

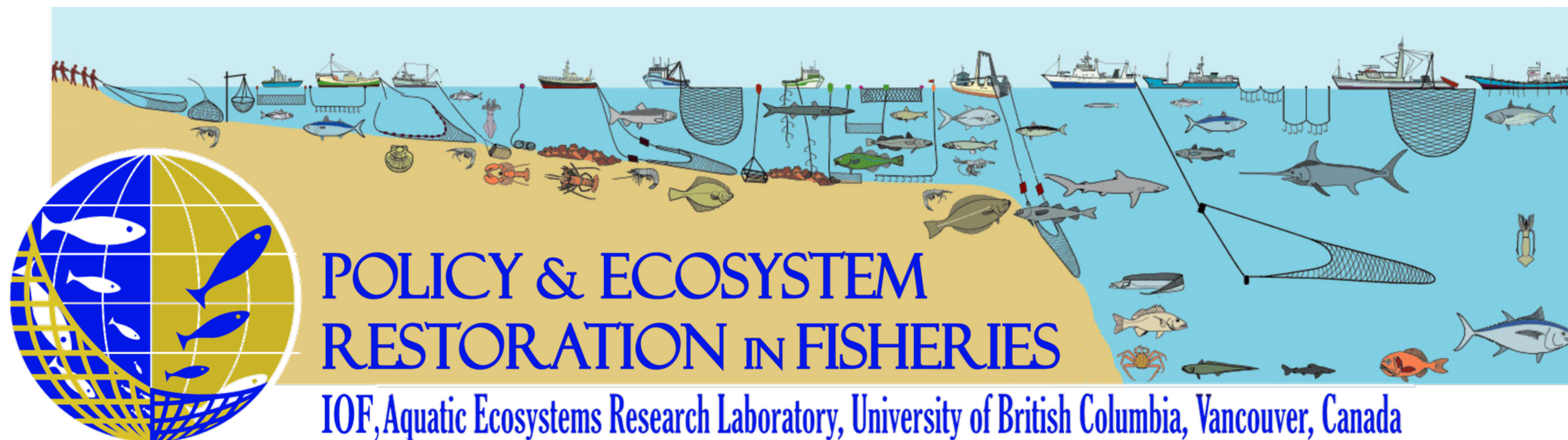
# Tradeoffs and uncertainty: towards ecosystem-based management of Northeast Pacific herring fisheries

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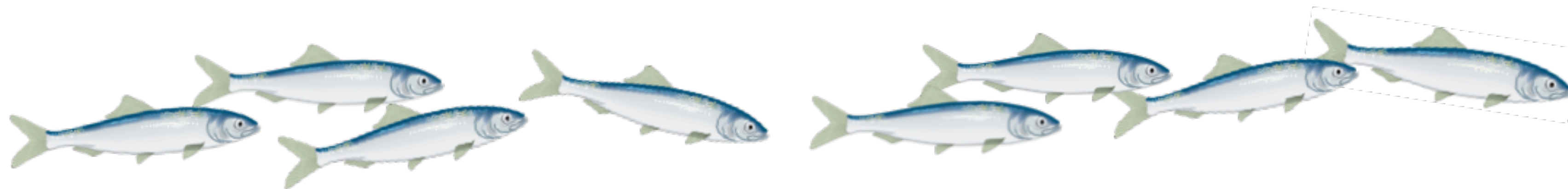
# Pacific herring

- energy conduit: zooplankton to larger predators
- food and income for many coastal communities
- stock declines, fishery closures, calls for EBFM
- how to reconcile human, ecosystem needs?**



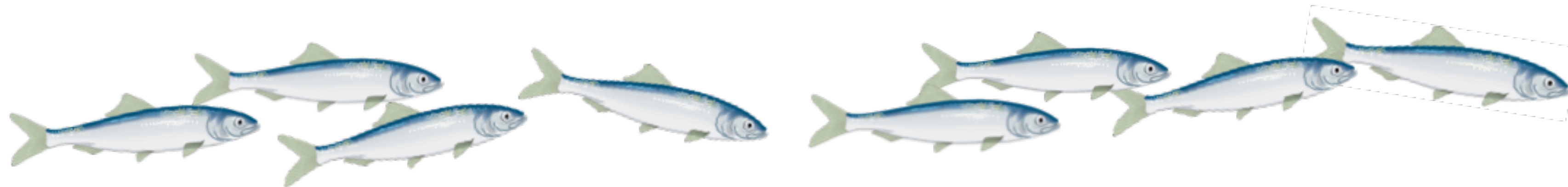
# Food web modeling

- framework: Ecopath with Ecosim (EwE)
- study area: N British Columbia, Canada
- basic principle: mass balance
- 80 functional groups



# MSE in EwE

- simulates long-term strategy implementation
- compares impacts of management strategies
- places herring & fisheries in food web context
- can use ecological & socioeconomic criteria

