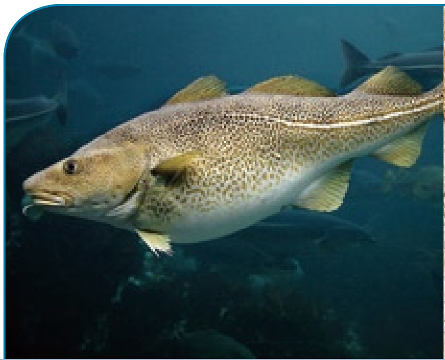


LENFEST OCEAN PROGRAM RESEARCH SERIES

APRIL 2008

Loss of top marine predators could have greater impacts than previously understood.

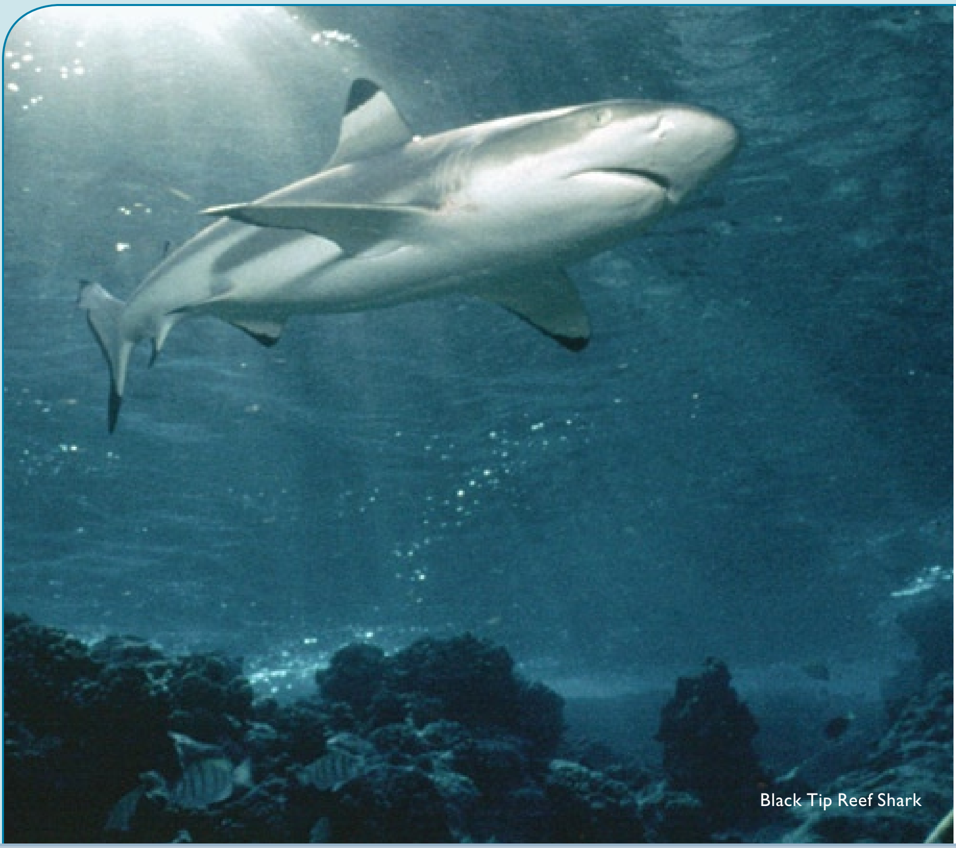
EFFECTS OF LOSING TOP PREDATORS

A SUMMARY OF NEW SCIENTIFIC ANALYSIS:

Heithaus, M.R, Frid, A., Wirsing, A.J and Worm, B. 2008. Predicting ecological consequences of marine top predator declines. *Trends in Ecology and Evolution* 23(4):202–210.

TOP OCEAN PREDATORS, such as sharks and marine mammals, can exert a profound influence on the structure and function of marine ecosystems. Yet their numbers have fallen dramatically in the 20th century—by over 90 percent in some regions of the world. Their loss has triggered a cascade of effects through succeeding layers of food webs.

Dr. Michael Heithaus and his colleagues reviewed their own and others' marine and terrestrial research to show the possible ecosystem effects of a loss of top predators. They concluded that the loss of top predators not only has *direct mortality* effects on the ecosystem (i.e., a possible population boom in the species they eat as well as changes in population size of prey even lower in the food chain), but equal and in some places more significant *behavioral* effects (i.e., changes in their prey's predator-avoiding behavior once they are no longer at risk of being eaten). The authors call for setting management goals that consider both direct predation and behavioral effects from top predators. This *Lenfest Ocean Program Research Series* report is a summary of the scientists' analysis.



