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Synthesis, part of a Special Feature on Pathways to Resilient Salmon Ecosystems

Resilient Salmon, Resilient Fisheries for British Columbia, Canada

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ABSTRACT. Salmon are inherently resilient species. However, this resiliency has been undermined in British Columbia by a century of centralized, command-and-control management focused initially on maximizing yield and, more recently, on economic efficiency. Community and cultural resiliency have also been undermined, especially by the recent emphasis on economic efficiency, which has concentrated access in the hands of a few and has disenfranchised fishery-dependent communities. Recent declines in both salmon stocks and salmon prices have revealed the systemic failure of the current management system. If salmon and their fisheries are to become viable again, radically new management policies are needed. For the salmon species, the emphasis must shift from maximizing yield to restoring resilience; for salmon fisheries, the emphasis must shift from maximizing economic efficiency to maximizing community and cultural resilience. For the species, an approach is needed that integrates harvest management, habitat management, and habitat enhancement to sustain and enhance resilience. This is best achieved by giving fishing and aboriginal communities greater responsibility and authority to manage the fisheries on which they depend. Co-management arrangements that involve cooperative ownership of major multistock resources like the Fraser River and Skeena River fisheries and community-based quota management of smaller fisheries provide ways to put species conservation much more directly in the hands of the communities most dependent on the well-being and resilience of these fisheries.

Key Words: *fishery management; Pacific salmon; resilience; sustainable fisheries*

INTRODUCTION

Pacific salmon (*Oncorhynchus* spp.) are iconic in both prehistoric and modern Pacific Northwest Coast culture. Residents of the region associate healthy salmon populations with a healthy productive environment. However, the historic expansion of human activity in the Pacific Northwest has been associated with a loss of phenotypic and genetic diversity in Pacific salmon (Nehlsen et al. 1991, Slaney et al. 1996, Gustafson et al. 2007). In British Columbia, Slaney et al. (1996) found that 142 salmon populations had gone extinct since recording began in the mid-20th century and that 624 more populations were at high risk out of 5487 salmon populations that could be assessed (57% of the total number of populations). These figures are biased toward the larger, economically important populations because many small populations were not routinely enumerated. In a subsequent analysis, Northcote and Atagi (1997) concluded that British Columbia populations of all five species were reduced to 13–50% of historic abundance and that many small populations had been lost. The situation is even more disturbing in Washington, Oregon, and California, where 101 of 214 salmon populations assessed by Nehlsen et al. (1991) were considered at high risk of extinction. Habitat loss, the damming of rivers, freshwater and coastal pollution, the proliferation of hatcheries, and overfishing are usually identified as the principal causes of population declines and extirpation (Ruckelshaus et al. 2002). More recently, species invasions and global climate change have been added to the list.

Although one must be concerned about the future of wild salmon resources of the Pacific Northwest, salmon are highly resilient species. Given reasonable access to good-quality habitat and protection from destructive overfishing, salmon species are capable of rapid recovery and high, sustained productivity. Here, I describe attributes of Pacific salmon that make the species resilient and

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propose an approach to fishery management that would sustain, rather than undermine, the species' natural resilience. A fundamental assumption of the management prescription is that increases in the resilience of salmon stocks will increase the resilience and sustainability of salmon fisheries.

RESILIENT SALMON

Seven main attributes contribute to the resilience of Pacific salmon populations. Each resilience attribute confers its own defenses against environmental or other stressors. From the standpoint of evolution, these attributes must have arisen because they conferred individual benefits. Their resilience benefits, which occur at the population level, are secondary. I briefly describe each attribute and one primary resilience benefit (Table 1).

Multiple reproducing populations

All Pacific salmon species exist as multiple, isolated or semi-isolated breeding populations. Historically, virtually every creek and river of the British Columbia coastline, as well as most of the accessible tributaries of larger river systems, supported a spawning population of one or more species. Slaney et al. (1996) identified 9662 anadromous salmon populations in British Columbia, including 866 chinook, 1625 chum, 2594 coho, 2169 pink, 917 sockeye, 867 steelhead, and 612 sea-run cutthroat trout, and this was by no means a complete count. A primary benefit of this great subdivision of species populations into small, semi-autonomous units is protection from extinction. Large parts of river systems can suffer a severe catastrophe, yet multiple local salmon populations will survive to recolonize the places from which salmon were extirpated once conditions again become suitable (Anderson and Quinn 2007). This is how much of British Columbia must have been colonized by salmon and trout as the Wisconsin glaciation receded 10,000 yr BCE. Indeed, salmon in the drainage basins of the territory now known as British Columbia must have experienced large-scale extinction and reestablishment multiple times over the past 2 million years as periods of glaciation alternated with warm interglacials.