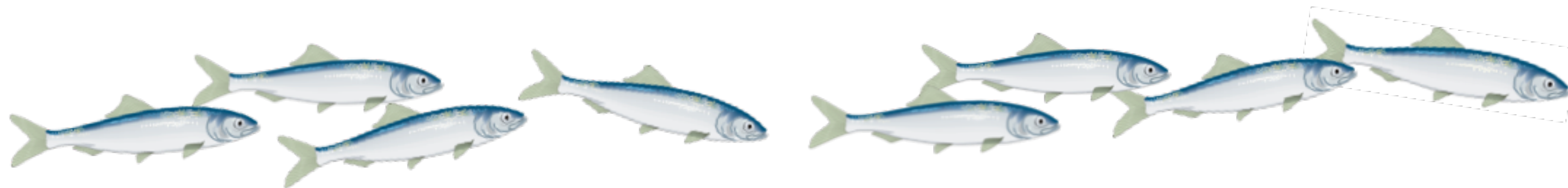


# Cefas EwE MSE tool

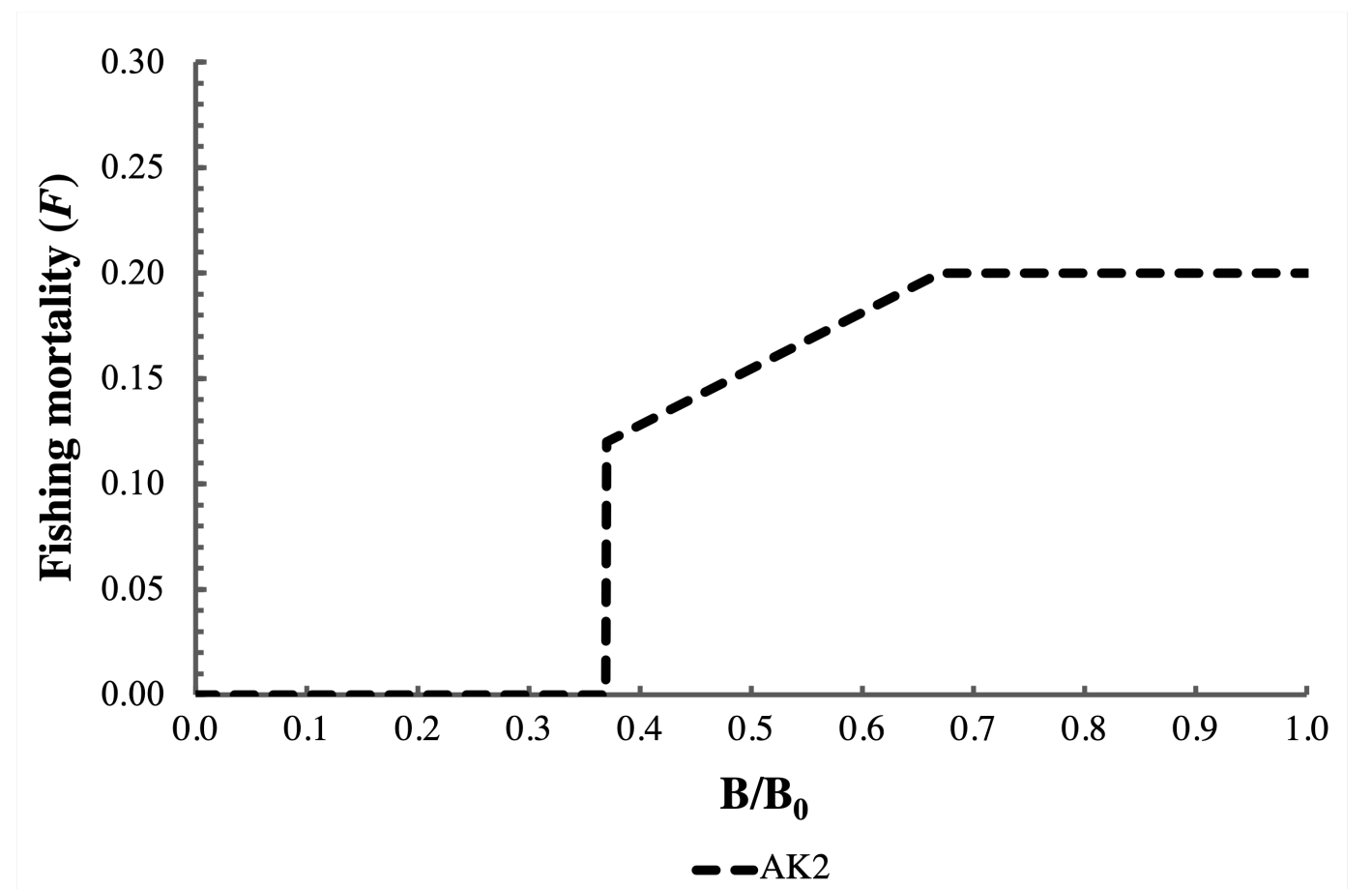
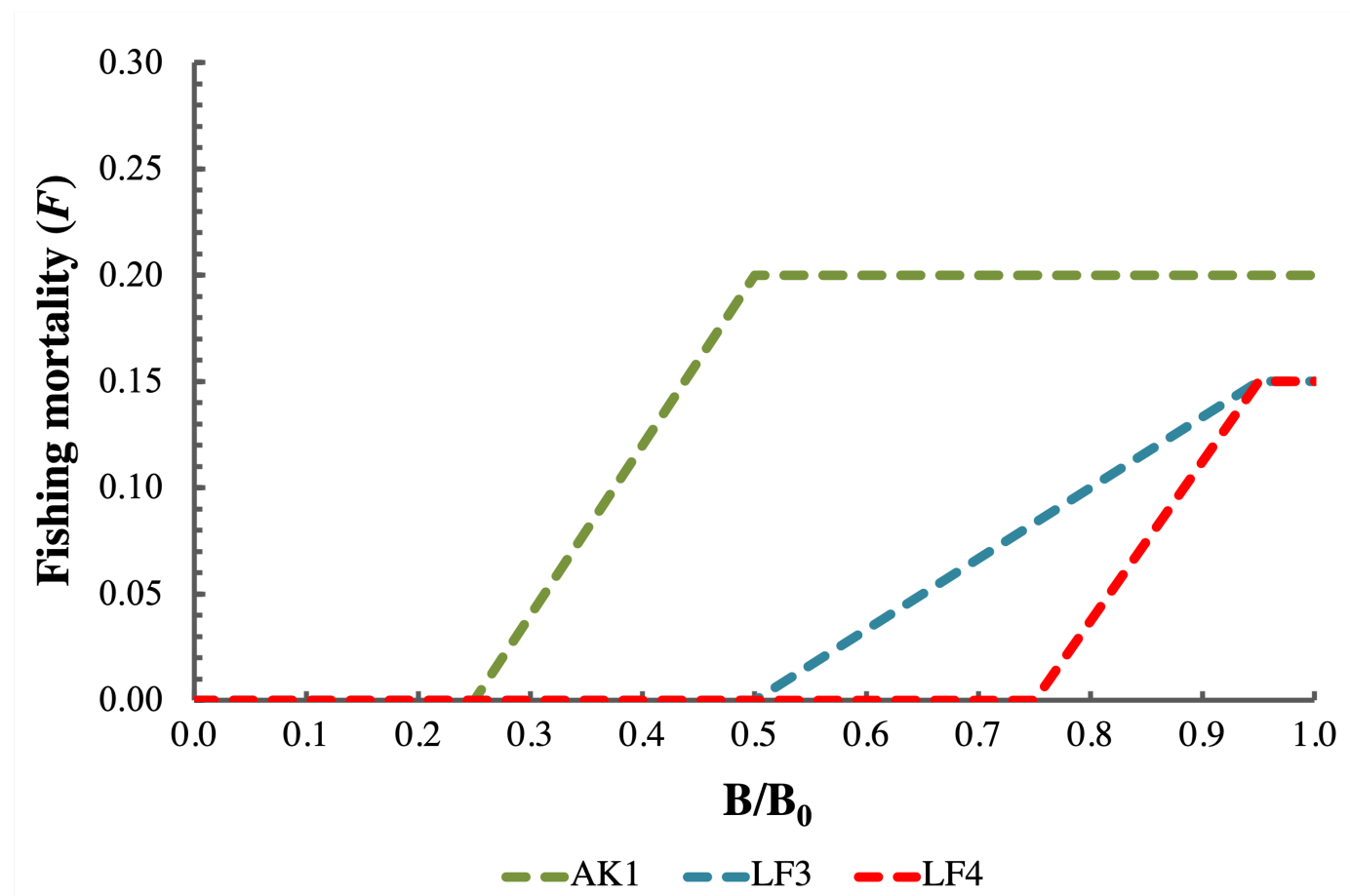
