

Effects of herring fishing strategies on a modelled Northeast Pacific ecosystem

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Pacific herring (*Clupea pallasii*) is an important North Pacific forage fish, channeling energy from zooplankton to marine mammals, seabirds and other commercial fishes. It also supports numerous commercial, subsistence and aboriginal fisheries. Given the current poor status of many herring stocks and calls for ecosystem-based forage fish management, there is a clear need to examine the effects of herring management strategy design on food web structure. We investigated these effects using ecosystem modeling in Ecopath with Ecosim (EwE). A mass-balance Ecopath model representing the current state of the northern British Columbia marine food web was constructed. Effects of harvest control rule (HCR) type, biomass limit reference point (B_{lim}) and target fishing mortality (F_{target}) for herring on all model functional group biomasses were examined using EwE's management strategy evaluation (MSE) module. Our results show that current herring management strategies, as well as some more precautionary ones, may have significant negative effects on several mammalian herring predators and significant positive effects on some pelagic planktivores due to reduced prey availability for herring predators and competition for prey between herring and other planktivores. Effect strength increased at lower B_{lim} and higher F_{target} values and under step or constant-effort HCRs, although these differences were not always significant. Management based on both single-species and ecosystem-based estimates of F_{MSY} for herring had strong effects on much of the food web. Assessment error and poor primary productivity occasionally combined to exert notable negative effects on most functional groups. These findings illustrate the complexity of ecosystem-based herring management.

Keywords: herring, Pacific herring, *Clupea pallasii*, forage fish, Northeast Pacific, British Columbia, Canada, ecosystem model, Ecopath with Ecosim, EwE, management strategy evaluation, MSE, harvest control rules, HCR, ecosystem-based fisheries management, EBFM, precautionary approach, reference points, B_{lim} , F_{target} , F_{MSY}

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