations toward a broader ecosystem approach to fishery management (Ney 1990). Thus, the selection of sportfishery harvest regulations presents an excellent opportunity for research/management cooperation.

because often the goal of harvest regulations is to provide for long-term public enjoyment of the resource. As is true for us all, anglers would like to have their cake and eat it, too, unless they are told otherwise. It is up to us, as fisheries professionals, to ensure that sound science is the basis for selecting regulations and to instill realistic public expectations for the resource. Management goals also must be appraised. These goals may include reducing harvest to increase the reproductive potential of a population and reduce the reliance on stocking, or encouraging harvest to reduce intraspecific competition or exploit fisheries with high natural mortality. Managers also should consider the likelihood of compliance with the regulation and its enforceability.

Most fishery managers recognize the need of evaluating the target-population biology before prescribing a particular harvest regulation. Managers may be aware of the relevance of evaluating indirect effects but may have lacked the means to conduct such evaluations. Tools are available to begin to adopt a multispecies approach to address indirect effects of harvest regulations. We present one strategy for expanding the scope of the regulation selection process to include an assessment of some indirect effects of regulations on nontarget species.

The selection process gone awry

In our experience, most anglers have strong opinions about harvest regulations. Many of these opinions are a consequence of public information campaigns by well-meaning fishery professionals and the outdoor media to promote harvest restrictions. As a result, climate in the angling community is changing to accept reduced harvest in favor of increased catch rates and size structure. Despite increased biological understanding among serious anglers and their involvement in the management process, unrealistic angler expectations for a given resource are common.

The process of selecting sustainable regulations can be easily short-circuited when these angler desires override the biological and ecological constraints and dictate management goals. To prevent this, it is important for managers and researchers to evaluate biotic constraints before soliciting public opinion on the selection of specific regulations. In this way they can present the

Table 1. History of lake trout harvest regulations in Colorado.

Regulation period	Regulation type	Length limit (inches)	Daily bag limit	Number of waters	Range of lake sizes (ha)
1970	Minimum	15	4	1	1,000
1972	Minimum	20	2	3	59–1,378
1974	Minimum	15	2	Statewide	8–3,706
1977	Minimum	15	2	2	724–1,000
1979	Minimum	15	2	1	1,120
1985	Minimum	20	1	5	140–3,706
1986	Minimum	20	1	6	653–3,706
1988	Minimum	20	1	1	9
	Protected slot	20–32	1	9	205–3,706
1990	Minimum	20	1	4	9–202
	Protected slot	22–34	1	10	15–3,706
1993	Minimum	20	1	6	9–202
	Protected slot	22–34	1	9	15–3,706
	Protected slot[a]	26–36	2	2	205–2,936

[a] Regulation also protects recently stocked splake (*Salvelinus namaycush* x *S. fontinalis*).

public with tradeoffs in fishery outputs associated with different regulations. However, too often in the past, the process of selecting regulations has been to assess angler and manager goals and then arbitrarily select a regulation and hope it will meet these goals. We argue that there can be too much emphasis on public opinion and not enough emphasis on biology. The result is "trendy" regulations that the target population or ecosystem may not be able to support.

The history of lake trout (*Salvelinus namaycush*) regulations in Colorado illustrates how trends in fishing preferences can influence the regulation selection process. Colorado has been a national leader in the development of biologically sound stream trout regulations. However, trophy lake trout regulations may have been enacted with insufficient consideration given to their evaluation or potential ecological consequences. In the 1980s, interest in managing for trophy lake trout became more widespread in several western states and Canada (Dextrase and Ball 1991; Luecke et al. 1994; Martinez 1994). Catches of record lake trout in places such as Flaming Gorge Reservoir brought on a kind of "lunker fever." Enthusiasm for trophy lakers swept through the fishing community, afflicting anglers and fishery biologists alike. The result in Colorado was a rapid increase in both the number and range of sizes of waters with special regulations for lake trout (Table 1).

These new limits became progressively more restrictive on both the size and number of fish that could be harvested (Table 1). First, daily bag limits were reduced from four fish to one. Then, in the late 1980s, slot length limits were enacted, with the upper end of the slot steadily increasing. Regrettably, managers and researchers did not have the opportunity to work together to address the lake trout population or ecosystem effects of these regulation changes. This is unfortunate because the evaluation of indirect effects of regulations is especially important with lake trout in western reservoirs for several reasons.