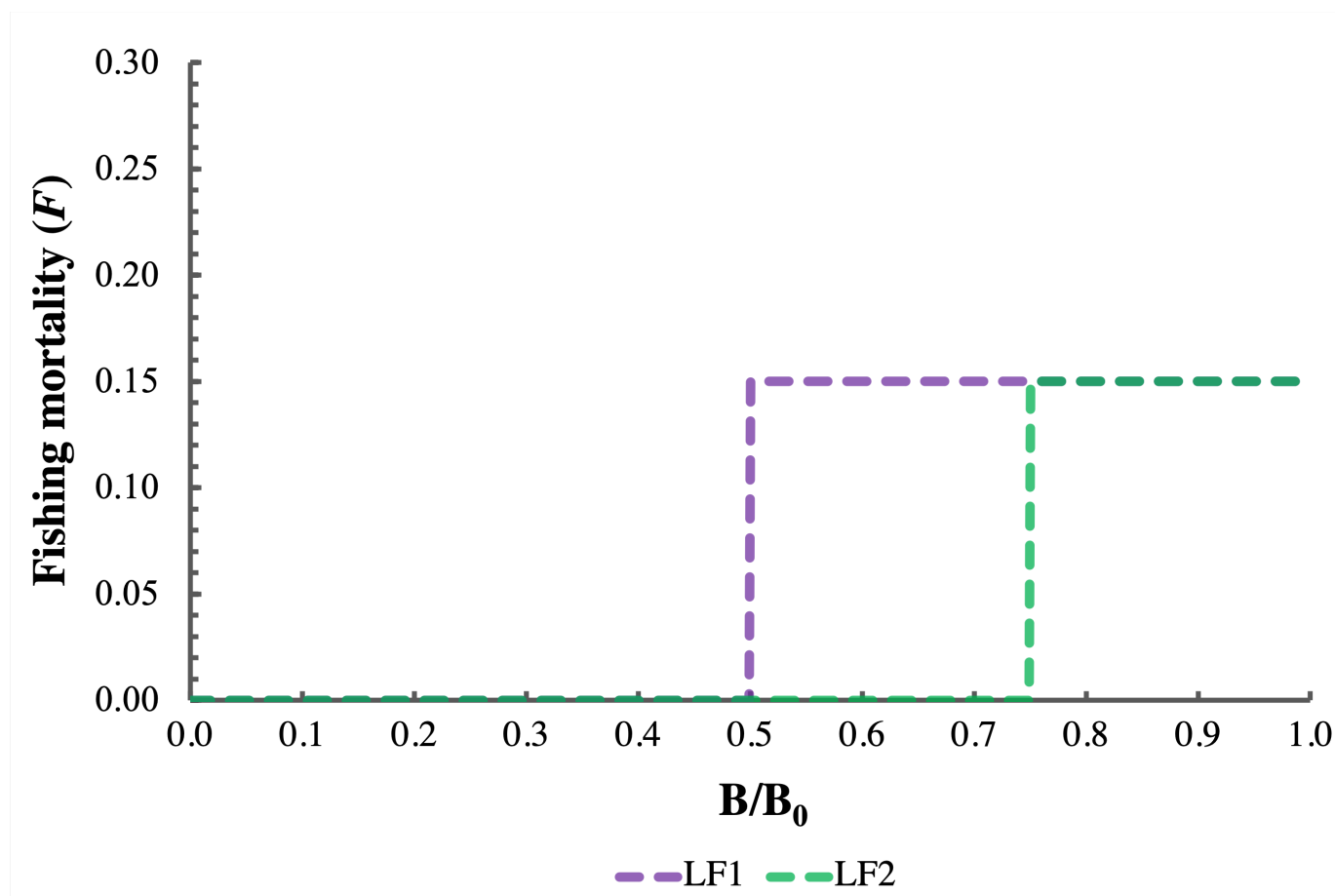
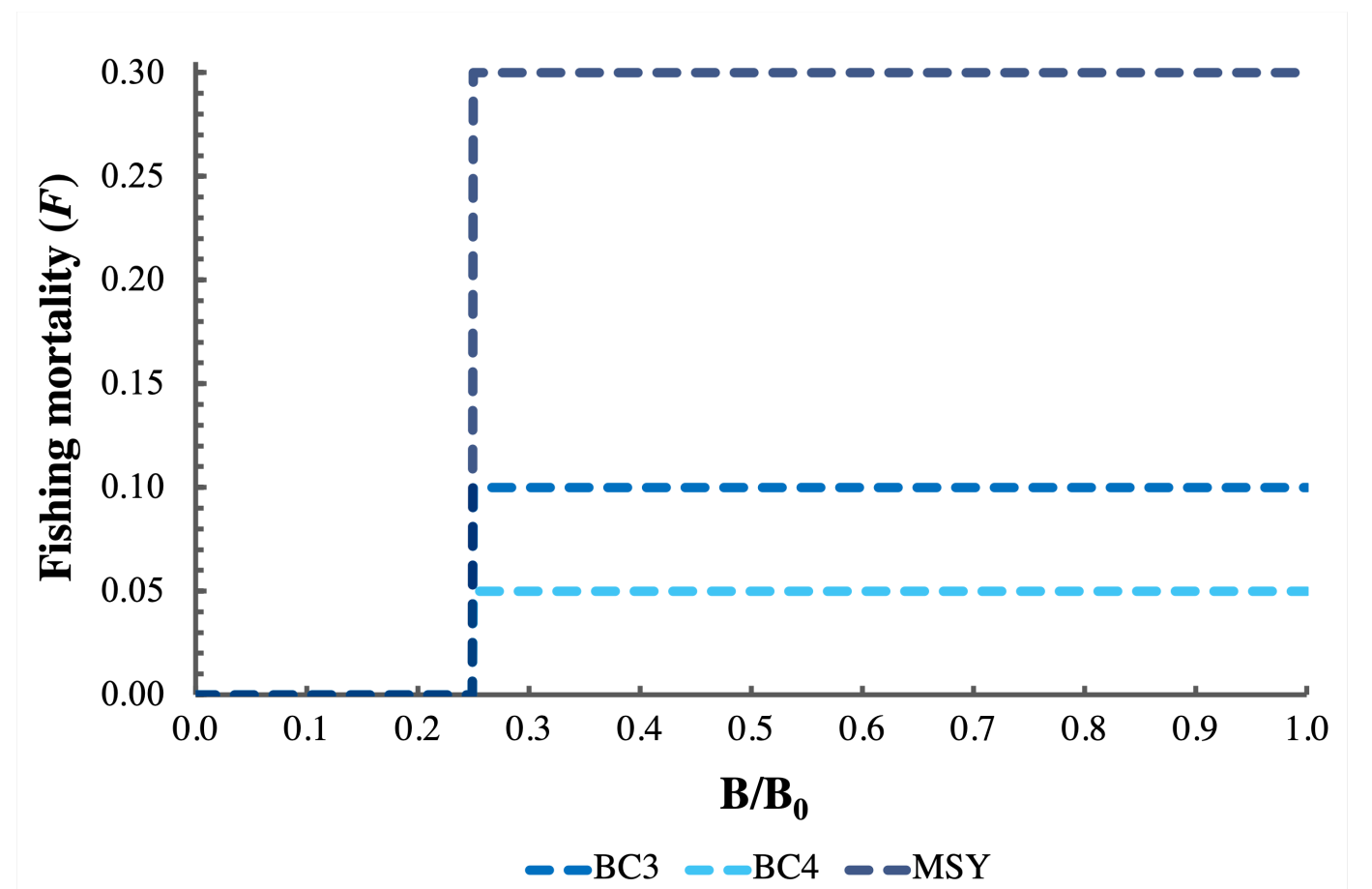
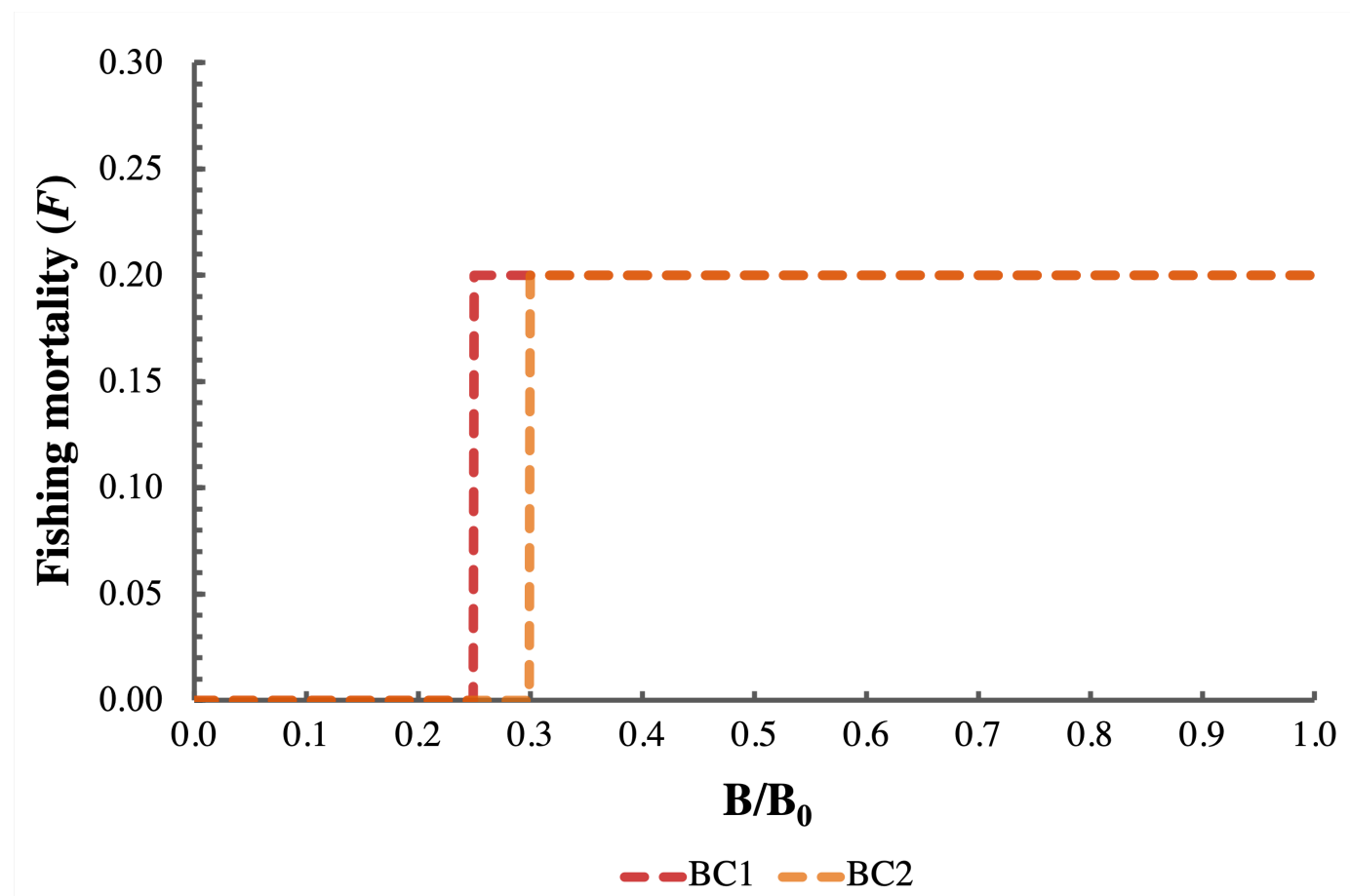
