

## **Jellyfish, forage fish and the world's major fisheries.**

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### **Summary**

A majority of the world's largest net-based fisheries target planktivorous forage fish that serve as a critical trophic link between the plankton and upper-level consumers. Because the plankton production that drives forage fish also drives jellyfish production, these taxa often overlap in space, time, and diet. This overlap leads to predatory and potential competitive interactions. The trophic interplay between these groups is made more complex by the harvest of forage fish, which presumably releases jellyfish from competition for shared prey. To understand the roles forage fish and jellyfish play as alternate energy transfer pathways, we explored how functional group productivity in three coastal ecosystems changed when jellyfish were abundant and when fishing was reduced using ecosystem modeling.

### **Concern about shifting marine ecosystems from fish to jellyfish**

Large coastal jellyfish are major consumers of plankton production in heavily-fished ecosystems. Yet, because they are not in the direct ascension from fish food to fish predators (excepting fish eggs and larvae), they are routinely overlooked in ecosystem-based fishery management models (Pauly *et al.*, 2009). Evidence of jellyfish-forage fish replacement cycles in some ecosystems supporting large forage fish fisheries have intensified concerns some are shifting from fish to jellyfish—a perceived 'trophic dead end'. Because forage fish and jellyfish often overlap in diet, space and time, but only forage fish are targeted by fishers in most regions, it is expected that fishing can lead to a competitive release for jellyfish. However, interactions between jellyfish, forage fish, and fishing are not well understood.

We present here a review of interactions among jellyfish, forage fish, and fisheries. The socioeconomic risks jellyfish present to fishers and the ecological reasons why forage fish are vulnerable to jellyfish are discussed. The roles jellyfish and forage fish play as energy transfer pathways and the ecosystem-wide consequences when blooms occur or fishing is reduced are explored using ecosystem modeling in the eastern Bering Sea (EBS), Northern California Current (NCC), and northern Gulf of Mexico (GOM) analysis (Ruzicka *et al.*, 2012; Aydin and Mueter, 2007; Steele and Ruzicka, 2011).

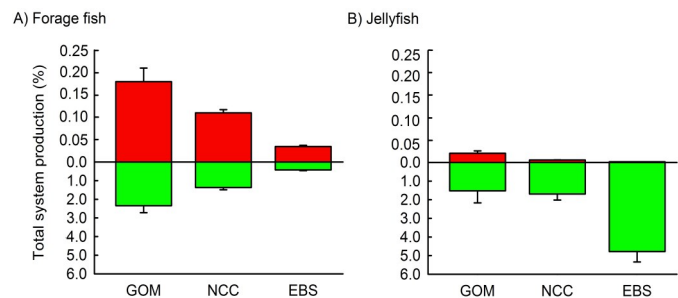
### **Risks, drivers, and trophic energy transfer**

The high biological productivity where forage fish fisheries are centered (e.g. upwelling areas, large river plumes, and shallow seas) also supports large jellyfish biomass. Socioeconomic consequences for fishing that can occur when large jellyfish bloom include injuries to fishers, gear destruction, loss of harvest,

and increased fishing effort. Estimated costs associated with jellyfish outbreaks can reach upwards hundreds of millions of dollars US (Graham et al., In Press).

Both forage fish and jellyfish experience fluctuations in population size in response to environmental variability due to their heavy dependence on plankton production cycles. