An adaptation of:

the fish & the forest

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Introduction

In North America hungry bears have long attracted attention as they gather along streams and rivers to scoop up spawning salmon. In the late 1940s, fishery managers thought that the predators might be devastating salmon populations and proposed that many bears should be killed in Alaska to reduce their "economic damage" to fisheries. In fact, several sensationalized reports implied that Alaska might fall into "financial and social collapse" unless bear populations were controlled.

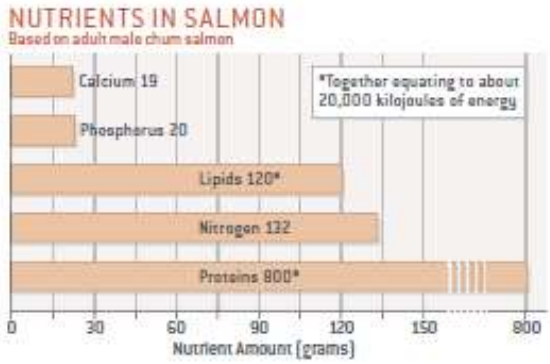
Fortunately, the fishery managers' plan never happened, but scientific interest in the interaction between bears and salmon died down. Recent research has shed light on an important part of this relationship, and the finding has changed ideas about how salmon, streams and bordering woodlands affect one another, which has influenced ideas about how they should be managed.

We have collected data for more than a decade; we have walked hundreds of kilometers along salmon streams, examined tens of thousands of salmon carcasses, and had many close encounters with upset bears. Our findings surprised us: bears actually fertilize the forests, providing nutrients by discarding salmon carcasses. Bears unintentionally bring valuable ocean nutrients, in the form of salmon tissue, to the streamside woodlands, where the uneaten fish provide energy and nutrients to many animals and plants. The flow of nutrients from ocean to streams to woodlands is an unexpected uphill direction for resources to travel. ***A close look at the life cycles of salmon and bears helped us and other scientists understand how this unusual transfer system works.***

The Nutrient Express

Pacific Salmon vary in abundance, size and behavior, but share the same general life cycle. In spring young salmon migrate to the ocean from streams or lakes. After living at sea between one and four years, they return to the streams they were born in to spawn and die. The young salmon are small when they leave freshwater, weighing between one ***gram*** to about 20 ***grams***, and are big when they return, ranging from two to 10 ***kilograms*** or more. Even though most juveniles die at sea, the return of adult salmon brings a large flow of nutrients and energy from the ocean to stream and lake ecosystems.

These nutrients and energy from the ocean can have a big impact on freshwater systems because there are so many salmon, and each one contains so many nutrients. For example, an adult male chum salmon contains an average of 130 grams of nitrogen, 20 grams of phosphorus and more than 20,000 kilojoules of energy in the form of protein and fat. Multiplying this average by the total number of salmon showed that one stretch of stream in southeast Alaska received more than 80 kilograms of nitrogen and 11 kilograms of phosphorus from salmon in just over a month.



BEAR PREDATION

Creek	Average no. of salmon	Average no. killed by bears	Average percent killed
Bear	3,907	1,183	32
Big Whitefish	786	342	49
Eagle	918	399	53
Fenno	5,228	666	12
Hansen	6,229	2,450	49
Hidden Lake	2,010	671	43
Little Whitefish	173	93	58
Pick	5,837	1,949	35

The behavior of bears also affects the way that nutrients from salmon help forest ecosystems. Salmon provide bears with fat to store in order to survive winter, and to reproduce. Bears spend most of their lives alone, when many come together in one area to catch salmon they become aggressive. In order to survive and reproduce, bears compete to get the most food, because of this bears show two behaviors that affect the whole ecosystem.

First, to avoid confrontation with aggressive bears, they often carry captured salmon to the stream bank or into the forest before eating.