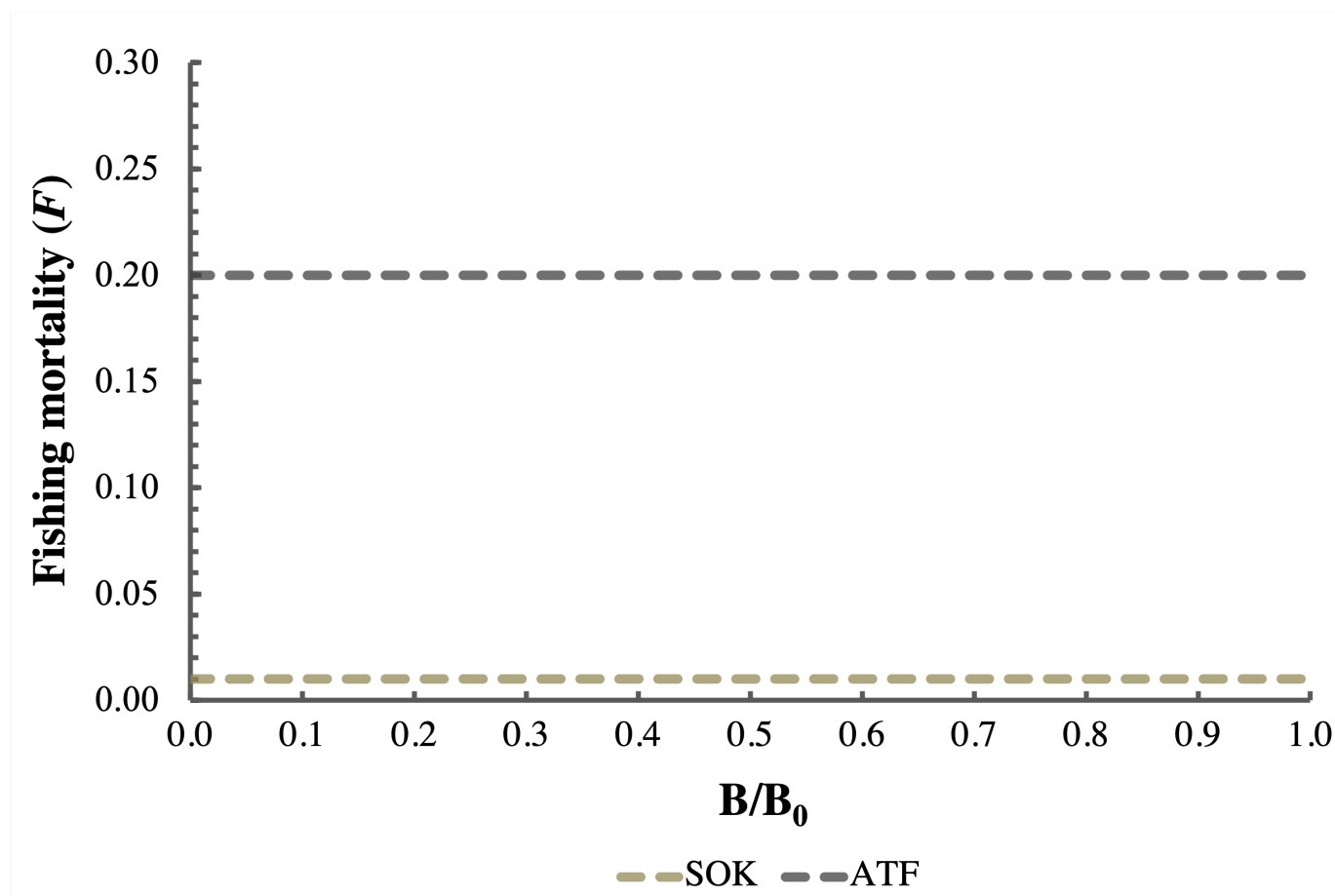
- ecosystem parameter uncertainty
- stochastic realized fishing mortality
- stochastic stock assessment error



