to states, since they are the primary escapement managers. While the costs for additional research may seem prohibitive, long-term recovery and sustainability may be worth the price, just as it has been for other depleted fisheries such as the Atlantic coast striped bass *Morone saxatilis* (Field 1997).

Ensuring Healthy Escapements

Increasing escapements of depleted populations and maintaining adequate escapements of healthy populations are the quickest ways to realize conservation goals (Riddell 1993) and should be the ultimate goal of fishery managers trying to achieve sustainability. As stated by NRC (1996), a shift must be made from focusing on catch to focusing on escapement. Salmon managers should be required to provide evidence that a population is healthy enough to allow a fishery rather than having to prove the population may be jeopardized by overfishing before curtailing fishing (Wright 1981). Several authors have demonstrated the concept that, in many cases, fishing less (increasing escapement) can result in larger catches in the long term (Hilborn and Walters 1992; NRC 1996). Optimal escapements are numbers that not only perpetuate the population and ensure biodiversity (Riddell 1993), but also provide enough carcasses to maximize the carrying capacity potential of the system. The goal should be to identify the appropriate harvest rate in light of each population's naturally varying mortality schedule. There are a number of specific fishery management recommendations that support sustainability through increasing and optimizing escapements.

Identify and Achieve "Safe" Escapement Levels.—As recommended by NRC (1996), the concept of MSY should be replaced with minimum sustainable escapements (MSE) for as many populations as possible. Rather than selecting a specific escapement goal, about which target escapements fluctuate, as has been done in the past, the MSE is an escapement level which should always be met. Most importantly, escapements should range well above the MSE. This will enhance productivity and biodiversity by allowing for years in which so-called excess escapement builds resiliency into the system, supplies abundant carcasses (nutrients), and allows for sufficient escapements of any smaller, weaker populations within the management unit. Further work will be required to estimate how much escapements should range above MSE.

Since salmon survival is intimately dependent on highly variable ocean conditions, it is critical that we ensure adequate escapements in years of poor ocean productivity (poor marine survival). It is important to remember, for example, that short-term upswings in apparent abundance may result from variation in marine production rather than improvements due to habitat changes or improvements in escapement management (see, for example, Lawson 1993).

Collect Accurate, Consistent, and Fully Representative Run Size Data.—Regardless of the theoretical modeling approach employed for data analysis and run prediction, basic data collection will always be a critical component of the salmon management process. Although this chapter is about escapement, it is essential that consistent data be collected on all aspects of the run size, including both catch and escapement. As can be seen in the summary of escapement estimation (Table 17.2), the majority of populations have poor or no escapement data. Management agencies need to increase emphasis on escapement assessments, as well as other critical population-specific data.

In large, remote areas, where it is impractical to survey escapement of every population, it is vitally important to routinely and accurately assess the status of populations of a range of sizes and productive capacities. Escapement assessment programs should be designed to include intensive monitoring of small and less productive populations in approximately the proportion that they occur naturally. In this way, early warnings can be raised when these important components of the population structure are thought to be jeopardized.

Avoid the Use of Temporary Escapement Goals.—Managers should also avoid the use of "interim," "target," "phased-in," "gradual," "eventual" or other short-term escapement objectives when dealing with depressed salmon populations because they tend to lead to deliberate overfishing of salmon runs (Wright 1981). For any salmon run returning at or below the level required for MSE, all target fisheries must be closed. There is no viable alternative (Wright 1981). In addition, management options to reduce incidental harvest should be invoked.

Reduce the Number of Populations per Management Unit.—Whenever possible, it is preferable that escapement goals be established for individual populations, i.e., in the context of this chapter, that each population become a management unit. This will help reduce the effects of mixed population fisheries on small or less productive populations. Whether the fisheries on these populations can actually be managed to harvest each population separately is a separate issue (addressed below); the salient point is that managers must understand how many populations occur within a management unit, the natural productivity of each population, and how fisheries are influencing their total production and viability.