High reproductive capacity

The combination of high total reproductive investment (ripe female gonads can exceed 15% of the total body weight), modest parental care, and large eggs (high investment per offspring) gives salmon a high reproductive capacity. Eggs buried in the gravel of the spawning bed do not move during embryonic development and, where the gravel is suitable, the female can position her redd so that the emerging fry have only a short distance to travel to find a nursery environment. This will maximize the proportion of offspring that become successful "members," rather than unsuccessful "vagrants" (Garant et al. 2000). Because salmon eggs are large, fry become free-living with relatively well-developed physical capabilities. These adaptations all serve to enhance survival and contribute to the high surplus production characteristic of exploited salmon populations. They also confer upon salmon a great capacity to recover from catastrophe. Provided that the local habitat remains suitable, all but a few members of any population can be wiped out and the population will recover its former abundance in a few generations. A dramatic example of this capacity was shown by Fraser River sockeye salmon (*O. nerka*) stocks that recovered after nearly being wiped out by overfishing and a rock slide at Hell's Gate in 1913 that blocked most fish from migrating upstream (Ricker 1987).

Metapopulation structure

Schtickzelle and Quinn (2007) used Bristol Bay sockeye as an illustrative case to argue that groups of Pacific salmon populations are organized as a metapopulation. A metapopulation is made up of a number of semi-isolated subpopulations that exchange individuals at a low rate. Individual subpopulations of a metapopulation may go extinct from time to time, only to be reestablished by individuals that disperse from other subpopulations. Schtickzelle and Quinn (2007) identified three attributes that are required for metapopulation structure: the population consists of a number of subpopulations that occupy discrete patches of habitat, individual subpopulations show some asynchrony in life history or dynamics, and exchanges among subpopulations are not sufficient to break down the asynchrony. Many clusters of salmon populations appear to satisfy these conditions, although the frequency of exchanges of individuals and their subsequent reproductive

Table 1. Seven attributes of Pacific salmon species that contribute to their resilience, and a primary resilience benefit of each attribute.

Resilience attribute	Primary resilience benefit
Multiple, independent reproducing populations	Reduced extinction risk
High reproductive capacity	Strong capacity to recover from mortality events
Metapopulation structure	Optimal habitat use
High genetic diversity	Adaptive capacity
Phenotypic plasticity	Flexible response to variable environments
Variable life-history tactics	A well-stocked adaptive tool kit
Opportunistic use of habitat	Rapid response to new opportunities

success remain uncertain (e.g., Tallman and Healey 1994, Withler et al. 2000, Waples et al. 2009). Other metapopulation structures are also possible (Reiman and Dunham 2000).

A metapopulation structure has management implications. Cooper and Mangel (1999) cautioned that the metapopulation structure of anadromous salmon populations increases the risk of inadvertent extirpation of clusters of populations, particularly if the metapopulation consists of a few source and several sink subpopulations. Source populations produce more individuals than are needed to sustain the population; sink populations do not and are sustained by immigrants from source populations (e.g., Hindar et al. 2004). However, metapopulation structure can also allow the species to optimize habitat use and provides a hedge against extinction. The movement of dispersing individuals among subpopulations ensures rapid recolonization of any habitat from which a subpopulation has been extirpated (Milner et al. 2000, Withler et al. 2000). The metapopulation structure also works well in the face of local environmental fluctuations because subpopulations that are sinks under one environmental regime may become sources under another and vice versa, but the population as a whole sustains a positive growth potential. However, not all spawning groups of salmon are necessarily part of a metapopulation (Fontaine et al. 1997, Reiman and Dunham 2000).

High genetic diversity

The salmonid family apparently derived from a tetraploid ancestor 25 to 100 million years ago (Allendorf and Thorgaard 1984). The tetraploid event provided large numbers of gene duplications, and the conversion to full diploid status is still continuing. Gene duplication provided considerable opportunity for the evolution of complementary traits (Ohno 1970). Allendorf and Thorgaard (1984) suggest that the success of salmonids in anadromy may have resulted because they were able to develop different enzyme functions for fresh and salt water from their duplicate genes.