**Cefas**

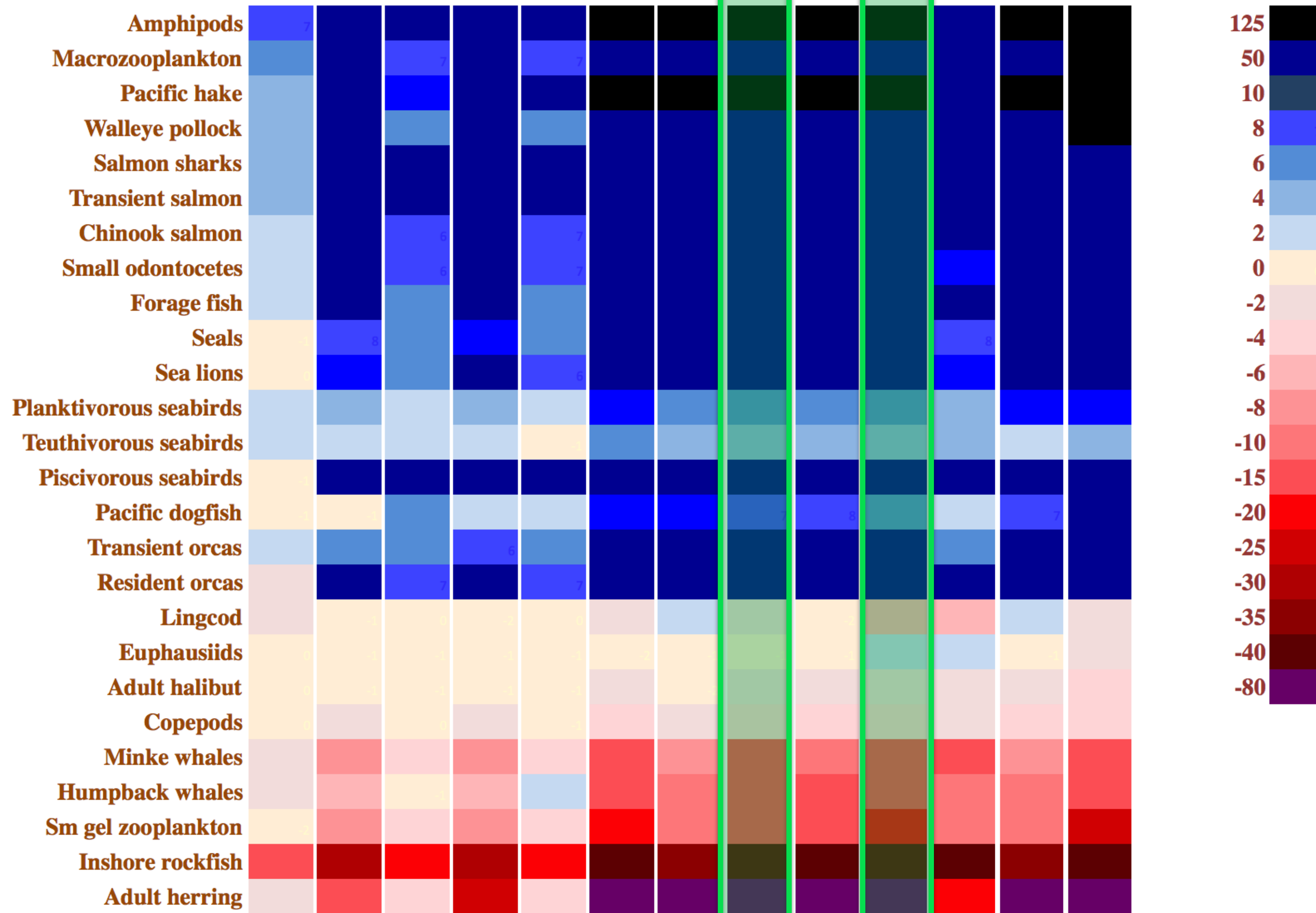


# Management strategies



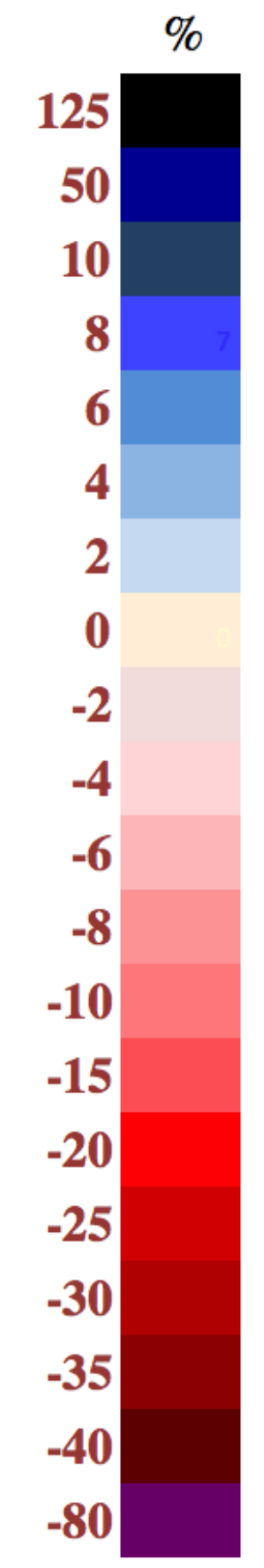
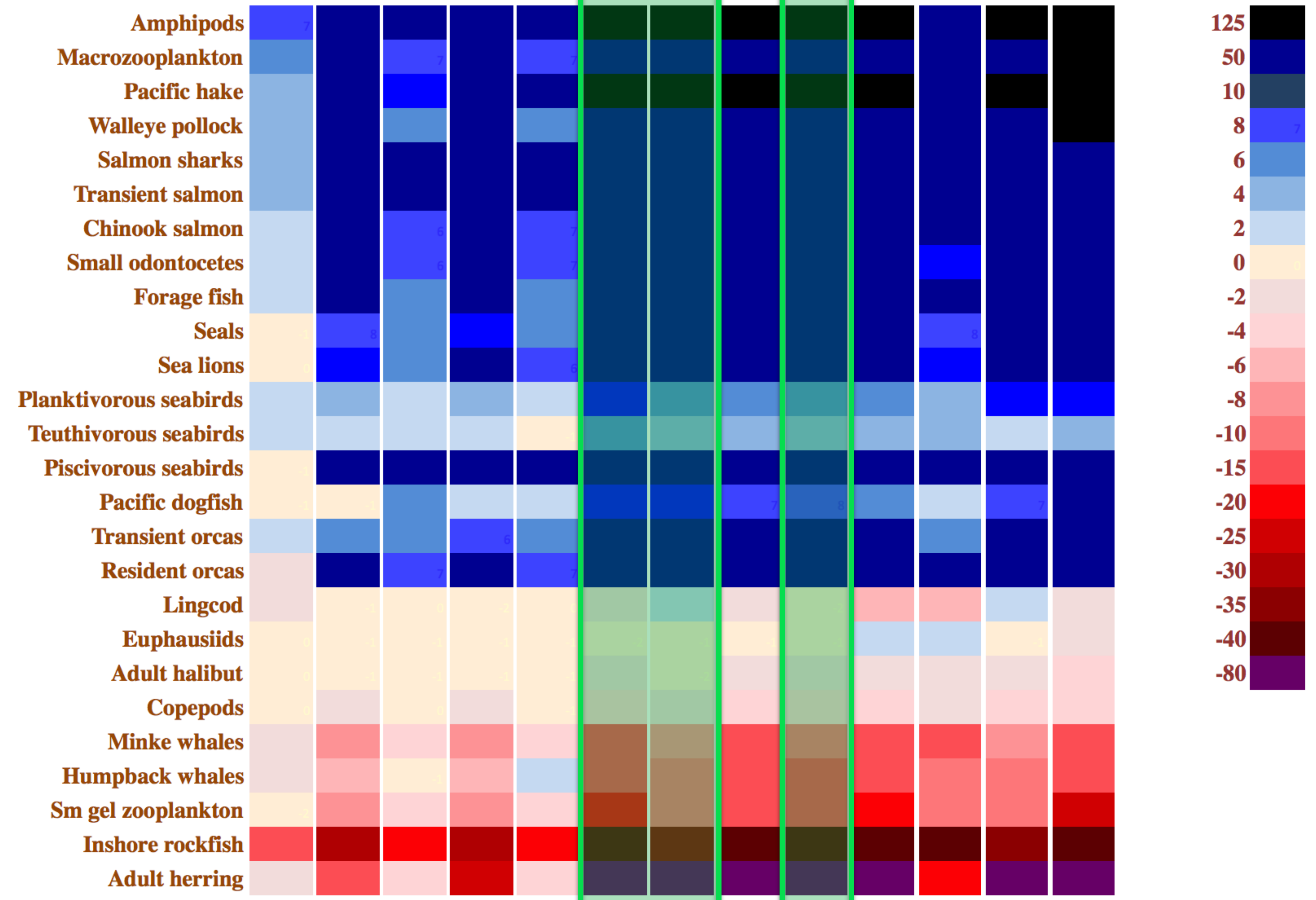
SCENARIO	SOK	LF1	LF2	LF3	LF4	AK1	AK2	BC1	BC2	BC3	BC4	MSY	ATF
Herring $B_{lim}$	0	0.50	0.75	0.50	0.75	0.25	0.37	0.25	0.30	0.25	0.25	0.25	0
Herring $B_{Fmax}$	0	0.50	0.75	0.95	0.95	0.50	0.67	0.25	0.30	0.25	0.25	0.25	0
Herring $F_{target}$	0.01	$.5F_{MSY}$	$.5F_{MSY}$	$.5F_{MSY}$	$.5F_{MSY}$	0.20	0.20	0.20	0.20	0.10	0.05	$F_{MSY}$	0.20

