River Conservation and Terrestrial Mammals: Key Ecological Processes

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Abstract: *Key ecological processes affecting interactions between rivers and terrestrial mammals are identified and explained, using floodplains of Alaska as examples of relatively pristine systems. Both coastal (Southeast Alaska) and Interior Alaska examples are used. Coastal Alaskan rivers tend to be relatively short, flashy, rain-driven systems, while Interior Alaska rivers tend to be large, glacial-melt driven systems. Seven key processes were identified: (1) flooding, (2) erosion/deposition, (3) dam building by beaver (Castor canadensis), (4) fish (especially salmon, Oncorhynchus spp.) production, (5) translocation of marine-derived nutrients, (6) nitrogen fixation by alder (Alnus spp.), and (7) herbivory by moose (Alces alces). Three key conservation measures are identified as being most important: (1) upland management practices, (2) streamside buffers and floodplain protection, and (3) trans-boundary agreements and international treaties.*

Introduction

Rivers and riverine habitats are especially important ecological features for a variety of reasons: They are unique, usually very species-rich habitats, yet they occupy a very small proportion of any landscape. Their valleys and floodplains are a principal focus for human development – for transportation (both water and roads), agriculture, and housing. The ecological interactions between the terrestrial and aquatic systems are strong and highly dynamic. And because of their long shape, rivers cross many ecological, ownership, and political boundaries. Water rights and land ownership are highly valuable, and their regulation is potentially highly contentious. Thus, rivers and their associated wetland habitats constitute a major challenge for conservation wherever they occur.

This paper focuses on floodplain systems of Alaska and some key ecological relations between floodplains and wild, terrestrial mammals. As such, it provides a perspective of natural ecological processes in relatively "pristine" ecosystems, which might serve as a useful reference in comparison with ecological processes in more human-dominated systems. I discuss examples from Southeast Alaska and Interior Alaska, two quite different regions of the same state. Southeast Alaska is a coastal region and archipelago with a strongly maritime climate of cool, wet summers and mild, wet winters. It is highly mountainous and densely forested terrain with relatively short rivers falling rapidly to the sea. The rivers are relatively low volume flow, but very flashy, and they are principally rain-driven. Interior Alaska, on the other hand, is relatively isolated from both the Pacific and Arctic Oceans by high mountain ranges to the south (Alaska Range) and north (Brooks Range), and its climate is strongly continental, with warm, dry summers and extremely cold, relatively dry winters (most precipitation occurs as fall rains and winter snow). It is a region of large, wide valleys drained by large, sinuous rivers driven mostly by summer melting of

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glaciers in the surrounding mountain ranges, especially to the south. Thus the two regions of Alaska provide contrasting examples of climate, terrain, plants, and animals.

Key Ecological Processes

Flooding – Fluctuations in water levels, especially floods that overflow river channels, create a highly dynamic environment for terrestrial plants and animals. Only plant species that can survive prolonged periods of inundation, and only animals that can find refuge in above-water vegetation or habitats can thrive in floodplain environments. Flood frequency, interacting with variation in site microtopography, plays a major role in species composition and species richness of riparian plant communities in Southeast Alaskan floodplains (Pollock et al. 1998). Additionally, silt deposited by floodwaters buries the soil surface and adds to both the elevation and composition of the floodplain soils, resulting in increasing terrace height with increasing age in Interior Alaska floodplains.

Erosion and deposition – Far more dynamic than flooding, per se, are the processes of erosion and deposition, often strongest during floods, but also persistent throughout the year. Erosion constantly eats away at river banks, and the sediments get redeposited as sand and gravel bars elsewhere. As such, erosion/deposition is constantly "resetting" primary succession of plant communities within the floodplain. All communities are potentially at risk, and the "reset point" is back to the very beginning – bare sand and gravel bars. In the process of bank erosion, large trees are frequently undercut and fall into the river, providing a continuous source of large woody debris. In Southeast Alaska, the large trees are frequently taller than the river is wide, and they remain in place for decades, having a major effect on flow patterns and aquatic habitat. In Interior Alaska, where rivers are much wider than any trees are tall, the large woody debris accumulates in piles and log jams, strongly influencing flow patterns locally and protecting some sandbars from further erosion. In both Southeast and Interior Alaska, the large trees have significant effects on patterns of water flow, resulting in shifts in river channels and increased spatial variation in floodplain dynamics.

Dam building by beaver – Beaver (*Castor Canadensis*) can have major effects on floodplain communities through their dam-building activity, especially in southeastern Alaska, where river side channels and backwaters are preferred habitat for beaver. Beaver dams built across relatively small, low gradient creeks and side channels create pond habitat, which is a relatively rare kind of habitat on the Southeast Alaska landscape and, therefore, provides habitat to relatively uncommon aquatic plant species in the region. Beaver ponds connected to the main river channel by stream or flood also provide especially important rearing habitat for juvenile salmon, especially coho salmon (*Oncorhynchus kisutch*).

