Creating the Nation's first BioPark

National Zoological Park · Smithsonian Institution · Washington, D.C. 20008-2598

150 1846-1996 Smithsonian

Letter From the Desk Of David Challinor
November 1997

When people exploit the landscape to raise crops or livestock, or to harvest freshwater fish more efficiently, there are often unexpected consequences. The landscape changes that such activity triggers are now being studied by scientists who perpetually seek an understanding of what is happening around them. This letter will discuss an unforeseen consequence of over-harvesting Pacific salmon, which spawn in the nutrient-poor mountain streams and lakes of northwestern North America.

Salmon that spawn in the streams and lakes of southern Alaska, British Columbia and northwestern U.S. spend most of their lives at sea where they consume smaller fish, which in turn eat plankton. Scientists now believe that the salmon that die after spawning may furnish essential nutrients from their decaying carcasses that are necessary for the survival and health of the next generation.[1] Scientists can analyze tissue from salmon (and other animals) to determine the original source of the carbon and nitrogen in their bodies. Stable isotopes[2] of nitrogen -15 and carbon -13 are represented in a higher proportion in ocean fish than in freshwater fish or land animals. Because salmon do not eat when they enter fresh water, they retain this high proportion of stable isotopes, which is passed on and detectable in the consumers of sea-run salmon. What this means is that it is now possible to trace parts of the path of nutrients generated from the carcasses of salmon that often line stream banks after spawning. This path can be followed, for example, in the tissue of bears that consume live salmon, as well as in the scavengers of dead ones. Even more remarkable, the nutrients from the decomposing salmon can be tracked in insects, algae and plants growing both in the water and along the shore.

An analysis done by a young scientist, Thomas Kline, in an Alaskan lake showed that the dead sockeye salmon that spawned there provided 90% of the nitrogen in the algae on the lake bottom, and up to 70% of the nitrogen in the lake's plankton and in the fingerlings of the next salmon generation.

---

[1]Much of the information on the nutrient cycling from dead salmon came from an interesting article by Sharon Levy in New Scientist (6 Sept. 1997).

[2]Isotope = one of two or more atoms whose nuclei have the same number of protons, but different number of neutrons.

Coho salmon, unlike sockeye, spawn in fast-flowing streams at the headwaters of rivers. These mountain streams have high oxygen contents from riffles and rapids, but are deficient in nutrients. It had been thought that dead coho were washed rapidly downstream after spawning, but thanks to careful observation by Jeff Cederholm of Washington's Department of Natural Resources, he confirmed that the healthiest streams in terms of nutrient content were those that were full of coho carcasses. It appeared that the salmon breeding cycle actually brought nutrients from the sea back to the land; just the opposite of the traditional view that the land, through river discharge, is a major source of nutrients to the sea.

To test his hypothesis, Cederholm obtained hundreds of dead coho from fish hatcheries and put them into streams. Where the stream was relatively undisturbed, the dead fish were frequently caught behind logs and other natural barriers that created small pools for the spawning salmon. Everything from bears to mice and small birds fed on the carcasses, which were most prevalent in the fall after the coho spawned. Dead salmon were thus an important winter food for a variety of wildlife. Just as in the lake bottoms and shores where sockeye spawn, about 25% of the nitrogen available to plants and invertebrates of the streams was traced back to the coho.

In March and April when the young coho hatch they feed on stream invertebrates for a whole year before returning to the ocean, thereby reaping the nutrient benefits contributed by their dead parents. Many of the coho smolts do not survive their first year and thus contribute their bodies to the health of their siblings.

With the rapid decline in salmon runs in many of the streams of the Pacific Northwest, the whole salmon cycle may collapse. Unless enough adults reach the headwaters to spawn and then die, there might not be enough nutrients in the water to support a healthy population of hatchlings. One temporary action being tried is to dump dead post-spawning hatchery salmon into streams instead of burying them in landfills. Although clearly a temporary expedient, biologists must now calculate the nutrient contribution of specific volumes of dead salmon in a given watershed or lake needed to maintain the critical nutrient level necessary for vigorous growth of smolts. It is not too soon for fishery managers to learn these parameters and to set harvest goals. Coho have recently been listed as a threatened species in California and southern Oregon. They are extinct in over half of their former range, and it will take a concerted effort to reduce their harvest, maintain their migration routes and insure the nutrient quality of the streams where they spawn.

If indeed the decaying salmon are an important or even an essential source of nutrients for the next generation, it raises many interesting questions. How did this sequence of death after spawning evolve and what were the survival advantages to the species? Is evident nutrient increase only incidental, and would some smolts and fingerlings always survive whether or not their parents died after spawning? Probably yes. Although there are undoubtedly nutrient benefits to the ecosystem from the dead salmon, from an evolutionary perspective it would not benefit only the smolts, but rather all the other fish and organisms living in the same water. Thus, the adult death/nutrients for young cycle appears to be only coincidental and did not evolve as some kind of group selection.

There are examples of spiders and mantids where the diminutive male is often eaten by the female during or immediately after copulation. Not all males so succumb for they, too, have evolved various devices, behavioral and otherwise, to avoid being eaten. From the male perspective, his fitness is best promoted by not putting all his sperm in the basket of one female, but saving some for another female. The male that is eaten, however, is a readily accessible protein source for the female who can use the extra nourishment to produce eggs for the next generation. The immediate beneficiary of the sacrificed male, however, is the recently bred female and thus only indirectly benefits the next generation.

There are other insect families where adults die after reproducing, such as cicadas whose nymphs survive for up to 17 years in the soil before emerging for one glorious, short reproductive frenzy. Scientists, however, have not yet seen any evidence of significant benefit to the underground nymphs from the scattered corpses of their parents. In fact, the adults are usually long dead and decomposed before the young hatch from their twig-deposited eggs. The hatchlings fall to the ground, burrow in the soil and begin their long underground life.

The adults of some cephalapods (cuttlefish) also die after reproducing, but again the benefit to the next generation, if any, is unclear. Thus the complicated reproductive cycle of salmon, wherein most or in some species all adults die after spawning, may be a chance benefit to the next generation rather than an evolutionarily determined one. The questions raised when trying to solve such puzzles seem endless. For example, the returning adults of Pacific salmon do not feed as they swim upstream and in the case of one species (Oncorhyncus gorbuscha), males, after a week in fresh water, turn a brilliant red and develop a large hump on their backs. Their jaws change so that just the tips meet, thereby keeping their mouths from closing.

Since they do not eat during the month or more they take to spawn, their jaw modification would seem only useful as a secondary sexual characteristic to help attract a female. There is still so much to learn.

In recent months the fascinating and commercially valuable salmon have been attracting considerable attention -- even in the halls of Congress where a hearing is planned on eliminating four existing dams on the lower Snake river in Idaho. The dams have allowed Lewiston, Idaho to become an important Pacific port, but they have decimated migrating salmon. The thought of destroying a dam would have been unthinkable a few years ago, but citizens are now beginning to realize the exorbitant long-term costs of the post-World War II dam building binge. Even the seeming benefits of cheap, federally subsidized electricity and irrigation water is beginning to lose its appeal to the vast majority of citizens who do not reap these benefits directly.

It will cost us all to live healthily on an increasingly polluted planet. The Kyoto conference on Global Warming next month is already under assault by anonymous television advertisements warning of the dire economic consequences of reducing our energy consumption. Does no one care about the next generations that will have to pay the cost of our profligacy? All of us living today should consider ourselves custodians for those who follow. Learning the results of our past actions can help us better to carry out this awesome responsibility.

David Challinor
202/673-4705
202/673-4607 FAX