Black Tip Reef Shark

WHAT HAPPENS WHEN TOP PREDATORS DISAPPEAR FROM AN ECOSYSTEM?

Changes in Direct Predation

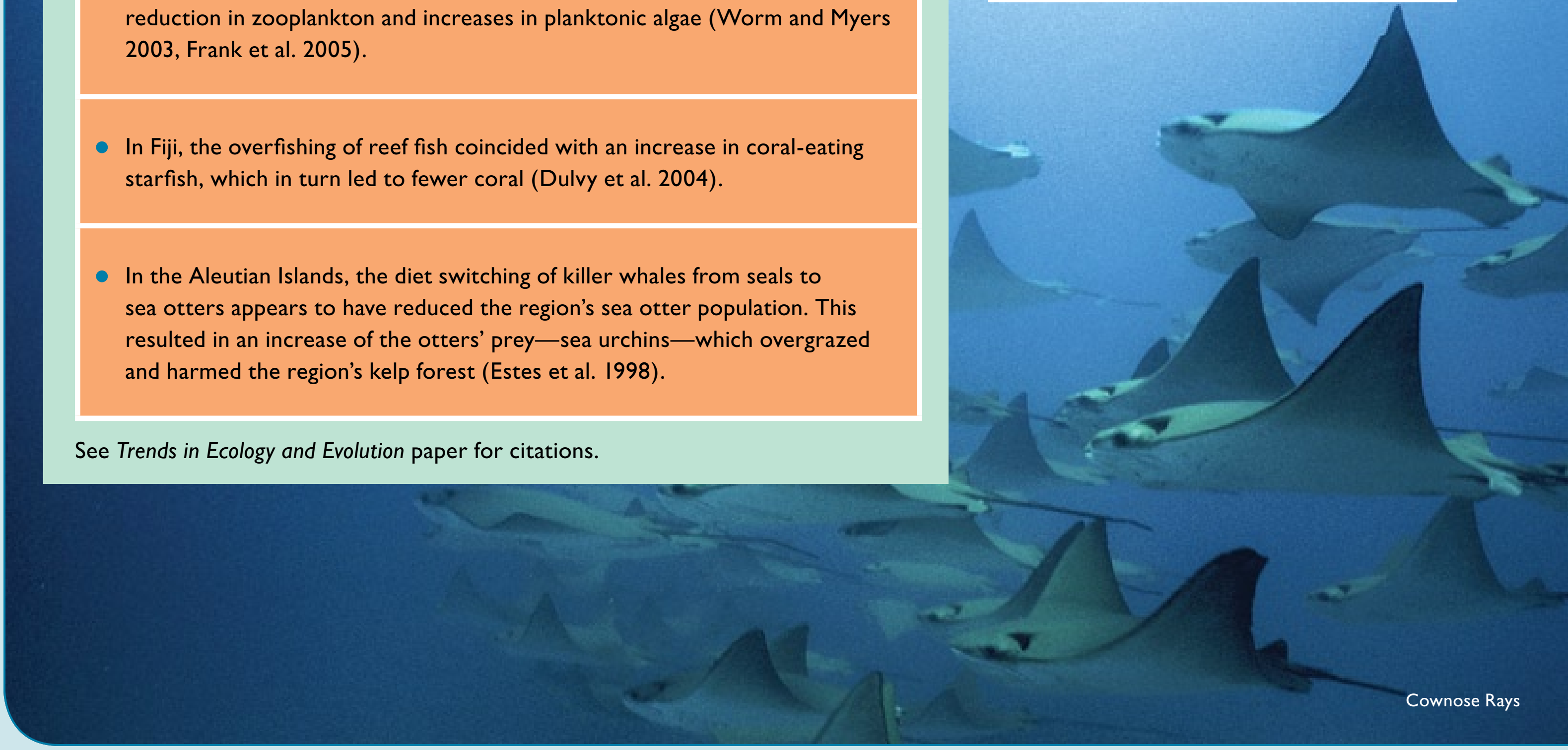
When top predators disappear from the ocean, their principal prey species, sometimes called *mesoconsumers*, can increase in abundance. These are species in the middle of the food web, such as rays, which both eat and are eaten by other marine species. As mesoconsumers increase in number, they can in turn put more pressure on the species that they consume. A cascade of effects can occur through several layers of the food web as the mesoconsumers eat more of the smaller fish, crustaceans and plants at lower levels in the web (See Box 1).