Fish (especially salmon) production – Salmon (*Oncorhynchus* spp.) are a "keystone" species in Alaskan riparian systems, being a critically important food source for a wide variety of animal species – both aquatic and terrestrial. Both the small, juvenile stage and the mature adults returning from the sea to spawn in their natal freshwater streams are important. The juveniles, especially resident, rearing juveniles are a year-round food source for small mammals and piscivorous birds. The spawning adults, however, provide a superabundance of high quality flesh upon their arrival in summer and fall each year. That

superabundance of animal protein fuels a significant part of the terrestrial food chains in Alaska.

Bears, especially brown bear (*Ursus arctos*) are voracious feeders on salmon in summer and fall. Brown bear body size, productivity (mean litter size), and population density have been found to be highly correlated to the percentage of meat (especially salmon) in their diets (Hilderbrand et al. 1999b). Similarly, in Southeast Alaska, salmon were found to comprise 49-57% of summer/fall diets of mink (*Mustela vison*) (Ben-David et al. 1997b), and Ben-David (1997) has argued that coastal Alaskan mink have shifted their reproductive cycle by about a month later (than continental populations at similar latitude) to make lactation demands coincide with the arrival of salmon in summer. American marten (*Martes americana*), not usually considered a riparian species, also were found to rely heavily on spawning salmon (29-33% of their diet) during years of low abundance of their preferred prey, longtailed voles (*Microtus longicaudus*), with the salmon thereby providing a buffer during otherwise lean years (Ben-David et al. 1997a). Similarly, wolves (Canis lupus), also not usually considered a riparian species, were found to rely heavily on salmon in coastal environments – with 18.3% of their *annual* diet (maybe almost half of the summer/fall diet?) comprised of salmon (Szepanski et al. 1999).

Translocation of marine-derived nutrients – Salmon returning from the sea to their natal streams constitute an enormous supply of marine-derived biomass and nutrients to the freshwater and riparian ecosystem. Bears play a significant role in transporting those nutrients from the freshwater to the terrestrial system. For example, frequency distributions of brown bear locations (radio-collared bears) in relation to distance from stream matched almost perfectly with the pattern of nitrogen stable isotope signature from salmon ($\delta^{15}N$) in the needles of spruce (*Picea glauca*) trees along streams in coastal Alaska, with salmon-N redistribution rates as high as 5.1 mg/m^2 per year per bear within 500 m of the stream (Hilderbrand et al. 1999a). Foodweb analyses based on nitrogen stable isotope signatures revealed similar patterns of elevated salmon-derived nitrogen in the bodies squirrels, voles, mice, and shrews, all decreasing with increasing distance from the river (Ben-David et al. 1998).

Whether such nitrogen fertilization by salmon carcasses has ecosystem productivity effects, however, remains unclear. Growth rates of riparian Sitka spruce (*Picea sitchensis*) trees growing near salmon-spawning reaches were reported to be about three times greater than those of similar trees not near salmon-spawning reaches (Helfield and Naiman 2001). However, coincidental differences in other site productivity factors (especially soil type) may also have played a significant role in those results (Kirchhoff 2003). Moreover, until a more complete picture of the full nitrogen budget of some coastal streams is better understood, it will be impossible to determine the limiting nature of various factors. For example, red alder (*Alnus rubra*) is a relatively common riparian tree in coastal Alaska, and other alder species are dominant vegetation of many headwater streams. Alders are nitrogen fixers and contribute large amounts of nitrogen to both the stream (directly) and its hyporheic zone. Thus, the relative contribution of salmon-N versus alder-N is an open question.

Moose herbivory in Interior Alaska – Alder species (especially *A. tenuifolia*) also play major roles in floodplain succession in Interior Alaska. They are the principal nitrogen-fixer in superabundance of animal protein fuels a significant part of the terrestrial food chains in Alaska.

Bears, especially brown bears (*Ursus arctos*), are voracious feeders on salmon in summer and fall. Brown bear body size (presumably mean litter size) and population density have been found to be highly correlated to the percentage of meat (especially salmon) in their diets (Hilderbrand et al. 1999b). Similarly, in Southeast Alaska, salmon were found to compose 45-57% of summer/fall diets of mink (*Mustela vison*) (Ben-David et al. 1997b), and Ben-David (1997) has argued that coastal Alaskan mink have shifted their reproductive cycle by about a month later (than continental populations at similar latitudes) to make lactation demands coincide with the arrival of salmon in summer. American marten (*Martes americana*), not usually considered a riparian species, also were found to rely heavily on spawning salmon (21-42% of their diet) during years of low abundance of their preferred prey, longtailed voles (*Microtus longicaudus*), with fish acting as a "buffer" during otherwise lean years (Ben-David et al. 1997a). Similarly, wolves (*Canis lupus*), also not usually considered a riparian species, were found to rely heavily on salmon in coastal environments – with 18.3% of the [illegible] half of the summer-fall diet composed of salmon (Szepanski et al. 1999).

