Understanding Bering Sea Groundfish Populations USING MODELS TO SHED LIGHT ON PATTERNS AND TRENDS

We developed simulation models of predator-prey relationships that allowed us to reproduce observed changes in populations of pollock, cod, and flatfish in the eastern Bering Sea since the 1980s. We learned that, in warm years, age-1 juvenile pollock were more heavily eaten by arrowtooth flounder and cannibalized by adult pollock, whereas fewer age-2 pollock were eaten by cod. These different temperature responses likely reflect different thermal preferences by species, which may change with life stage. For instance, a lingering

pool of cold bottom water after cold winters may provide refuge for juveniles, reducing cannibalism by adult pollock. Because of the dominant abundance of pollock, the net effect of warmer temperatures is increased juvenile mortality, resulting in fewer survivors to grow to adults to support future fisheries. We continue to explore ways that environmental conditions alter these relationships, and to evaluate their implications on fishery management and expected future fishery yields.

How We Did It

We developed and evaluated two alternative multispecies fish models for the eastern Bering Sea that consider the interactions among walleye pollock (separated into juvenile and adult groups), Pacific cod, arrowtooth flounder, and a small-mouth flatfish group comprising yellowfin sole, flathead sole, northern rock sole, and Alaska plaice. One type, called a biomass dynamics model, generally performed better than the

Fig. 1
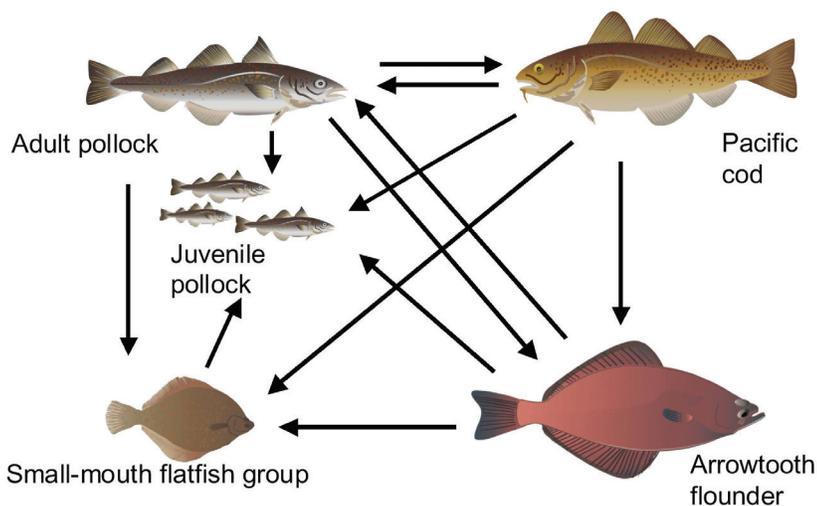
Predator-prey relationships among eastern Bering Sea fish species included in this study. Arrows represent the directions of predator ⟶ prey. Predator-prey relationships were inferred from the contents of fish stomachs sampled during the eastern Bering Sea bottom trawl surveys by the Alaska Fisheries Science Center.

The Big Picture

To understand variability of multiple species in the ocean, scientists often develop whole ecosystem models that attempt to explain the flow of energy from phytoplankton throughout the marine ecosystem. Such ecosystem models tend to be very complicated and require large quantities of data, many assumptions, and large teams of modelers and other researchers. Instead, we developed simpler multispecies models, informed by routinely collected assessment and ecological data, to better understand patterns and trends of the most commercially important fish species in the eastern Bering Sea. Results are intended to foster an improvement in the collective sustainable management of these important fishery resources.

other type, called a delay difference model. Both models describe the predator-prey interactions among these five groups of fish. Because juvenile pollock serve as prey for all species, juvenile pollock were modeled separately from adults. Our model was developed based on many years of fish stomach samples collected by the National Marine Fisheries Service, Alaska Fisheries Science Center. Once we worked out the predator-prey interactions, we used our models to examine the effects of fishing and environmental factors on these groundfish species based on findings from companion studies.