In these systems the apical predator (lake trout) is an exotic and, therefore, has not coevolved with its prey. The lack of coevolutionary history can result in an unstable food web (Rieman and Myers 1992; Yule and Luecke 1993). Lake trout are often stocked so that predator abundance is further decoupled from density regulation by the prey. Because western mountain reservoirs are often oligo-mesotrophic systems, they have limited prey fish biomass and production; therefore, the sustainable biomass of lake trout is also limited. Often, the prey base includes other salmonids stocked to enhance sportfishing. Finally, lake trout reach large sizes (>20 kg) and are long-lived (>15 y). Therefore, once released into a system they exert predation on forage populations for many years, giving lake trout high predation inertia. In heavily fished systems, restrictive regulations may increase lake trout survival, increasing the likelihood for lake trout to alter prey communities (e.g., Luecke et al. 1994).

This scenario may be occurring at Lake Granby, Colorado. Lake Granby is a 2,900-ha reservoir in north central Colorado. The surface elevation is 2,524 m above sea level, and the lake is oligo-mesotrophic (Martinez and Bergersen 1991). It is noteworthy because it was historically one of Colorado's best kokanee salmon (*Oncorhynchus nerka*) fisheries and also one of the best kokanee egg sources for hatcheries in the western United States (Martinez and Wiltzius 1995). Granby was also at the forefront of Colorado lake trout regulation changes.

Before protective regulations in the 1980s, the reservoir had already produced many trophy trout, but biologists believed the population needed to be protected and enhanced with slot and bag limits. However, little population data were used to select these limits. Under statewide regulations until 1985, special protection of Granby's lake trout started with a 20-in (508 mm) minimum length limit and a bag limit of one. The protected slot length limit enacted in 1989 (20–32 in, 508–813 mm) became more restrictive in 1990–1992 (22–34 in, 559–864 mm). In 1993, the slot increased again to 26–36 in (660–914 mm) with a bag limit of two and only one fish more than 36-in (914 mm). Thus, the regulation changes protected larger and larger fish for a longer time.

Based on trends in adult kokanee size, harvest estimates, and data from the spawning runs, the

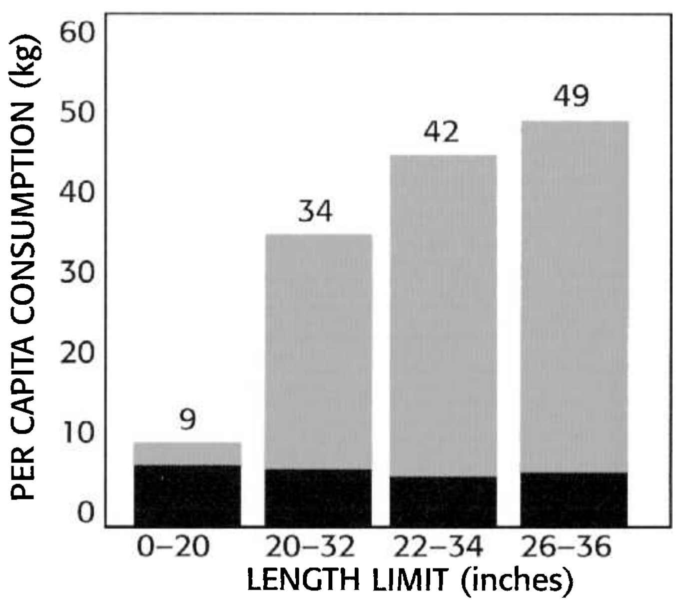

Fig. 2. Prey biomass consumed by a single lake trout growing through various length limits in Lake Granby, Colorado, was predicted with a bioenergetics model (Hewett and Johnson 1992). For example, the 0–20-in bar represents the biomass of food eaten by a single lake trout growing from 0–20 in (the length interval the fish is protected under a 20-in minimum size limit).