Translocation of marine-derived nutrients – Salmon returning from the seas to their natal streams constitute an enormous supply of marine-derived biomass and nutrients to the freshwater and riparian ecosystem. Bears play a significant role in transporting those nutrients from the freshwater to the terrestrial system. For example, frequency distributions of brown bear locations (radio-collared bears), in relation to distance from stream, matched almost perfectly with the pattern of nitrogen stable isotope signatures from salmon ($\delta^{15}N$) in the needles of spruce (*Picea glauca*) trees along streams in coastal Alaska, with salmon-N redistribution rates as high as 5.1 kg/km² per year per bear within 500 m of the stream (Hilderbrand et al. 1999a). Follow-up analyses based on nitrogen stable isotope signatures revealed similar patterns of elevated salmon-derived nitrogen in the bodies of squirrels, voles, mice, and shrews, all decreasing with increasing distance from the river (Ben-David et al. 1998).

Whether such nitrogen fertilization by salmon carcasses has ecosystem productivity effects, however, remains unclear. Growth rates of riparian Sitka spruce (*Picea sitchensis*) trees growing near salmon-spawning reaches were reported to be about three times greater than those of similar trees near non-salmon-spawning reaches (Helfield and Naiman 2001). However, coincidental differences in other site productivity factors (especially soil type) may also have played a significant role in these results (Kirchhoff 2003). Moreover, until a more complete picture of the nitrogen budget of some coastal streams is better understood, it will be impossible to determine the limiting nature of various factors. For example, red alder (*Alnus rubra*) is a relatively common riparian tree in coastal Alaska, and other alder species are dominant vegetation of many headwater streams. Alders are nitrogen fixers and contribute large amounts of nitrogen to both the stream directly, and its riparian zone. Thus, the relative contribution of salmon-N versus alder-N is an open question.

Moose herbivory in interior Alaska – Alder species, especially [illegible] (*Alnus tenuifolia*) also play major roles in [illegible] succession in interior Alaska. They are the main nitrogen-fixer in [illegible] the primary successional sequence of willow (*Salix* spp.) to alder to poplar (*Populus* spp.) to spruce (*Picea* spp.), which occurs from sand/gravel bars to mature forest, each with increasing age and terrace height above river (from silt deposition). The nitrogen fixed by alder in that sequence remains the principal source of nitrogen in long-term site productivity, long after the alder has disappeared in the successional sequence.

Moose (*Alces alces*) play a very significant role in early successional dynamics of the floodplains in Interior Alaska – primarily by concentrating their browsing on willow and not on alder, the effect of which can be a significant shift in community composition from willow to alder, effectively speeding up the early successional sequence by about 10 years (Kielland and Bryant 1998). Although that result is impressive at the stand-level of scale, it can be even more impressive at the landscape-level of scale, where the net effect of moose herbivory is highly interactive with erosion/deposition rates and can result in a shift in alder composition (percentage of landscape) from less than 10% under no moose herbivory to as much as 33% under high rates of both herbivory and erosion/deposition (Butler et al. 2007). Thus, moose can play a major role in both the structure and function of floodplain landscapes in Interior Alaska.

Conservation Measures and Conclusions

Key conservation measures for rivers and riparian zones in Alaska include the following: (1) upland management practices; (2) streamside buffers and floodplain protection, and (3) trans-boundary treaties and agreements. Upland management practices affect floodplains and riparian systems indirectly, but very importantly. Uplands are major sources of nutrients, downstream food sources (e.g., aquatic insects), sediments, and/or pollution. The stream and river is, in effect, largely a reflection or integration of what occurs in the uplands and its headwaters. Streamside buffers and floodplain protection, of course, are aimed at protecting the stream itself. Laws and regulations in Alaska differ greatly for buffer protection, depending on whether the land is federally, state, or privately owned; the most protective measures currently apply to U.S. Forest Service administered land, and the least protective measures apply to privately owned land. Additionally, however, given that many rivers cross many land ownerships and even national boundaries, trans-boundary agreements are a potentially important part of river conservation. In Alaska currently, trans-boundary agreements are best exemplified by international treaties between the United States (and/or Alaska) and Canada – especially regarding salmon. Many highly productive salmon rivers cross the U.S.-Canada border and are the subject of much international negotiation and cooperation.

Conclusions – I have three principal conclusions: (1) Although species composition and habitat structure always are important and obvious conservation concerns, ecological processes, too, are extremely important for ecological function. (2) Floodplain conservation must include consideration of upland processes (e.g., affecting sedimentation, pollution) and headwater processes (e.g., affecting nutrient and food inputs), too. And (3) Rivers provide unique and important habitat for terrestrial wildlife, and terrestrial wildlife play important roles in ecological processes of rivers.

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