Part Two

Some Considerations in Salmon Management

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Introduction

The west coast of North America exhibits one of the richest assemblages of marine and terrestrial ecosystems on the planet. One of the most important animals in this geographically diverse region is salmon. Not only do the great migrating schools of these silver fish form an important nutritional and cultural focus for coastal First Nations, but they are also important for over a hundred species of wildlife that share the coast. This ecological association, which is widespread throughout coastal regions of western North America and Asia, is millions of years old.

Yet, over the last century, the fabric of this ecological network has become increasingly strained, largely as a consequence of human population growth and resource demands that have resulted in precipitous declines in salmon abundance. This decline has brought increased attention to understanding the ecological role of salmon, and all of the available data from these studies suggest that the ecological reach of salmon extends much farther into coastal ecosystems than most people realized.

PHOTO: *Tom Reimchen coring a Sitka spruce in the flood plain of the Quartcha River in Roscoe Inlet (Area 7) on the central coast.*

Scientific study of the role of salmon

Recent investigations have increasingly focused on the contribution of salmon to the productivity of freshwater lakes, streams and riparian ecosystems. Most lakes in coastal regions of western North America have intrinsically low productivity, due primarily to low levels of nitrogen and phosphorus. Research in these lakes is showing that the decomposing carcasses left after large schools of sockeye salmon spawn provide the single largest source of nutrients to the lake. These carcasses account for 50-70% of the total nitrogen and phosphorus found in the plankton and fish in these lakes. The availability of these nutrients then influences the abundance of phytoplankton at the base of the food chain which in turn influences the abundance of zooplankton and then higher trophic levels such as fish.

This cycling of nutrients to primary producers also occurs in estuaries. Salmon carcasses drift downstream and provide nutrients that are used by green algae, the new growth of which is consumed by copepods which in turn comprise the major food item for young salmon migrating downstream. In both lakes and estuaries, the abundance of salmon carcasses is a good predictor of productivity and resource availability.

This yearly pulse of nutrients, originating as far away as the mid-Pacific Ocean, is the largest such event in coastal forests. These great migrating schools of salmon are the ecological equivalent of the herds of migrating wildebeest of the Serengeti, and the yearly abundance of each is fundamental in determining the abundance and diversity of the species that depend on them.

Some of the most conspicuous animals present on salmon rivers are bears, who move from the alpine and surrounding forests onto the rivers, where they feed on salmon. The density of grizzly bears in areas with salmon rivers is up to 40 times greater than densities in regions where salmon are not present, such as interior rivers. The biologist Grant Hilderbrand's work has shown that some 75% of the yearly dietary requirements of bears is obtained during the four to six weeks when salmon return to their natal rivers.

Humans and salmon abundance: the balance between predator and prey

Predators co-exist with their prey as part of a dynamic feedback loop. As increased numbers of prey species appear in a community, the population of predators increases until a new equilibrium is achieved. When predator numbers exceed the carrying capacity of the prey community, the numbers of prey decline, and the predator community follows suit. Feedback loops like this one have been a feature of terrestrial and aquatic ecosystems for hundreds of millions of years.

To understand natural predator-prey interactions one must identify the characteristics of the prey (i.e. age and condition) that are taken by the predators. The major trend observed in studies of terrestrial predators like wolves and large cats is that young, old and unhealthy members of the prey species are targeted because these have the greatest benefit/

cost ratios for the predator. Predators do not target reproductive adults. In *aquatic* habitats, predatory fish are much more constrained by prey size than are terrestrial predators. Typically, it is the smallest and most abundant size classes that are consumed, while the larger, less abundant reproductive adults are less preyed upon.

Also important is the proportion of the total prey population taken by predators. Such proportions, often referred to as exploitation rates, have only been determined for a small number of natural communities. In terrestrial habitats, a study of a stable grouse population in a forest ecosystem in the eastern United States demonstrated that cumulative exploitation by a multi-species predator community was approximately 50% of the total grouse population. Each predator species took only a small proportion, typically less than 10%.

