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Effects of Apex Consumers Cascade Dynamically across Trophic Levels

In recent decades, it has been hypothesized that the loss of large apex consumers may exert pervasive influence on nature, and the idea that an ecosystem is shaped by the top-down effects is now widely accepted.

Simple ecosystems in the northern Pacific Ocean are particularly suitable to test the hypothesis. In 1970's, communities at islands lacking sea otters were characterized by high density of sea urchins and a distinct lack of macrophytic vegetation.. In contrast, communities at islands with sea otters had relatively high kelp densities and low sea urchin biomass (Estes and Palsamino 1974). However, in 1990's, sea otter populations declined unexpectedly over large areas and the increased killer whale predation was supposed to be the likely cause of these declines (Estes et al. 1998).

In this talk, we propose simple mathematical models of the communities without or with sea otters, and those with killer whales. We will show that competition between kelps and coralline algae in the basal trophic level strongly affects community dynamics and causes violent oscillations which lead to imminent extirpation of the kelp population. However, introduction of the sea otters suppresses not only the sea urchin population but also the violent oscillations in communities with the sea urchin as an apex consumer. Thus, in this model, no population oscillations appear in communities at islands inhabited by sea otters, although the coralline algae may become extinct. Finally, top-down effects of the killer whales cascade down to the kelp population through the sea otters and sea urchins and save the coralline algae from extinction. However, strong top-down effects of the killer whales destabilize the community and release the violent oscillations that were suppressed by top-down effects of the sea otters. Thus, the trophic cascades have not only static but also dynamic effects on food chains and the effects are totally different depending on the number of trophic levels.

Estes, J.A. and Palmisano, J.F. (1974) Sea otters: Their role in structuring nearshore communities. *Science* **185**, 1058-1060.

Estes, J.A., Tinker, M.T., Williams, T.M., and Doak, D.F. (1998) Killer whale predation on sea otters linking oceanic and nearshore ecosystems. *Science* **282**, 473-476.