The evolution of diversity has also been assisted by the population structure of salmon species. The occurrence of large numbers of semi-isolated breeding populations, each experiencing unique selective forces, has generated considerable within-species genetic variance (e.g., Zhivotovsky et al. 1994, Withler et al. 2000, Olson et al. 2003). High diversity and the apparent capacity for rapid genetic evolution in response to new environmental conditions (Hendry et al. 2000) is an important source of resilience. The small effective population size of many salmon populations is a countervailing force, however, that reduces genetic diversity through genetic drift. Since the advent of intensive fisheries for salmon, the loss of genetic diversity has probably accelerated both through the loss of small populations and reductions in the effective population size of many surviving populations (Waples 1990, Bucklin et al. 2007, Waples et al. 2009).

Phenotypic plasticity

Like genetic diversity, phenotypic diversity is high in Pacific salmon. The reaction norm is quite broad for fitness traits such as age or size at maturity and fecundity. Anadromous male sockeye salmon, for example, mature as young as 3 yr or as old as 8 yr old and as small as 30 cm or as large as 73.7 cm (Healey 1986). Because sockeye salmon divides its life between freshwater and marine environments, the proportion of time spent in each environment is an important life-history trait that affects survival and size at maturity. Male sockeye salmon mature at 22 different combinations of freshwater and marine age. Some of this variation reflects a latitudinal cline, i.e., the average age of mature males increases from south to north, but 21 of the 22 known age combinations have been observed in the Karluk River on Kodiak Island (Healey 1986). The other species also show considerable variation in age at maturity, except for pink salmon, which always matures at 2 yr of age. Pink salmon introduced to the Great Lakes, however, sometimes delays maturation to age 3 yr, revealing previously unknown variation in age at maturity (Kwain and Chappel 1978).

Age and size at maturity have both a genetic and an environmental basis. Phenotypic plasticity is the way a species responds to the environment it actually encounters (short-term or macroenvironmental variation), as opposed to the long-term average environment that shaped its genotype (Dieckmann and Heino 2007). Whereas most measured genotypic variation is found within populations, most measured phenotypic variation occurs among populations or regions (Healey and Prince 1995). Each population of Pacific salmon, therefore, carries the majority of genetic variation representative of the species. Phenotypic variation maps the various environments in which the species lives and illustrates the species' capacity for short-term adaptation. Age and size at maturity are undergoing long-term change, however. Bigler et al. (1996) documented dramatic reductions in size at maturity in all species over the 30+ years that records had been collected. Many other marine species have also shown dramatic reductions in size and age at maturity, suggesting that intensive, size-selective fisheries may be driving a change in the underlying genetic schedule of maturity (de Roos et al. 2006, Marshall and Browman 2007).

Variable life-history tactics

A particular aspect of phenotypic variation is variation in life-history tactics. Here, I describe some aspects of life history associated with reproduction to emphasize that salmon have a well-stocked adaptive tool kit. Female salmon, like males, typically mature at a range of sizes and ages. Large size should be favored in females because larger females are more fecund, produce larger eggs (and fry), and can dominate in contests for preferred nesting sites. Evidence suggests that an increase in body size is favored over an increase in fecundity (Healey and Heard 1984, Healey 1987). However, salmon spawn in a heterogeneous environment in which small females that spawn in locations that appear less favorable for incubation can sometimes out-perform larger females (Holtby and Healey 1986). The average size and variance in the size of females appears to be a response to the quality and uncertainty of the spawning and incubation environment (Holtby and Healey 1986, Quinn et al. 1995).

Male Pacific salmon are typically larger than females; however, coho males can be considerably smaller than the females. Coho males are also more abundant than the females, even among fish of the same age, despite the fact that many males mature at younger ages than do the females. The difference in average size between female and male coho is positively related to the male:female sex ratio; males are more abundant when they are small compared to females. Holtby and Healey (1990) hypothesized that these differences in size and relative abundance between the sexes reflect differences among populations in characteristics of the breeding environment and growth opportunities experienced during the final summer at sea. Coarse spawning gravels, high risk of winter scour, and intense competition for high-quality breeding sites favor large female size, and females will risk high marine mortality to achieve large size as adults. Males are concerned only with access to females, which is favored by large size. However, male coho can achieve successful mating by tactics other than dominating access to a female, such as sneaking or satelliting (Healey and Prince 1998). In most populations, therefore, males do not need to accept high predation risk to achieve large size at maturity. Thus, environmental conditions push the mature sizes of the sexes and subsequent breeding behavior in different directions, creating a complex pattern that shifts and changes annually (Holtby and Healey 1986, 1990). The capacity of the species to respond to environmental variation by producing different phenotypes with different yet successful reproductive tactics is one of the species' great adaptive strengths.