In the Serengeti, the social and solitary cats take about 16% of the total prey biomass, while exploitation of individual species within the community is even lower. In California, mountain lions take 6% of the deer, while in Idaho these cats capture 3% of the mule deer and 5% of the elk. In northern latitudes, wolves are known to take on average 10% of the caribou when they are abundant. However, where caribou densities are low, wolf predation rates can occasionally rise to 30%, a rate thought to be unsustainable and leading to a decline in caribou numbers. Wolves take up to 15% of the elk population and from 6% to 20% of moose; again, the upper values are thought to lead to population declines.

In aquatic habitats, field data on exploitation by natural predators are limited, but suggest trends comparable to those in terrestrial habitats. One of my studies of a lake ecosystem demonstrated that 22 species of fish-eaters fed on stickleback, the single dominant prey species. The major predatory fish, cutthroat trout, consumed about 5% of the sub-adult prey population, while common loon, the major avian fish eater, took 3% of the adults. In communities where multiple predator species target the same prey, it is logical to conclude that individual exploitation rates will have to be low. The prevalence of exploitation rates below 10% in nature suggests that such proportions have long term sustainability and that higher exploitation rates are ecologically unsustainable for the prey, the predator, or both.

Human predation through fishing: how much is too much?

The annual global extraction of fish from the sea is approaching 90 million tonnes. Although early fisheries were unregulated, fisheries have been extensively managed during the last 50 years through the use of increasingly complex mathematical models aimed at achieving a Maximum Sustainable Yield (MSY). Paradoxically, this increased sophistication of fishery management has been attended by the collapse of some of the major global fisheries such as the Peruvian anchovy, North Sea herring, Pacific pilchard and Atlantic cod.

Fishing is predation, and it is useful to consider what proportion of the prey species is taken. The quotas or exploitation rates established for commercial fisheries are based on several life history variables including egg production and age class distribution. These quotas reflect the concept of MSY, which is the greatest number of fish that can be harvested without reducing sustainability of the stock. While different countries calculate MSY in slightly different ways, exploitation rates determined from these models tend to be similar. Atlantic striped bass, for example, had exploitation rates of 29%, considered marginally higher than the recommended rate of 25%. In the North Sea, the Grand Banks, the Georges Banks and the Gulf of Maine, exploitation rates of cod, flounder and hake averaged 50-60% of the total population prior to the wide scale decline in abundance during the 1990s.

For species like herring, which are low on the food web and provide the nutritional base for many sea birds and larger fish and mammals, one might expect quotas rarely to rise above 10%. Yet commercial fishing quotas for Pacific herring were set as high as 80-90% in the mid-1900s. Herring stocks have collapsed repeatedly on the Pacific coast over the last 50 years. In response to these collapses, exploitation rates have been reduced to about 16%, considered by fisheries biologists to be an exceptionally conservative figure, sustainable and without any serious ecosystem-level effects.

In Newfoundland, average exploitation rates for Atlantic salmon prior to 1970 ranged from 52% to 72%. Following decline of the stocks, these rates were subsequently reduced to 25%. In the Pacific Ocean, exploitation rates on chinook salmon in Puget Sound from 1982-89 averaged 58%, and additional extraction from freshwater resulted in total exploitation rates reaching 75%. Exploitation rates on chinook salmon rose as high as 90% for some stocks.

A plea for reduced harvest and a new management paradigm

In the light of our understanding of ecosystem processes, single-species fisheries models based on the Maximum Sustainable Yield seem fundamentally flawed. The average exploitation rates for commercial fisheries, including salmon, are three to twenty times those observed in most natural multi-predator species communities. This disproportionate take by a superior predator may be the single largest cause of the widespread decline in commercially important fish species throughout the global oceans, including salmon on the Pacific coast. The ecological costs of these high harvest rates are profound, as they will produce a corresponding reduction in other species that require the same resource. Orcas, sea lions, seals, salmon sharks, black bear, grizzlies, wolves, otters, eagles, gulls, ducks, and many forest invertebrates all use salmon. This diversity cannot persist in the presence of a single predator that maintains high capture rates through continuous technological adaptation, despite declining abundance of the resource. In a marine ecosystem, humans are just one of a tremendous diversity of predators feeding on salmon. As such, we must bring our consumption in line with that of these predators. Research needs to be carried out to quantify predation/prey relationships within the salmon life cycle.

All of the current data suggests that a long term harvest rate that is sustainable ecologically, cannot exceed 5% of the salmon population.