Why We Did It

Landings of pollock, cod and flatfish account for more than half of all U.S. commercial fishery landings. Annual catch limits are set for each species individually, based on assessments of their abundance and productivity. Yet, patterns in fish abundance are not independent. Good years for pollock and cod reproductive success tend to coincide, and display patterns opposite those for flatfish. Are these trends a result of see-saw patterns in predators and prey, or due to species' responses to environmental variations, or perhaps a result of commercial fishing? Our study intends to develop a deeper understanding of interactions among major groundfish species in the Bering Sea, thereby fostering a joint management approach that acknowledges ecological interactions of these species and the combined effects of climate and fishing.
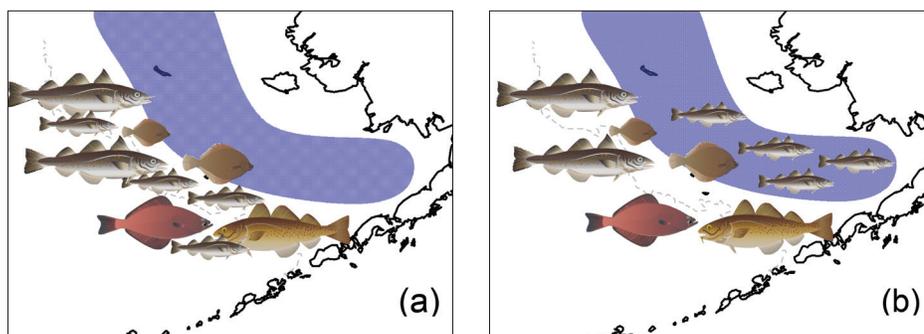
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Fig. 3a

(a)

Fig. 3b

(b)
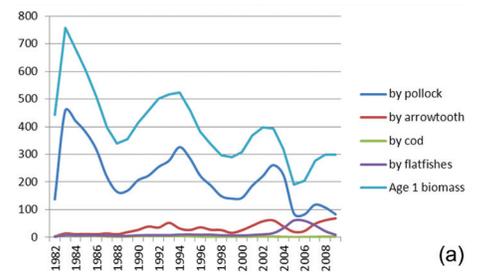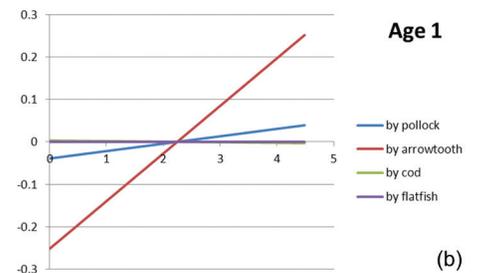
(a) Model-estimated biomass of age-1 pollock and age-1 pollock biomass lost to predation by adult pollock, arrowtooth flounder, Pacific cod, and small-mouth flatfishes (values in 1000 metric tons); and (b) Effect of bottom temperature on predation of age-1 juvenile pollock by these same predators. The x axis is bottom temperature in °C, whereas the y axis shows estimated biomass of juvenile pollock lost to predation, expressed as a percentage relative to the biomass lost to predation at the mean bottom temperature of 2.25°C

Fig. 2

(a)

(b)

Schematic diagrams showing alternative hypotheses on how cold climate may affect distribution of fish on the eastern Bering Sea shelf and predation on young pollock. The cold pool (blue) is a pool of cold water (< 2°C) on the Bering Sea shelf formed by melting sea ice. In cold years, the cold pool covers a large portion of the middle shelf region. Most fish species are driven to the outer shelf region by the cold water, where predation is intensified by increased prey and predator density (a). However, there is some evidence that young pollock (major prey for other fish, including adult pollock) are more tolerant to cold water, in which they are protected from predators (b). If this is the case, predation on young pollock would decline under cold climate and increase under warm climate.