Opportunistic use of habitat

Although renowned for their precise homing, salmon are also quite opportunistic in their use of habitats. When new habitats are opened up, salmon will often colonize quickly. Many observations testify to this opportunism. Patton (2003) constructed a new, 2 km long, stream channel as part of a gravel pit rehabilitation and observed that coho parr invaded almost as soon as the channel was connected to adjacent Pepin Creek, which had a resident coho population. Anderson and Quinn (2007) observed that adult coho invaded and spawned upstream of the Landsburg dam on the Cedar River, Washington, the year that a fishway was constructed around the dam. Milner et al. (2000) studied biotic colonization of 16 streams in Glacier Bay, Alaska, that became established over the past 250 years as a neoglacial ice sheet receded. Streams tended to be colonized by spawning coho salmon within a few decades, although the abundance of salmon was positively correlated with stream age. Sockeye colonized stream systems with lakes somewhat later than did coho and pink salmon during a particularly large run to the region. These results give a sense of how quickly suitable new stream habitat in Washington, British Columbia, and Alaska was colonized as glacial ice sheets receded.

Pacific salmon are essentially transient species. During some life stages, they may remain in a particular habitat for a period of time, as do eggs during incubation or sockeye during lake residence as juveniles. At other times, they are almost continually on the move through or between the landscapes that ecologists have arbitrarily delineated as separate salmon habitats: stream, lake, estuary, coast, and ocean. Even where a species appears to be resident at the landscape scale, at smaller scales, individuals or groups of fish are exploring and probing new habitat opportunities, leading to the kind of rapid habitat colonization observed by Milner et al. (2000), Patton (2003), and Anderson and Quinn (2007). Such opportunism is an important element of resilience, facilitating metapopulation exchanges, the rapid reestablishment of extinct subpopulations, and local range expansions.

These resilience attributes of Pacific salmon species have made them successful in environments that have been highly dynamic and unpredictable over a range of timescales. Pacific salmon species have existed for approximately 10 million years (McKay et al. 1996). During this time, they have survived prolonged periods of warm climate, tectonic upheaval that changed drainage patterns, and, over the past 2 million years, multiple periods of prolonged glaciation. As the most recent glaciation receeded, salmon encountered a new disrupting force as colonizing aboriginal peoples began to exploit salmon for food. Exploitation by aboriginal fisheries may have been relatively intense, particularly during periods of poor salmon returns. However, alterations to habitat and fisheries sufficient to drive many populations to extinction did not develop until the 20th century, when European colonists brought industrial forestry, dams, wetland destruction, toxic discharges, urbanization, and increasingly effective fishing methods to the region. The fact that salmon species have been able to survive this many-fronted human onslaught is a testament to their intrinsic resilience. However, human actions have greatly weakened the resilience attributes described here. As a result, the persistence of salmon as economically productive species in the wild is becoming increasingly tenuous as the impact of humanity spreads inexorably around the globe. The restoration of as much of the lost resilience of salmon populations as possible appears to offer the best hope of sustaining both salmon and their fisheries. I next offer some suggestions for restructuring fisheries to help restore salmon resilience.

MANAGING FISHERIES TO RESTORE RESILIENCE

As salmon runs dwindle and more individual populations are lost, the central question for salmon managers is not, or should not be, how to maximize yield from the remaining populations, but rather how to sustain or restore the resilience that has allowed salmon to perform well in a changing environment for millions of years. Management practices can be classified as anti- or pro-resilience (Table 2). Currently, salmon management in British Columbia emphasizes anti-resilience practices. The future of salmon fisheries and of coastal communities depends on a shift of management policy to pro-resilience practices.

