The statement by Wattenberg that thousands of tons of topsoil washed into streams after the 1988 fires is true (*5*), but similar erosion has occurred after fires in Yellowstone repeatedly in the past. The geological record is clear: radiocarbon dating shows that debris flows and flash floods, which carry the great majority of sediment into streams after major fires, have recurred at intervals of about 300 to 450 years over the last several 1000 years (*6*). It is also clear that major fires and erosion are much more prevalent in periods of warming climate, and instrumental records in Yellowstone show a significant trend of increasing temperatures and summer drought severity over the last 100 years (*7*).

Fire-related erosion and sedimentation have both positive and negative aspects (*8*). In addition to siltation, debris flows and floods are a major source of spawning gravel, boulders, and woody debris to streams, clearly important functional components of aquatic habitats. Erosion is a transient response after fire and is greatly reduced even by relatively sparse growth of herbaceous plant cover in Yellowstone, where deep-seated soil slips are rare (*9*). Fire-related debris flows and floods became uncommon after 1991 and have continued only in limited areas, such as from dry south-facing slopes that are slower to revegetate. Fine sediment input is therefore greatly reduced within a few years after fire in Yellowstone. Also, much fire-related sediment is deposited locally along valley sides and on floodplains (*9*), where this organic- and nutrient-rich material contributes to the productivity of those environments.

Clearly the potential remains for future large, intense fires in the greater Yellowstone area. If climate warming continues, as appears likely (*10*), then we may anticipate more drought years like 1988, when fires probably will be impossible to control even if managers decide that complete suppression is desirable.

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Otter-Eating Orcas

The report "Killer whale predation on sea otters: Linking oceanic and nearshore systems" by James A. Estes *et al.* (16 Oct., p. 473) poses an intriguing explanation for the recent precipitous decline of sea otters in the Aleutian Islands. This crash began in the early 1990s, in the same year as one

Sea otter, a victim of orca predation

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of the first confirmed sightings of a killer whale attacking a sea otter. The proposition that orca predation is decimating otter populations is not conclusive, but it is supported by a collection of evidence, including continued sightings of killer whale attacks.

The analysis in the report was limited to the Aleutian chain, but the report has implications elsewhere: killer whale predation on sea otters has also been witnessed in Prince William Sound, Alaska. In fact, of the nine sightings in the 1990s, three were in Prince William Sound (*1*), the site of the largest oil spill in North America and the focus of continuing scientific and legal disputes regarding recovery. Nearly a decade after that March 1989 spill, some researchers believe that sea otters are among the handful of species that still have not recovered (*2*).

There has been much controversy regarding the number of sea otters that died as a result of the spill, the number remaining, and their status in terms of population recovery (*3, 4*). Studies of recovery have centered on Knight Island, an area that took the brunt of the spilled oil. All three sightings of killer whales attacking sea otters in Prince William Sound were made at Knight Island (*1*); these attacks involved two different whales. Estes *et al.* showed that as few as four whales, eating only otters, could have been responsible for the loss of some 40,000 sea otters in the Aleutians. Thus, a few whales can potentially kill a great many otters. Two otter-feeding orcas at Knight Island, an area with about 300 sea otters (*4*), should raise concern, not just for the otters, but for interpretations of the ongoing scientific inquiries there. A good deal of study has been directed at Herring Bay at the north end of Knight Island, which, because of its northward orientation (facing the *Exxon Valdez* tanker), collected large amounts of oil. This bay is inhabited by less than 10 otters, two of which are known to have been killed by a whale. It seems ironic that killer whales, continually under scrutiny for effects of the spill, may themselves be confounding studies of another spill-affected species. Linkages in the Alaskan marine ecosystem may be even more extensive and complex than Estes *et al.* propose.

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Response

Garshelis and Johnson correctly point out that three of the nine attacks by killer whales on sea otters reported by Hatfield *et al.* (*1*) occurred in Prince William Sound. On the basis of this fact and our analyses, they suggest that the area over which killer whale predation has suppressed sea otter populations extends beyond the Aleutian archipelago, perhaps as far eastward as Prince William Sound. This suggestion is plausible because (i) the areal limit over which we reported otter population declines (Kiska to Seguam islands) was defined only by available data, not direct evidence; (ii) killer whales move long distances (*2*), so the home ranges of otter-eating whales in the Aleutians might easily include Prince William Sound; and (iii) sea lion and harbor seal population declines, which we propose caused killer whales to begin eating sea otters in the early 1990s, extend eastward to about Prince William Sound (*3*).

Garshelis and Johnson's proposal is especially pertinent because of its implications to biological impact assessment from the *Exxon Valdez* oil spill. Specifically, it raises the intriguing possibility that killer whale predation is confounding or even supplanting the effects of spilled oil on sea otter populations in Prince William Sound. Further evaluation of this proposal is needed, however, because of the powerful legal, monetary, and policy implications. The following activities should prove useful to that end.

Sea otter surveys were conducted in the 1980s or early 1990s for most of the species' range from Prince William Sound westward through the Aleutian Islands. By repeating these surveys for the area between the eastern Aleutians and Prince William Sound, the geographical pattern of population change could be determined. A decline in otter numbers over all or most of this region would make the wide-ranging impact of killer whale predation more likely than if the declines were discontinuous.

Numerous sea otter surveys have been conducted for Prince William Sound since the *Exxon Valdez* spill, from which patterns of population change can be assessed. Because otter declines among islands of the Aleutian archipelago were widespread, synchronous, and of uniform magnitude, a similar pattern might be expected in Prince William Sound if killer whale predation has been significant.

Demographic and observational analyses, similar to those we did for the Aleutians, should be repeated for Prince William Sound. These analyses might further clarify patterns and their causes for Prince William Sound .

Finally, further study of killer whales could help determine if individuals range between the Aleutian Islands and Prince William Sound.

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