Improve Escapement Goal-Setting Methods.—The results of this evaluation show that there are a large number of management units for which there are poor or no escapement goals, even when populations are combined (Table 17.1). I recommend that MSE (NRC 1996) be applied to all possible populations. This will require additional funding and personnel to implement but is essential for future sustainability. As new management technology develops and better information is collected for each unit, the goals should be refined. Escapement goal setting will also benefit from related improvements in escapement, stock discrimination, coded wire tag, age structure, smolt productivity, and habitat utilization data.

Use Smaller, More Precise Management Areas.—One way to gradually move salmon management toward sustainability is to decrease the size of some fishing management areas or districts. While this is now mostly limited by the inability to discern which populations of fish are being harvested in each area and the time required for processing information from the fishery to managers, I believe we should be striving in many fisheries for managing time and location of fishery openings on a smaller, more expedient scale. As the technical ability to rapidly process population discrimination information is further developed, fisheries can be opened in smaller areas or times to harvest any abundant populations and closed in areas to protect weak populations. More opportunities will be available for opening fisheries on discrete, abundant populations when management areas are smaller.

Guard against Gradual Escapement Goal Reduction.—Managers, decision-makers, and users should be vigilant against the temptation to reduce escapement goals. As described in detail above, standard spawner/recruit models can give the illusion that MSY will be attained with a lower escapement goal, particularly when based on recent population performance (Hilborn and Walters 1992). While there is often remarkable pressure from users, and the concomitant desire of fishery managers to satisfy constituents, decision-makers should require hard evidence that "excessive" escapements are actually reducing productivity before a goal or MSE is lowered.

Improve Harvest Management.—There is also a group of harvest management actions which can help to achieve healthy escapements, either by reducing the effects of mixed population fisheries or simply ensuring additional fish escape to the spawning grounds.

- *Reduce harvest rates.*—Reducing harvest rates where necessary will increase abundance (i.e., long-term catch) on strong populations (e.g., Cramer 2000), revitalize depleted populations, and protect weaker populations. Because abundant and depleted (or susceptible) populations are often mixed together in fisheries, it is important that management allow for separate harvest regimes for strong and weak populations (NRC 1996). Several recent cases demonstrate how reduced harvest rates have benefited escapement, particularly of smaller populations. In 1995, for example, Canada's Department of Fisheries and Oceans recognized the emergency nature of coho off the west coast of Vancouver Island and reduced the harvest rate from the previous 60 to 80% down to about 50%, increasing escapements of coho to Carnation and Clemens creeks at least tenfold (Tschaplinski 2000). Reduced harvest rates in many other locations will undoubtedly increase the size and diversity of spawning populations, as recommended by NRC (1996).

The following management actions can be applied, in various combinations on a case by case basis, to reduce harvest rates and/or the effects of mixed population fisheries.

Reduce exploitation rates on all populations simultaneously in one fishery.—Closing or reducing effort in mixed population fisheries, as necessary, will protect weak populations and allow more productive populations to pass to the next fishery for either harvest or escapement. It is recognized this may result in short-term disruptions and complications to the economic and social infrastructure of salmon-based economies (NRC 1996), but will improve the chances of sustaining production of all populations for the long-term benefit of society.

Increase specificity of fisheries.—Some fisheries can and should be managed with more specific time and area openings and closings to control how they influence populations migrating through management areas. That way, weak populations can be protected when they are mixed with strong ones, but strong populations can be harvested as they separate from others during migration. This strategy will result in a larger emphasis on terminal fisheries, not only providing harvest opportunities and weak population protection, but with the added advantage of more accurate documentation of fishing mortality (Mundy 1997). It must be noted, however, that these shifts will have their own harvest management challenges and cause disruptions to the existing salmon fishery social and economic infrastructure.

Establish fishery refuges.—It may be preferable to close some harvest management areas for the long term. These may be areas where a large number of particularly sensitive populations congregate. This will also result in larger catches in terminal fishing areas.