The second important behavior is that bears rarely eat the whole fish and they kill far more salmon than they eat. A bear can catch a salmon in less than a minute, eat the most nutritious and fatty parts (like eggs), and then catch another fish. Examination of more than 20,000 salmon carcasses showed that on average only about 25 percent of each salmon was eaten. At a small stream in southeastern Alaska a 200-kilogram female brown bear captured more than 40 chum salmon during eight hours. She removed over 143 kilograms of salmon (70 percent of her body weight!) from the stream but consumed only a small fraction of this bounty. Bears leave the rest of the salmon body on the bank or in the forest, and return to the stream to catch more fish.

Special Delivery

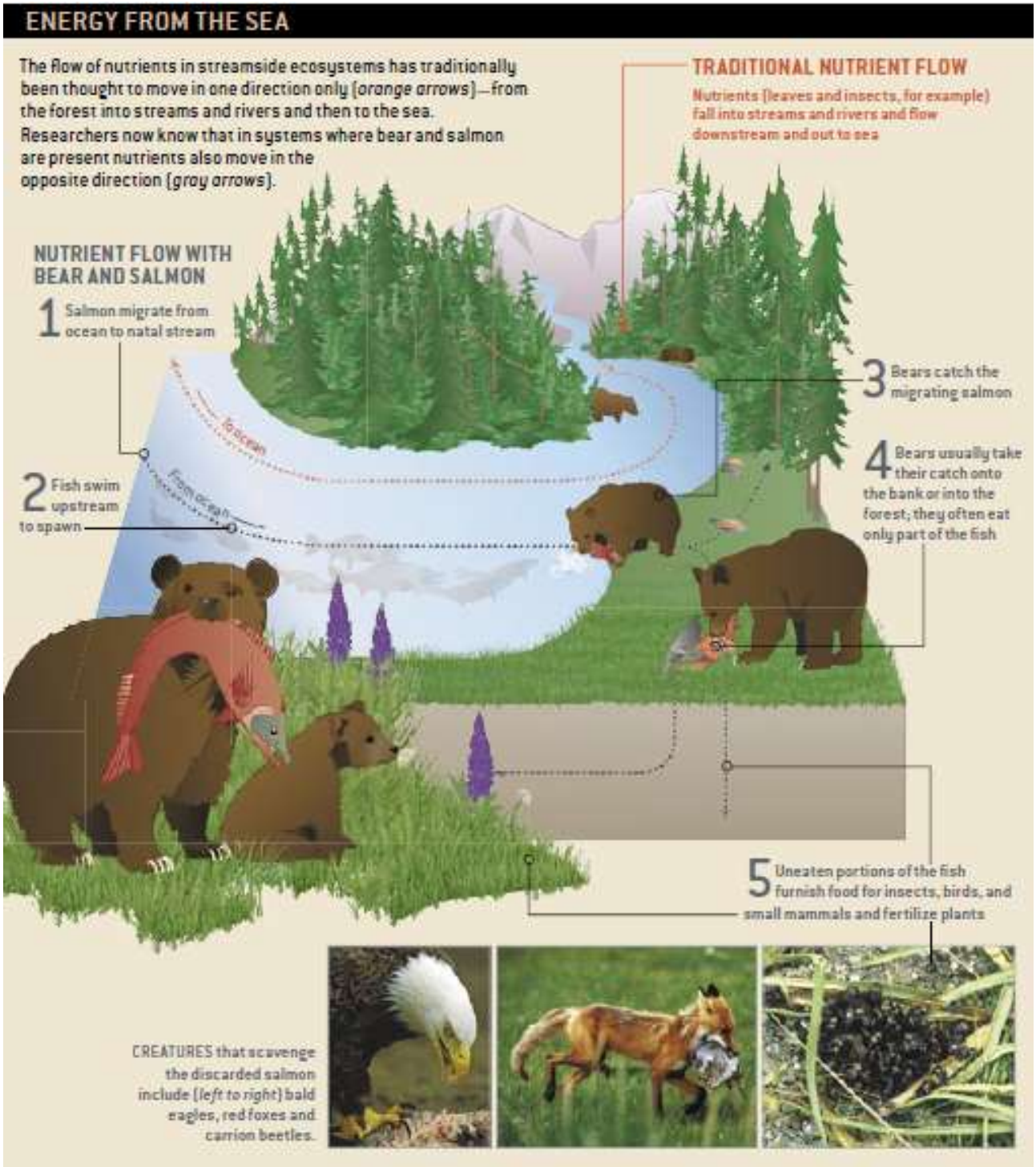
Why is this unusual feeding behavior important for the vitality of the ecosystem? Even if bears were gone the salmon would still die after spawning, and their carcasses would still be scavenged by birds, fishes and insects, then decomposed and their nutrients flushed out to the ocean. However, by killing the fatter salmon, carrying the nutrient-loaded fish to the forest, and leaving bodies with most of the biomass, bears make a tremendous amount of energy and nutrients available to streamside plants and animals that would not normally be able to access the fish. The bears are truly ecosystem engineers: they deliver marine-derived nutrients to the streamside (*riparian*) system.