BOX 1: EXAMPLES OF ECOLOGICAL EFFECTS OF PREDATORS

- In the North Atlantic, large shark declines have corresponded with an increase in the sharks' prey species—cownose rays—and a decrease in bay scallops, which are prey of the rays. These shifts in the food web may have collapsed the region's commercial scallop fishery (Myers et al. 2007).
- In maritime Canada, the collapse of cod in the 1990s corresponded with an increase in herring, shrimp and crab. This may have contributed to regional reduction in zooplankton and increases in planktonic algae (Worm and Myers 2003, Frank et al. 2005).
- In Fiji, the overfishing of reef fish coincided with an increase in coral-eating starfish, which in turn led to fewer coral (Dulvy et al. 2004).
- In the Aleutian Islands, the diet switching of killer whales from seals to sea otters appears to have reduced the region's sea otter population. This resulted in an increase of the otters' prey—sea urchins—which overgrazed and harmed the region's kelp forest (Estes et al. 1998).

See *Trends in Ecology and Evolution* paper for citations.

Bay Scallop



Cownose Rays

Dugong

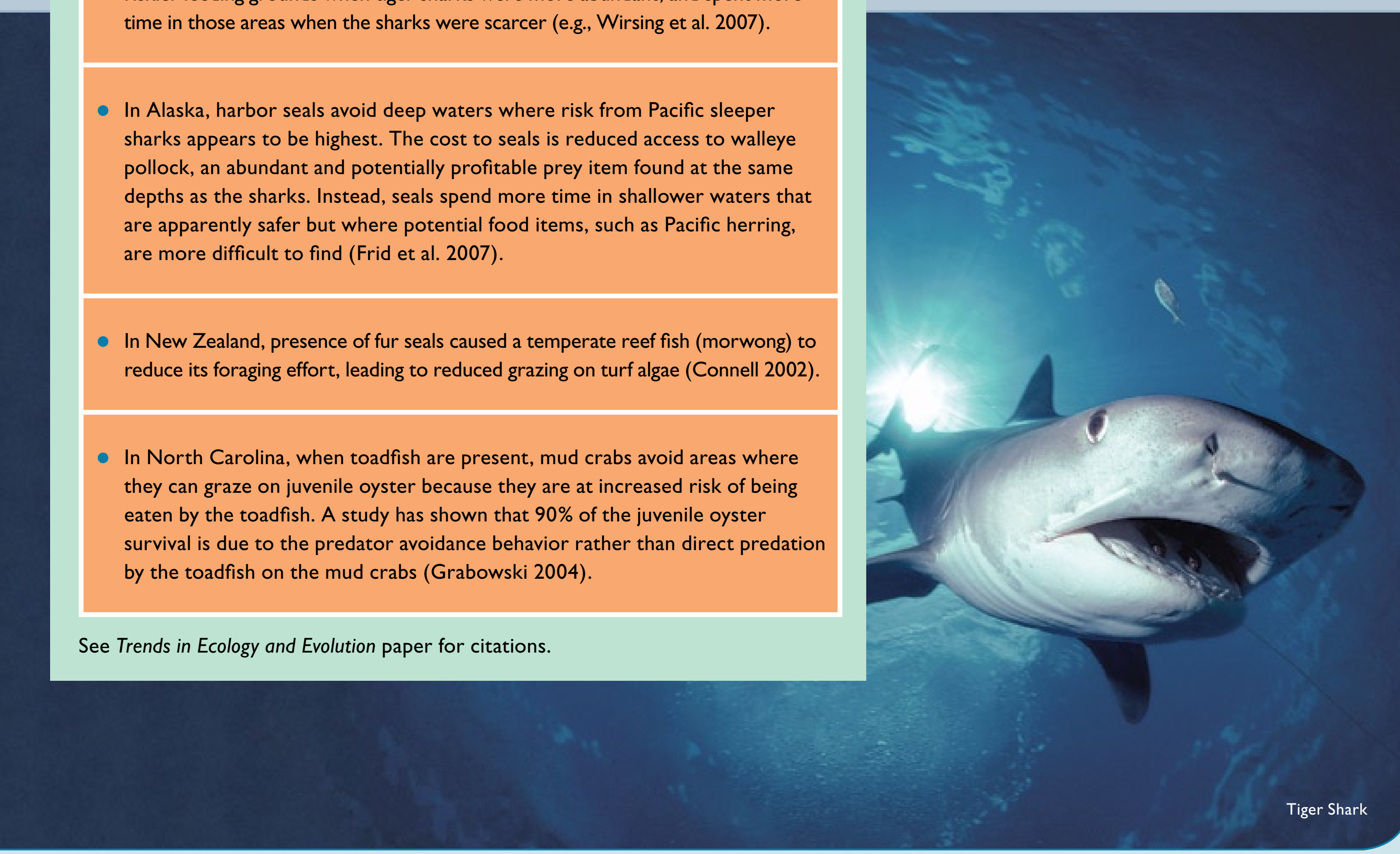
Changes in Behavior: the ‘Risk Effect’