Use selective fisheries.—Selective fisheries have been recommended as one method of effectively harvesting strong populations while allowing others to escape (Lincoln 1994). There are a number of gear and management options that can be combined to create selective fisheries. A most popular option being proposed and investigated is the fin-clipping of all hatchery-reared coho and chinook salmon (Lawson and Comstock 2000). Non-clipped, wild fish could be released from non-lethal fisheries, such as purse seines, trollers, sport, live traps, and fish wheels, while all fin-clipped fish could be retained. Fishers using those same gear types could also retain or release fish on a species-by-species basis as necessary.

Invoke gear limitations.—Use of less selective gears, such as gill-nets in certain fisheries, should be reduced or eliminated except in areas where it is demonstrated that they have no impact on weak populations. This again could have significant implications for existing salmon fisheries.

Increase use of limited entry.—Most salmon fisheries are already limited (NRC 1996). There is some hope that individual transferable quotas (ITQs) may provide incentive for harvesters to limit catches when run sizes are low (e.g., Fujita and Foran 2000). Since ITQs apply to specific runs, ITQ holders may recognize that an investment in future production (i.e., by sometimes reducing or eliminating fishing effort in the short term) will increase their catches in the longer term.

Buy back fishing boats and licenses.—Although buy-back programs have been implemented in certain fisheries in the past with mixed success, it is still a viable option to help reduce the potential effort in certain fisheries (NRC 1996) and the pressure on managers to open fisheries on populations that cannot withstand fishing mortality.

- *Accept "overescapement" at hatcheries.*—In areas currently managed for hatchery harvest rates, exploitation should be reduced to allow sufficient natural spawners to fully seed all available habitat. This may result in so-called overescapement of hatchery fish unless they can be harvested in a terminal area where they are separated from wild fish. In cases where too many hatchery fish might result in negative ecological or genetic impacts in the adjoining habitat, it might be preferable to reduce the hatchery program so that it simply augments wild production. If programs can be developed to market the excess hatchery salmon carcasses, then another plausible strategy might include fishing at the rate sustainable by the natural population while harvesting all excess at the hatchery rack. Some combination of these alternatives should allow hatchery production beyond what would be produced from wild production alone while protecting and maximizing wild production.

- *Use adaptive management.*—The principal of adaptive management (Walters 1986; Hilborn and Walters 1992) should be applied to as many management units as possible. This is because, regardless of the methods presently used or those to be used in the future, managers need to evaluate the success or failure of the variety of management alternatives that are intentionally or inadvertently invoked. Managers should follow the six steps of adaptive management (Walters 1986; Hilborn and Walters 1992), making new decisions each year using decision theory and evaluating the consequences of those decisions.
- *Settle Pacific Salmon Treaty allocation issues.*—Although an updated Pacific Salmon Treaty (PST) was recently signed, it would be naive not to recognize problems caused in past U.S. and Canadian escapement management by the inability to resolve international allocation issues. Many of the other recommendations in this chapter need to be implemented by one country to benefit populations originating in the other country and vice versa. The challenges of the PST have been discussed in detail by other authors (e.g., NRC 1996). Suffice to say that resolution of these international issues is essential to the future of all salmon populations originating in one country and migrating through the other country's fisheries.
- *Separate allocation issues from biological process.*—Fishery biologists charged with determining whether there is a harvestable surplus should not also be involved in allocation decisions. Biologists should be free to make recommendations of escapement levels or harvest rates necessary to maintain abundant populations and biological diversity. They should also make recommendations about whether there is a harvestable surplus and when and where the surplus will be available with the least impact on other populations. This information should then be provided to the political process for final allocation decisions. The Alaskan management process has generally worked well locally and serves as a good model (Holmes and Burkett 1996).