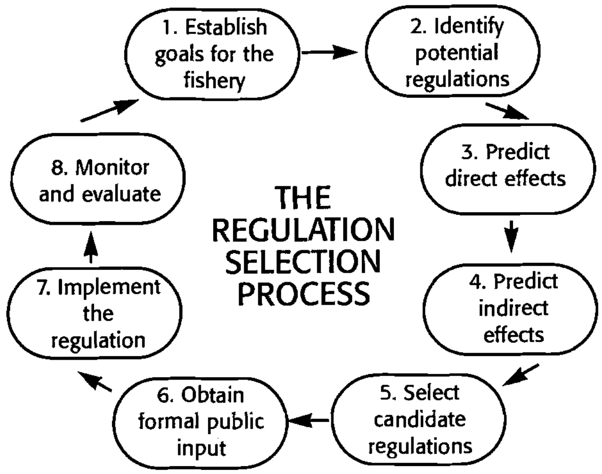

Fig. 3. We suggest this strategy for the harvest regulation selection process. Direct effects are the demographic changes in the target population computed with a fishery model, and indirect effects are predicted consumption of prey by the target population altered by regulations.

kokanee population in Granby has declined since the late 1980s (Martinez and Wiltzius 1995). This decline does not appear to have resulted from a change in environmental conditions (Martinez and Wiltzius 1995). Available data document lake trout predation on kokanee during spring and fall in Lake Granby. Stomachs of 20 lake trout ranging in size from 444 mm to 864 mm examined in 1985 and 1994 all contained at least one kokanee. As was the case for lake trout predation on Utah chubs (*Gila atraria*) in Flaming Gorge Reservoir (Luecke et al. 1994), several years of intensive lake trout management at Granby appeared to increase lake trout predation pressure on the forage population.

How could managers have foreseen the implications of trophy lake trout regulations on Lake Granby and averted this predicament? We believe that research and management working cooperatively to predict direct and indirect regulation effects via modeling may have revealed the risks associated with trophy lake trout regulations.

Incorporating indirect effects

Simply considering angler and management goals and the biological potential of the target population is not always enough. We also need to evaluate ecological considerations of regulation changes. That is, we need to assess the direct effects of a regulation on the target population and indirect effects of the change on other trophic levels. Indirect effects may include attraction of additional angling pressure; alteration of nutrient cycling; or, as is our interest here, increased predation on prey populations.

While surprisingly little demographic information is available for Lake Granby, we can begin to look at how restrictive regulations on lake trout may have indirectly affected predation pressure on kokanee and other fishes in the reservoir. As Ney (1990) noted, various methods are available to compute the amount of prey consumed by a fish or fish population. We have found the "Wisconsin Model" of Hewett and Johnson (1992) to be a powerful and convenient framework for this purpose. This model uses known physiological parameters to construct an energy budget for the species of interest. Given inputs on the predator's thermal experience, prey selection, energy content, and growth, the model computes the biomass of various prey that the predator must have eaten to attain the observed growth rate under the specified lake conditions. This bioenergetics approach is becoming more widely accepted as field studies corroborate model predictions (Rice and Cochran 1984; Brodeur et al. 1992).

Using growth rates of lake trout in similar Colorado reservoirs (Weiler 1982), Lake Granby water temperatures (Martinez 1994), and knowledge of the ontogeny of lake trout feeding habits (Rieman and Myers 1991; Yule and Luecke 1993) we asked, How much prey will a single lake trout consume while it is protected by various length limits? When we looked at the Granby lake trout regulations using this bioenergetics approach, we found that the slot regulations could actually affect the predation exerted by lake trout on kokanee and other prey fishes in the system. Predicted per capita consumption increased from 9 kg for a lake trout growing 0–20 in to 49 kg as for a trout growing 26–36 in (Fig. 2). Population-level consumption estimates under various regulations may not be as striking because even under protection, natural mortality reduces the abundance of the largest lake trout size classes; hence, their overall consumption may be lower than that for more abundant, smaller size classes. Compensatory declines in growth also may occur, and that would increase the amount of prey required to grow through a given predator size. However, striking differences in per capita analysis are cause for concern and show the dire need for more detailed demographic and ecological data on this fishery.

Applying the process

The strategy we propose for selecting harvest regulations involves several collaborative steps and provides a framework for research and management cooperation. First, some basic goals for what the fishery should and potentially can provide need to be established—these can come from public comment and manager experience (Fig. 3, Step 1). Goal-setting is essential to the process because inappropriate goals may make subsequent analyses irrelevant. The goals should suggest a set of potential regulations suited to accomplishing those goals (Step 2). For example, if larger fish are a goal in populations with high recruitment and slow, density-dependent growth of young fish, closed slot regulations may be suggested; when the population dynamics are the reverse, i.e., low recruitment but rapid growth, then minimum length limits may be more appropriate (Willis 1989; Noble and Jones 1993). Obviously, natural mortality, hooking mortality, and likelihood of compliance are necessary considerations as well.