Salmon fisheries are in crisis in British Columbia, with declining prices and declining catches (Schwindt et al. 2003). This problem is not unique to British Columbia. The highly productive Bristol Bay sockeye fishery has also become uneconomic in its current configuration (Hilborn 2006). However, as the resource has needed stronger and more sophisticated stewardship, investment in management has declined. The operating budget for the Canadian Department of Fisheries and Oceans, the agency responsible for salmon management, has declined progressively (Peterson et al. 2005). Under reduced budgets, new management policies and initiatives will have to be streamlined and have to engage more closely with fishing communities. Changes in policy and management are also needed if aboriginal and coastal communities are to receive a fair share of the economic benefits of salmon fisheries (McRay and Pearse 2004). Since the 1960s, the emphasis in fishery management has been on improving economic efficiency by limiting the number of fishing license holders and by fostering professionalism among fishers. These policies have done little to reduce overcapitalization in the fisheres, but have reduced participation by residents of coastal communities, particularly aboriginal fishers. Fishing power has become concentrated in fewer, large, heavily capitalized fishing vessels (Edwards et al. 2005). At the same time, the ability of fishers to adapt to fluctuating abundance by shifting fishing effort among species is prohibited by regulation. As a result, the salmon fisheries, like the species, have become less resilient (Martin 2008). If salmon harvests are to provide income and cultural sustenance to fishing communities in the future, community development must go hand in hand with fishery management (Robards and Greenberg 2007). I suggest a number of institutional and policy reforms to promote salmon and fishing community resilience based on the pro-resilience practices listed in Table 2 (see also Hanna 2008).

Protecting and conserving small salmon populations

Small salmon populations have suffered the majority of extirpations in British Columbia. Because many, or perhaps the majority, of these populations were not routinely monitored, the full extent of loss is unknown. Since the proclamation of the *Species at Risk Act* in 2003, several British Columbia salmon populations have been identified as endangered (Irvine et al. 2005). These and other small populations commingle with larger, unthreatened populations and are at great risk of extirpation if fishery practices are not changed. Fishing effort must be shifted from the mixed stock, large-vessel-dominated fisheries toward more terminal fisheries that use nonlethal harvest techniques, e.g., traps, weirs, fish wheels, and beach seines, which allow better targeting of specific runs, sorting and release of threatened species, and careful handling of harvested fish to maximize quality.

Enhancing populations to sustain and increase life-history diversity

Production enhancement is now integral to salmon management; techniques range from habitat enhancement to artificial spawning channels to hatcheries. Initially intended to supplement natural production, artificial production of salmon has frequently replaced natural production, particularly in the case of hatcheries (Lichatowich 1999). Programs of stock enhancement have frequently failed to achieve their objectives, and some observers consider hatchery programs a complete failure and an important cause of declining salmon runs (e.g., Lichatowich 1999). Molony et al. (2003) reviewed the numerous reasons for this failure, but concluded that if properly designed and implemented, enhancement could succeed. Among the necessary design features were an ecosystem approach, ecologically realistic enhancement objectives, a willingness to modify or abandon damaging approaches, and a program of monitoring capable of detecting both positive and negative enhancement effects. Considerable concern has been expressed about inadvertent selection in hatcheries for genotypes and phenotypes that are not well suited for life in the wild (e.g., Utter 2004). Used judiciously to encourage diversity and to help sustain metapopulation structure, rather than as a form of production aquaculture, however,

Table 2. Management practices that degrade or enhance salmon and fishery resilience.

Anti-resilience management practices	Pro-resilience management practices
Allowing small populations to go extinct	Protecting and conserving small populations
Reducing life-history variation by targeting and enhancing the dominant tactic	Enhancing variation to sustain and increase life-history diversity
Domestication and genetic swamping	Allowing surplus escapement
Managing for maximum yield	Fishing to sustain diversity
Encouraging big boats and big gear	Encouraging smaller, targeted fisheries
Permitting incremental loss or degradation of habitat	Maintaining habitat quality and diversity
Managing for economic efficiency	Managing for community and cultural resilience

hatcheries and other enhancement techniques can help to rebuild and sustain resilience.