Change Public Attitudes and Expectations

Until recently, the general goal of fisheries management was to stabilize fisheries so that user groups could count on a certain level of harvest and stable income. While there may be some viable strategies to reduce the likelihood of closed fisheries (such as fishing regimes based on steady, but most likely lowered, harvest rate) salmon managers, harvesters, and the public may ultimately benefit by accepting that salmon abundance follows natural, often extreme, cycles (Cramer 2000). This means that user groups should be encouraged to adjust to fluctuations in fish availability and income. There are several ways salmon managers can assist in disseminating this message, thereby helping to ease the negative ramifications of the natural downswings in salmon abundance.

Improve Public Education.—Salmon managers and scientists should help people understand the concepts of (1) variable productivity; (2) less fishing can mean more fish over the long term; (3) the importance of large escapements to long-term productivity; (4) the connections between human population growth (and associated impacts) and salmonid populations; and (5) the importance of genetic and population biodiversity. This can be accomplished through public forums and workshops and by incorporating these concepts into high school curricula.

Public education of salmon harvesters and recreational users will help to support increased funding for research and management. As a negative example of how this feedback loop functions, notice how, as soon as fish become unavailable, the users tend to blame government managers for ineptness. Yet, agency funding is continually being reduced in state legislatures, preventing scientists and managers from conducting the research and basic data collection so desperately needed to support quality run size predictions and escapement management. An informed public will pressure legislators to support and fund the necessary programs.

- *Use adaptive management.*—The principal of adaptive management (Walters 1986; Hilborn and Walters 1992) should be applied to as many management units as possible. This is because, regardless of the methods presently used or those to be used in the future, managers need to evaluate the success or failure of the variety of management alternatives that are intentionally or inadvertently invoked. Managers should follow the six steps of adaptive management (Walters 1986; Hilborn and Walters 1992), making new decisions each year using decision theory and evaluating the consequences of those decisions.
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Increase Public Involvement in the Process.—There has been much discussion and progress toward an ecosystem-based, community approach to watershed management and salmon restoration (e.g., Lichatowich et al. 1995; Bingham 2000; Fields 2000; MacDonald et al. 2000). Yet these new public processes have usually failed to incorporate salmon production, escapement, and harvest management, primarily because harvest management remains the realm of agency and tribal fisheries managers. When salmon user groups and watershed landowners and citizens have the opportunity to hear all the evidence presented by harvest management biologists, and have the chance to voice their opinions about decisions, they may become more invested in the outcome of decisions and the status of the resource upon which they vitally depend (e.g., Riddell 1993). The salmon ecosystem extends from the ridgetops to the high seas. Watershed-oriented discussions designed to benefit salmon should include all stakeholders, cover all portions of the salmon ecosystem and all impacts along the way, and particularly include the effects of harvest and harvesters.

Encourage Harvesters to Adapt to Natural Variation.—A major public paradigm shift is particularly required, wherein all users' and managers' expectations are modified to coincide with the variable and unpredictable nature of salmon populations. Protection of the spawning escapement (the investment principle) must be given the highest priority (NRC 1996), rather than maximizing the catch. This may require significant economic and social adjustments because fishing patterns will necessarily be variable from year to year, resulting in disruptive and unpredictable employment patterns. However, if coastal communities can adapt to the variation, the pay-offs in improved long-term productivity will be substantial.

In closing, although it is obvious that invoking all these escapement management recommendations will be very expensive, the long-term economic, social, and cultural costs of not doing so (i.e., further depleting salmon populations and/or production) will be greater. Furthermore, voluntary, proactive implementation of these measures will forestall the otherwise inevitable, involuntary restrictions resulting from further Endangered Species Act listings or, worse, the eventual loss of additional populations. To truly achieve Pacific salmon sustainability depends on a public commitment to invest in expanded salmon research, management, and public education. We cannot count on repairing only one damaged aspect of salmon runs (e.g., degraded habitat) to fix the problem, but must work on all fronts simultaneously. Ultimately, though, both productivity and biodiversity depend on sufficient escapement of spawners to fully utilize the available freshwater habitat, fertilize the systems with carcasses, and optimize genetic diversity.

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