**HISTORICAL**



SCENARIO	SOK	LF1	LF2	LF3	LF4	AK1	AK2	BC1	BC2	BC3	BC4	MSY	ATF
Herring $B_{lim}$	0	0.50	0.75	0.50	0.75	0.25	0.37	0.25	0.30	0.25	0.25	0.25	0
Herring $B_{Fmax}$	0	0.50	0.75	0.95	0.95	0.50	0.67	0.25	0.30	0.25	0.25	0.25	0
Herring $F_{target}$	0.01	$.5F_{MSY}$	$.5F_{MSY}$	$.5F_{MSY}$	$.5F_{MSY}$	0.20	0.20	0.20	0.20	0.10	0.05	$F_{MSY}$	0.20

**CURRENT**

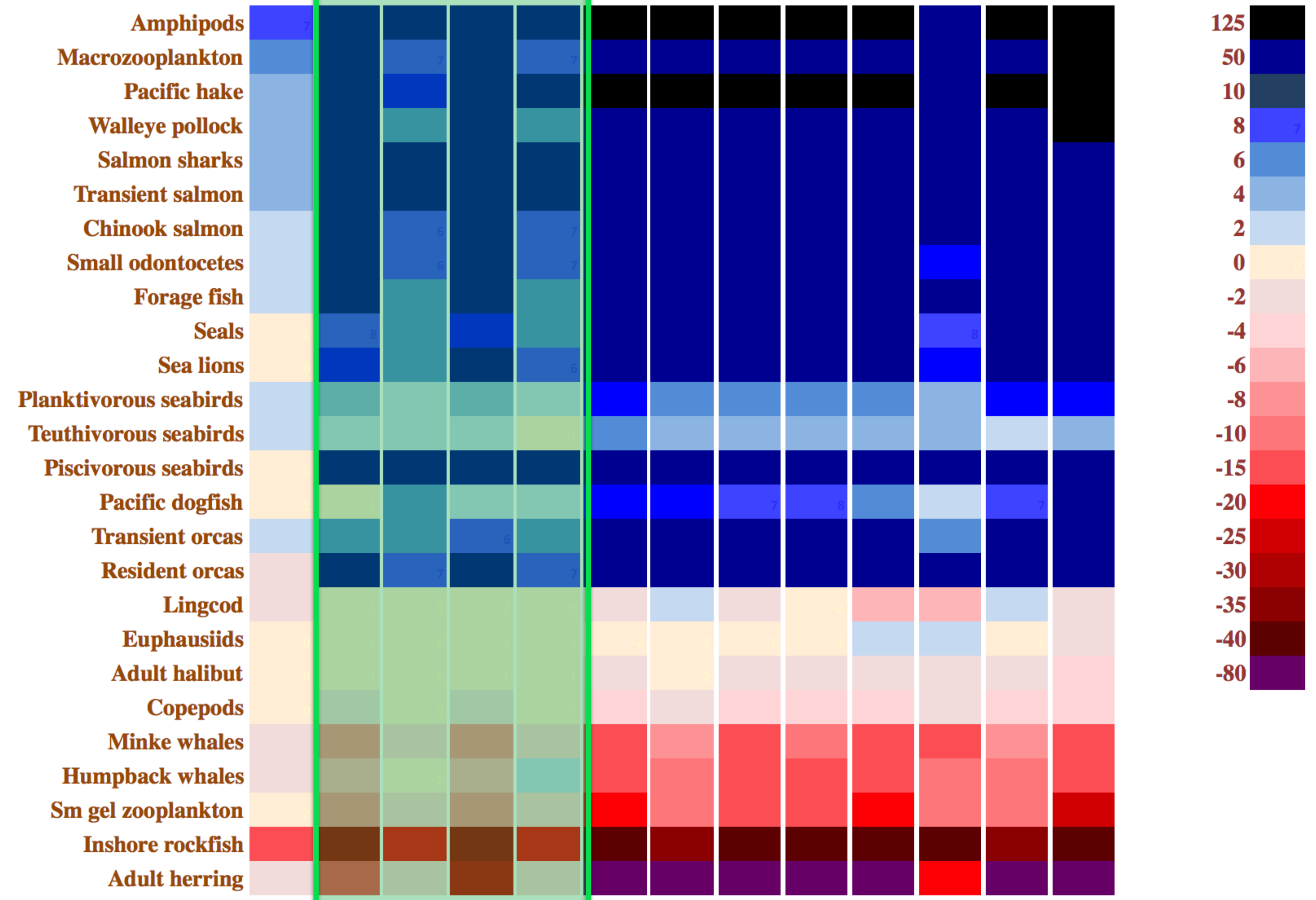




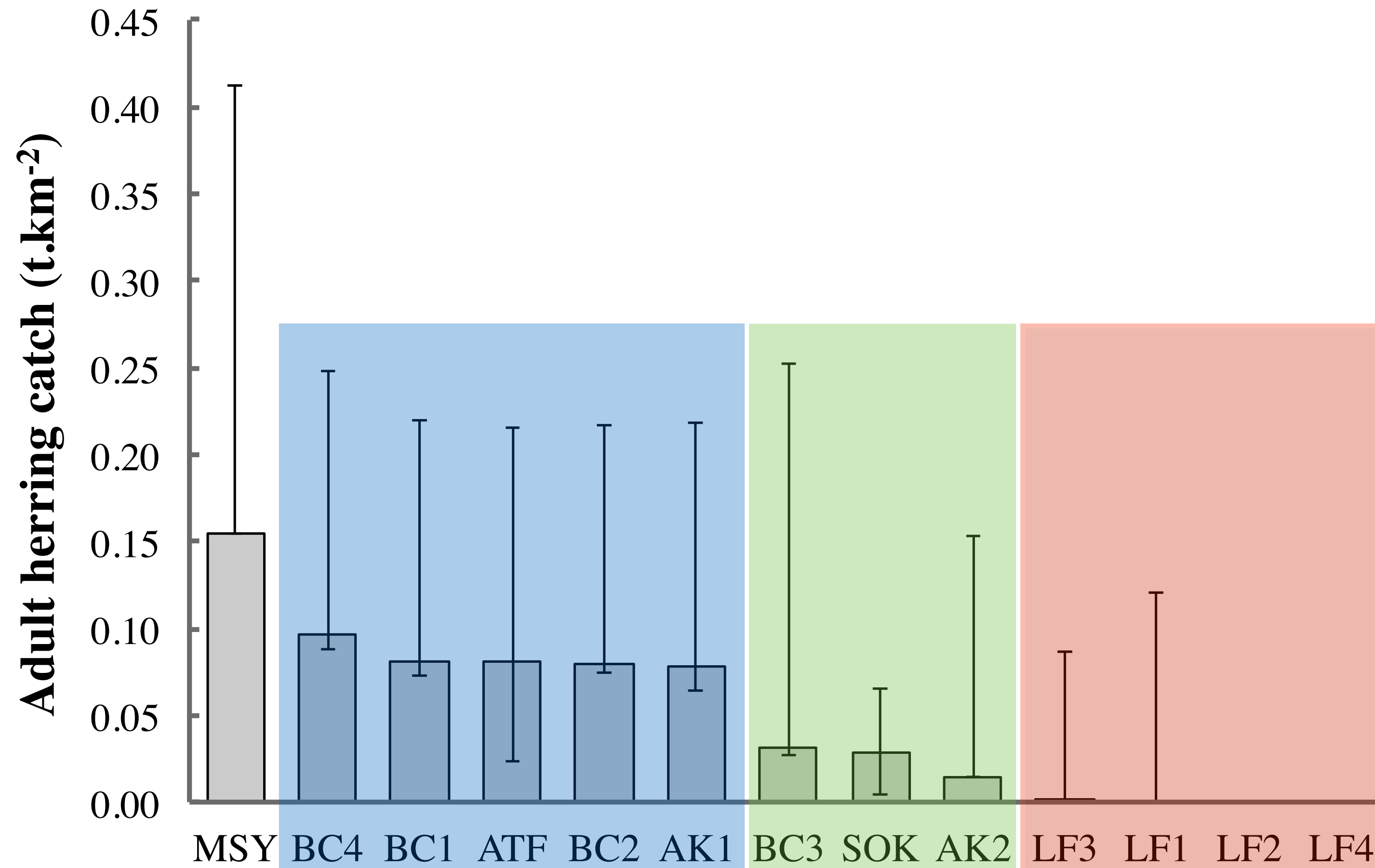


SCENARIO	SOK	LF1	LF2	LF3	LF4	AK1	AK2	BC1	BC2	BC3	BC4	MSY	ATF
Herring $B_{lim}$	0	0.50	0.75	0.50	0.75	0.25	0.37	0.25	0.30	0.25	0.25	0.25	0
Herring $B_{Fmax}$	0	0.50	0.75	0.95	0.95	0.50	0.67	0.25	0.30	0.25	0.25	0.25	0
Herring $F_{target}$	0.01	$.5F_{MSY}$	$.5F_{MSY}$	$.5F_{MSY}$	$.5F_{MSY}$	0.20	0.20	0.20	0.20	0.10	0.05	$F_{MSY}$	0.20