Allowing surplus escapement

Under the policy of maximizing yield, fishery managers have been very concerned about "over-escapement." According to fishery theory, there is an optimal spawning escapement for each population that will maximize yield. Allowing more than this number of salmon to spawn is regarded as a management failure because the extra spawners could have been harvested to generate present income and the over-escapement could theoretically result in lower than maximum returns, thereby also reducing future income. Ecologically, however, high numbers of spawners encourage ripening fish to explore new habitats as the main spawning areas fill up, potentially creating new or recolonizing previously extirpated subpopulations of a metapopulation. High spawning densities also give opportunities for alternative mating tactics, thereby supporting the full range of tactics. Hilborn's (2006) suggestion that the Bristol Bay fishery adopt a fixed catch, rather than a fixed escapement policy, would potentially create wider swings in escapement, allowing greater opportunity for multiple life-history tactics to be expressed.

Fishing to sustain diversity

Current fishery policy manages the heavily capitalized interception fisheries so as to harvest efficiently the large productive stocks and allows small and less-productive stocks to survive or disappear as they may. The progressive loss of small and less-productive stocks has been the result. The heavily capitalized interception fisheries cannot be managed to protect the diversity of stocks; they can only be managed on the principle that all fish are the same, which is patently not the case. To conserve salmonid diversity, mixed-stock fisheries need to be managed in a precautionary way to conserve small and less-productive stocks. This will mean reducing harvests in the interception fisheries and allowing greater harvests in terminal areas. The Canadian Department of Fisheries and Oceans, which is ultimately responsible for salmon management in British Columbia, cannot accomplish such a transition on its own. The fishing industry, aboriginal leaders, and coastal communities must all be engaged in an active program of co-management to ensure efficient harvest coupled with more effective stock conservation. The overall goal should be to transition gradually from heavily capitalized individual fishing units to smaller, lower capitalized, less-powerful units or alternative harvest techniques that will be economically viable with smaller total catch. Through co-management, fishers, aboriginal communities, and coastal communities can be given much more control over how the reduced harvest is taken and how it is shared among participants in the fishery. Through collaborative arrangements among fishers, coastal communities, and managers, small fishing units can be deployed to harvest local stock surpluses efficiently with much less danger of overharvest.

Encouraging smaller, targeted fisheries

The current British Columbia salmon fishing fleet consists of approximately 197 seiners, 1202 gillnetters, and 482 trollers. This represents an approximately 57% reduction in vessel numbers since the late 1990s, with proportionately more gillnetters and trollers leaving the fishery than seiners (Schwindt et al. 2003). However, the basic fleet composition has not changed, harvests and fish prices have both fallen, rent dissipation is high, and there are no incentives for fishers to practice conservation. As a result, the fishery is fundamentally uneconomic, and current policies are incapable of changing this situation (Schwindt et al. 2003, McRae and Pearse 2004). To revitalize the fisheries, something more radical than a further reduction in fleet size is needed. Schwindt et al. (2003) suggest that individual ownership of the harvest available in particular river systems would be the most effective approach to satisfy criteria of economic efficiency, equity, and conservation. This solution harks back to an earlier period in the coastal fishery when canneries were given exclusive rights to particular fisheries (Healey 1993) and even further back to the fishing rights system of aboriginal nations (Johnsen 2001). The solution would have many desirable effects, especially if it were modified to allow community or cooperative ownership of rivers or collections of small rivers. Smaller vessels and a variety of shore-based capture techniques would allow economically efficient harvest. Much management decision making could be turned over to the fishery owners by having them develop conservation harvest plans (Charles 1997) that would restore production and population diversity while generating jobs and revenue.

Maintaining habitat quality and diversity

Anadromous salmon present a uniquely difficult conservation challenge because their spawning populations extend to the headwater tributaries of the largest river systems and their oceanic phases are distributed throughout the North Pacific Ocean. Although the primary thrust of my discussion is the management of salmon fisheries to improve resilience, salmon and fishery resilience cannot be improved without an integrated program of both harvest and habitat management (see Hanna 2008). The loss of habitat for salmon has been widespread and extensive. The *Canada Fishery Act* provisions of no-net-loss of productive habitat have not been achieved (Quigley and Harper 2006). Quigley and Harper (2006) considered only freshwater and riparian habitat alterations; however, coastal habitats are also being altered in ways that can be detrimental to salmon. More emphasis on the protection of critical habitats is required if the resilience of salmon populations is to be restored. Centralized habitat management programs have demonstrated that they are incapable of this. It is time to put more responsibility and authority for habitat management into the hands of those for whom it is truly important: fishing communities and aboriginals.