Forest Communities

Many different animals make use of the protein and fat in the abandoned fish. Flies, beetles, slugs and other invertebrates colonize the carcasses almost immediately and deposit their eggs there. Gulls, ravens, crows, jays, magpies, mink, marten, and other species of birds and mammals quickly make a meal of the carcasses. In Washington State, researchers have compiled a list of more than 50 species of terrestrial vertebrates nourished by salmon carcasses. We once observed a bear capture a fish and walk into a meadow, where it began to eat its catch. When it was distracted by another bear, a mink darted out of the grass, grabbed part of the salmon and scampered back into the forest.

A creature does not have to eat the salmon to benefit from the ocean's nutrients. Wasps, birds, and small mammals such as voles and mice eat the insects that colonize carcasses. There are more birds along salmon streams than streams without salmon, suggesting that bird communities gather around insects produced by the salmon carcasses.

Over time, the carcasses are broken down making the nitrogen, phosphorus and other nutrients available to plants. Plant growth is often limited by either nitrogen or phosphorus, so the feeding behaviors of bears may influence growth rates of many plant species. ***Along several streams in Alaska, we have calculated that the total amount of nitrogen and phosphorus provided by the carcasses equals or exceeds recommended concentrations of commercial fertilizer for similar plants in northern forests.*** In some cases, up to 70 percent of the nitrogen in streamside shrubs and trees is from salmon. Not surprisingly, one study found that growth of Sitka spruce trees was three times greater along salmon streams than along non-salmon streams. Several studies have shown that the amount of salmon-derived nitrogen or carbon matches the movements of bears, providing further evidence that bear feeding behavior delivers salmon nutrients to streamside forest plants.



Managing the Nutrient Express

As a result of this new understanding, scientists are redefining how these ecosystems function and thus how they could be managed. Traditionally, it was thought that nutrient flow in streams and lakes moved in one direction: nutrients, in dead organic material, fell from the forest into rivers and creeks, flowed downstream and out to the ocean. We know now that they also move in the opposite direction: nutrients, in the form of migrating salmon, travel from the ocean to freshwater and then, carried by foraging bears, to forests. Any action that reduces the number of salmon or bears will affect the nutrient flow and the many creatures that depend on it.

Commercial fishing limits, for example, are based on the maximum number of salmon that can be captured without threatening the population; "excess" individuals are caught. Salmon fishery managers have begun to consider the needs of other species in the ecosystem when calculating this limit.

In areas where salmon runs are seriously reduced or wiped out, state agencies are now dropping salmon carcasses from helicopters or trucks as a restoration effort to restore nutrients until salmon runs return to their historical levels.

The new knowledge has even sparked business ideas: one company in Alaska is exporting compost soil made of wood chips and salmon carcasses.

Baker River salmon drop in Washington State

Conclusion

We have come a long way since the 1940s in understanding the role of fishing bears, and undoubtedly we will learn much more as research continues. What is clear now is that bears and salmon are key components in these ecosystems, and that both populations have been severely reduced or removed from their historical areas. It remains to be seen whether the greatest challenge lies in understanding the full extent of this relationship, or in restoring it where it once flourished.