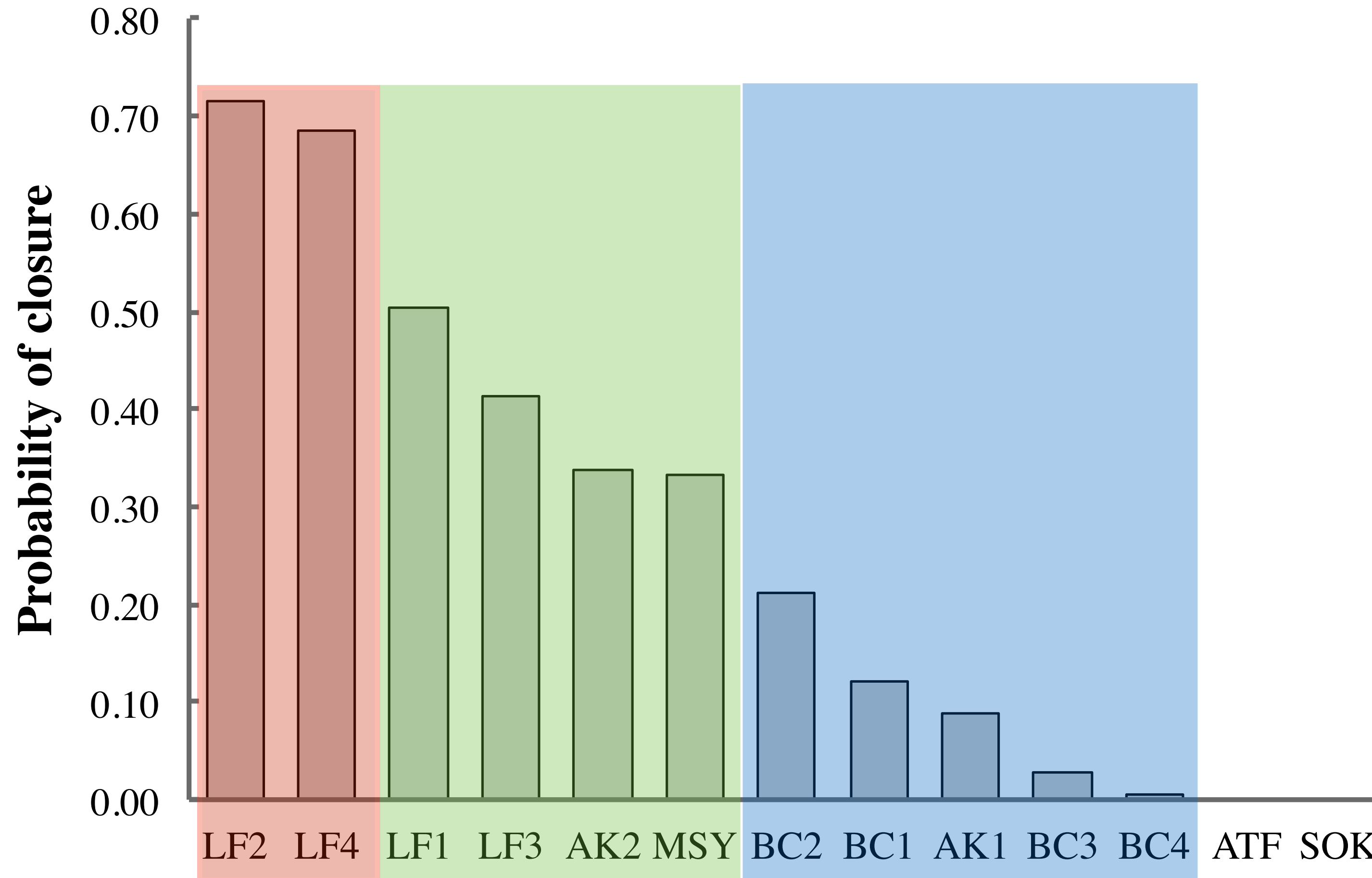
# EBFM

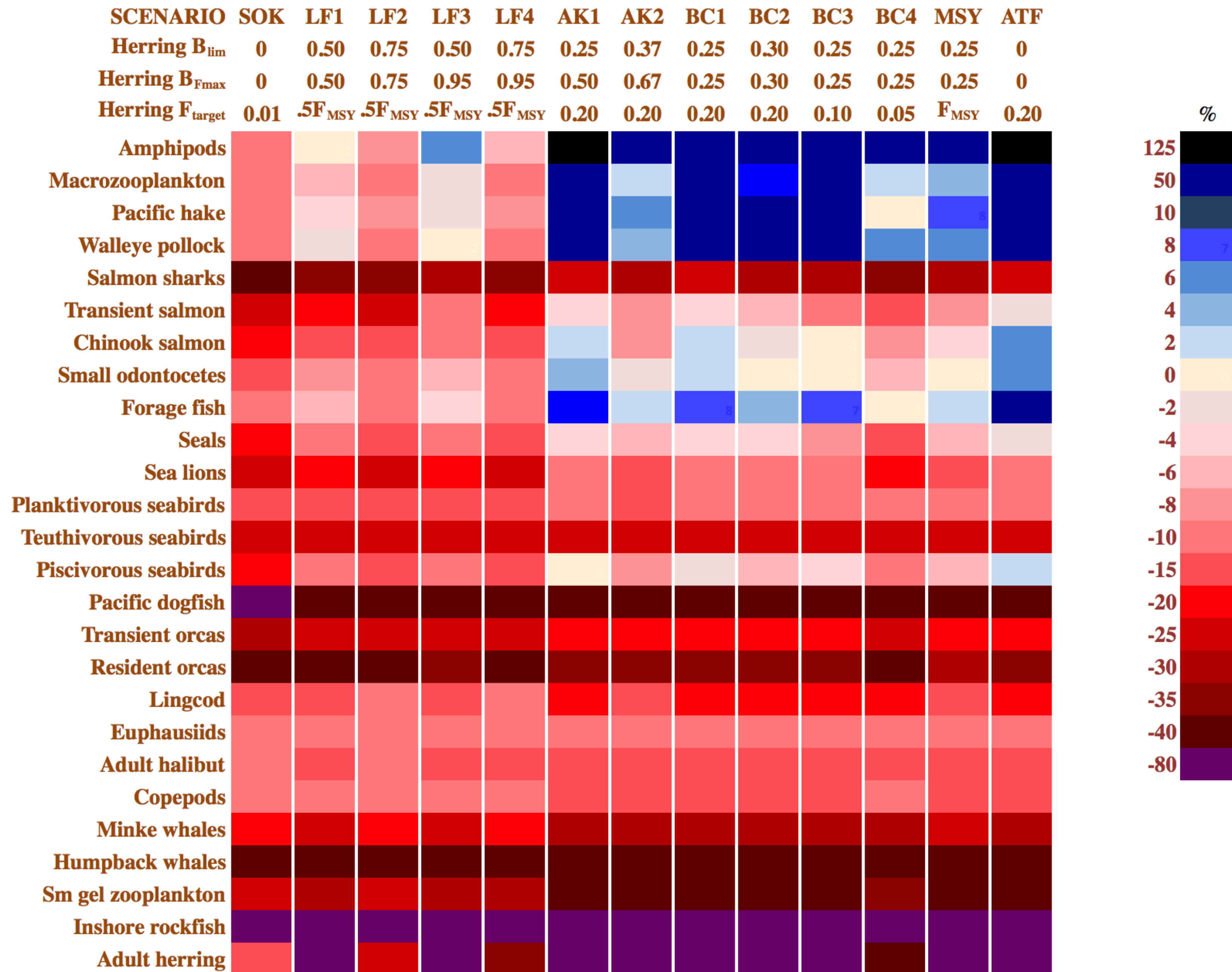


# Median catch



# Closure probability





# Conclusions

- ecosystem impacts of current strategies moderate
- tradeoff between ecological & socioeconomic goals
- strategy spectrum (historical & current, low F, EBFM)
- low predator biomass possible under all strategies



## Original Article

### Trade-offs and uncertainties in Northeast Pacific herring fisheries: ecosystem modelling and management strategy evaluation

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Pacific herring (*Clupea pallasii*) plays an important and multifaceted role in the Northeast Pacific as a forage fish in coastal ecosystems, target species for commercial fisheries, and culturally significant subsistence resource for coastal communities. This study comparatively evaluated herring fisheries management strategy performance relative to ecological and socioeconomic objectives. Management strategy evaluation employed a mass-balanced ecosystem operating model and accounted for parameter uncertainty, stock assessment error, and strategy implementation error through Monte Carlo resampling. Results revealed a notable trade-off between stable herring catches and high biomasses of herring and several predators. Herring biomass control point values influenced this trade-off more than harvest control rule form. All British Columbia and Alaska strategies yielded similar ecological and socioeconomic impacts relative to the un-fished herring baseline. Precautionary strategies recommended for forage fish combined high ecosystem benefits and socioeconomic costs. Reducing fishing mortality fourfold within an existing strategy suggested a possible compromise solution to this trade-off. However, ecological impacts of all strategies were sensitive to operating model parameter uncertainty, stock assessment error, and strategy implementation error, with the potential for undesirable ecosystem states across all strategies. This study suggests trade-offs among management objectives should be considered in pursuing ecosystem-based fisheries management for forage fish.