When top predators decline, mesoconsumers may also affect the *behavior* of their prey, which the authors call “risk effects.” When top predators are present, mesoconsumers or prey species move away from habitats where predators hunt, and may even shift to safer, but less nutritious, prey or habitats. When top predators disappear, mesoconsumers may shift foraging and grazing patterns and feed on different species. Thus, even if the size of a mesoconsumer population remains the same, behavioral changes in the mesoconsumers may have significant impacts across fish and other prey and plant communities in an ecosystem. (see Box 2).

BOX 2: EXAMPLES OF BEHAVIORAL EFFECTS

- In Shark Bay, Australia, dugongs, dolphins and green turtles avoided food-rich but riskier feeding grounds when tiger sharks were more abundant, and spent more time in those areas when the sharks were scarcer (e.g., Wirsing et al. 2007).
- In Alaska, harbor seals avoid deep waters where risk from Pacific sleeper sharks appears to be highest. The cost to seals is reduced access to walleye pollock, an abundant and potentially profitable prey item found at the same depths as the sharks. Instead, seals spend more time in shallower waters that are apparently safer but where potential food items, such as Pacific herring, are more difficult to find (Frid et al. 2007).
- In New Zealand, presence of fur seals caused a temperate reef fish (morwong) to reduce its foraging effort, leading to reduced grazing on turf algae (Connell 2002).
- In North Carolina, when toadfish are present, mud crabs avoid areas where they can graze on juvenile oyster because they are at increased risk of being eaten by the toadfish. A study has shown that 90% of the juvenile oyster survival is due to the predator avoidance behavior rather than direct predation by the toadfish on the mud crabs (Grabowski 2004).

See *Trends in Ecology and Evolution* paper for citations.



Tiger Shark

LESSONS FROM THE LAND

Marine ecologists can draw useful lessons from efforts to restore depleted terrestrial predators. For example, the successful reintroduction of wolves to Yellowstone National Park (USA) has had a significant behavioral effect on elk, the wolves' preferred prey. Elk have begun to shun riskier streamside foraging areas where they are easier targets for wolves. These changes have led to less grazing on aspen shoots along streams, which allowed new growth of aspens to take hold for the first time in over half a century. This has increased the health of streamside habitat, benefiting fish, beavers and songbirds (e.g., Ripple and Beschta 2006).

SUMMARY AND IMPLICATIONS

The relative importance of direct predation versus behavioral effects will depend on several factors, including the presence of protective habitat and variety of food sources. In general, the authors predict that risk effects will be more important in situations where the mesoconsumers have good stores of body fat and can afford to opt for less risky but also less profitable foraging approaches. But the authors find that risk effects can constitute a significant proportion of the overall predator effects in an ecosystem, sometimes even overshadowing direct predation.

Thus, the authors suggest that resource managers need to take into account the implications of changes in prey behavior, not just direct mortality. So far, however, managers have often underestimated the larger roles that top predators play in marine ecosystems, in part because of a lack of information about them.

Even if detailed information about a specific marine site or species is not currently available, the authors note that managers could use what is known generally about species interactions in that specific ecosystem or others to inform decision making. For example, risk effects occur in strikingly similar fashion in terrestrial, freshwater and marine species. While imperfect, this common sense approach could help to estimate the important changes in the food web and behavior of prey species that may occur in the presence, or absence, of predators. To strengthen the ability to estimate these effects, the authors recommend ideas for further research to clarify the roles of top predators in marine ecosystems.

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LENFEST OCEAN PROGRAM

Lenfest Ocean Program: Protecting Ocean Life Through Marine Science

The Lenfest Ocean Program supports scientific research aimed at forging new solutions to the challenges facing the global marine environment.

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