Managing for community and cultural resilience

A subtext in my discussion of pro-resilience practices is that management decision making and management practice should be much more in the hands of fishing communities and aboriginals. This is now a common theme in resource management theory and practice (Weinstein 2000, Armitage 2005). There are numerous examples of fishing groups or fishing communities that successfully manage complex fisheries (Pinkerton 1989, Weinstein 2000). Although the Canadian Department of Fisheries and Oceans has taken some steps in this direction with fishery advisory committees and the aboriginal fishery strategy, the government has been very reluctant to abandon its command-and-control approach to salmon fisheries management (Pinkerton 1999). The fisheries are complex, and no single approach will address this complexity. However, a variety of community-based approaches involving quasi-property rights and co-management offer the potential to enhance salmon and fishery resilience without compromising the constitutional authority of the Minister of Fisheries. For the larger multistock fisheries (i.e., the Fraser River and Skeena River fisheries) a co-management approach analogous to the conservation harvest planning introduced in the Scotia Fundy region of Canada could be implemented (Charles

1997, Wingard 2000). The community of fishers licensed to fish the runs to each river would be required to form a cooperative responsible for designing a conservation harvest plan for taking the harvest. The cooperative would be responsible not only for fishing plans, in-season monitoring, and enforcement, but also for stock conservation and enhancement. The Department of Fisheries and Oceans would approve conservation plans, provide technical expertise for monitoring and conservation, conduct the necessary audits to ensure that conservation goals were being met, and assist with enforcement. Because aboriginal nations have significant interest in the Fraser and Skeena fisheries as well, a separate cooperative arrangement would have to be developed with aboriginal nations on the two rivers, as well as an agreement about sharing allowable harvest. This is already done under the aboriginal fishing strategy, so I essentially propose the extension of a similar arrangement to nonaboriginal fishers for these rivers. Nothing would prevent the aboriginal and nonaboriginal cooperatives from collaborating on various responsibilities such as escapement monitoring and enhancement. Giving fishers the authority to plan and administer the harvest would open opportunities for significant efficiencies in fleet distribution and resource use. For the Fraser fishery, conservation harvest plans would have to satisfy the terms of the Pacific salmon treaty.

For the smaller fisheries, property rights could be allocated to coastal communities under an arrangement similar to the community development quota system in Alaska (National Research Council 1999, Mansfield 2007). Both federal and provincial levels of government claim an interest in sustaining small, resource-dependent communities, yet fishery policy has served to undermine the economic viability of these communities. By providing communities individually or in cooperating groups with a nontransferable property right to salmon fisheries in their geographic region, the economic benefits of the fishery would accrue to the communities, rather than to fishers from outside the region (Wingard 2000). As with the Fraser and Skeena fisheries, communities would be expected to develop conservation harvest plans and take responsibility for most aspects of fishery management, monitoring, habitat protection, and enhancement. The Department of Fisheries and Oceans would retain its responsibility for ensuring that conservation objectives were met. Having a diversity of communities each developing somewhat different approaches to conservation and resource management would ensure that institutional arrangements are better designed for local conditions. This diversity, in turn, would increase community, fishery, and species resilience (Ostrom 1990).

CONCLUSIONS

Salmon are inherently resilient species. However, this resiliency has been undermined in British Columbia by a century of centralized, command-and-control management focused initially on maximizing yield and, more recently, on economic efficiency. Community and cultural resiliency have also been undermined, especially by the recent emphasis on economic efficiency, which has concentrated access in the hands of a few and disenfranchised fishery-dependent communities. Recent declines in both salmon stocks and salmon prices have revealed the systemic failure of the current management system. If salmon and their fisheries are to become viable again, radically new management policies are needed. For the salmon species, the emphasis must shift from maximizing yield to restoring resilience; for salmon fisheries, the emphasis must shift from maximizing economic efficiency to maximizing community and cultural resilience. For the species, an approach is needed that integrates harvest management, habitat management, and habitat enhancement to sustain and enhance resilience. This is best achieved by giving fishing and aboriginal communities greater responsibility and authority to manage the fisheries on which they depend. Co-management arrangements that involve the cooperative ownership of major multistock resources like the Fraser River and Skeena River fisheries and community-based quota management of smaller fisheries provide the means to put species conservation much more directly in the hands of the communities that are most dependent on the well-being and resilience of these fisheries.

Responses to this article can be read online at:
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