Once a set of potential regulations has been identified, the direct effects of various regulations can be predicted using population models (e.g., GIFSIM, Taylor 1981; FISHREGS, Espegren et al. 1990; MOCPOP, Beamesderfer 1991; Fig. 3, Step 3). The outputs are the predicted effects of the regulation on target-population size structure, abundance, and mortality rates. A recognized deficiency of this approach, and of most fish population modeling, is the inability to predict recruitment. Hence, the approach may be more effective for modeling stocked populations.

To link the direct effects predicted above with indirect effects of regulations, we input the target population's new demographics to a bioenergetics model (Hewett and Johnson 1992) to predict how each regulation will change consumption demand by the target population (Fig. 3, Step 4). Translating consumption demand into expected responses in the prey populations is difficult. However, if annual predator consumption demand is predicted to become a substantial proportion of annual prey production in the modeled system, then less-restrictive predator harvest regulations may be prudent.

This process of estimating direct and indirect effects of regulations can and should be used proactively to help select an appropriate regulation. Evaluating proposed regulations in this fashion also identifies weaknesses in knowledge about the system that need to be shored up before evaluation of enacted regulations can occur.

After assessing the target population's response to various regulations and considering the potential effects on consumption demand of the target population, a sensible subset of regulation options (Step 5) can be proposed to the public for comment (Step 6). While a variety of models exist for public participation in setting resource management policy (Durning 1993), we believe it is important for managers to have evaluated a range of strategies in advance to identify untenable options and make public meetings most productive. Once the most-appropriate regulation for achieving goals is selected, it is implemented, monitored, and evaluated (Steps 7, 8). The time needed to evaluate responses to a given regulation will vary with the species and degree of environmental variability. The whole process is cyclical to emphasize that regulation strategies should be adaptive to changing biotic conditions and societal demands.

a major advantage of the modeling approach is that it allows the user to rapidly evaluate unforeseen changes in the fishery as they occur and to revise predictions and management strategy accordingly

The approach has proven insightful for evaluating proposed harvest regulations for lake trout at Flaming Gorge Reservoir, Utah and Wyoming

(Luecke et al. 1994), and for walleyes on Lake Mendota, Wisconsin (Johnson et al. 1992). In Lake Mendota the process was used proactively by university researchers and agency managers to predict how walleye consumption demand would respond to various harvest regulations and stocking of these predators (Johnson et al. 1992). Here, the goals for the regulations were to increase predation on planktivorous prey fishes in a biomanipulation experiment and to improve walleye size structure and catch rates for anglers (Kitchell 1992). Large gains in consumption demand were predicted to result from the new regulations. However, greatly increased angler use because of this high-profile project (Johnson and Carpenter 1994) reduced actual walleye abundance and predation demand and proved the necessity of monitoring and evaluating new regulations.

Fisheries are dynamic, so the regulation selection process also must be dynamic and adaptive. Ideally, fishery models will evolve to become more comprehensive and predictive. In the meantime, a major advantage of the modeling approach is that it allows the user to rapidly evaluate unforeseen changes in the fishery as they occur and to revise predictions and management strategy accordingly.

Making cooperation happen

We believe that the regulation selection process offers an ideal opportunity for management and research to work together. Researchers and managers should have a vested interest in the outcome, and both can contribute greatly to its success. Modeling workshops, where researchers and managers collaborate to arrive at agreeable model inputs, have proven effective for addressing contentious resource management issues (Walters 1986). We suggest that modeling workshops directed at evaluating proposed harvest regulations are an excellent forum to unite managers and researchers. They allow the groups to be a part of the process and have ownership in the outcome. The result is a reasonable subset of candidate regulations that managers and researchers can support. Only then should this rational subset of proposed regulations be taken to the public for comment. At this stage we believe researchers should help managers at public meetings. Research representation at public meetings shows managers and the public that researchers stand behind their analyses. Finally, a regulation is selected and implemented, then monitored and evaluated. Throughout the implementation of a regulation, regular communication between management and researchers is needed along with shared efforts and rewards, necessities for any cooperative enterprise.

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