**Keywords:** *Clupea pallasii*, Ecopath with Ecosim, ecosystem modelling, forage fish, Gulf of Alaska, management strategy evaluation, MSE, Northeast Pacific, Pacific herring, Pacific Ocean

#### Introduction

Pacific herring (*Clupea pallasii*) functions as an important forage fish and prey resource for numerous predators in the Northeast Pacific (Willson and Womble, 2006). These include seabirds (Schrimpf *et al.*, 2012; Bishop *et al.*, 2015; Sydeman *et al.*, 2017a; Dr- ever *et al.*, 2021) and commercial fish (Brodeur *et al.*, 2014; Osgood *et al.*, 2016), as well as numerous marine mammals, e.g. humpback whales (*Megaptera novaeangliae*; Boswell *et al.*, 2015; Moran *et al.*, 2018; Straley *et al.*, 2018) and Steller sea lions (*Eumetopias jubatus*; Gende and Sigler, 2006; Womble and Sigler, 2006; Sigler *et al.*, 2017).

The ecological role of Pacific herring is especially strong and tax- onomically widespread during the spring spawning season, when both fish and roe become available to a diverse coastal predator guild (Willson and Womble, 2006). Thus, Schweigert *et al.*, (2010) describe herring as the primary forage fish in British Columbia waters, while Fox *et al.* (2015, 2018) categorize it as a foundation species (*sensu* Soulé *et al.*, 2003). Moreover, its high energy con- tent relative to most other Northeast Pacific prey species (Perez, 1994; Anthony *et al.*, 2000; Vollenweider *et al.*, 2011) strengthens the importance of herring to its predators (Surma *et al.*, 2018a). Fur- thermore, many aboriginal, recreational, and commercial fisheries

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***CRSNG***





A photograph capturing two humpback whales breaching the ocean's surface. The whales' dark, wet skin is glistening, and their massive, ribbed heads are angled upwards. The water around them is turbulent, with white foam from the splash. Several seabirds, likely albatrosses, are in flight around the whales, some appearing to be perched on the whales' heads or wings. The background shows the vast, greenish-blue ocean under a bright sky.

Thank you!

どうもありがとうございました!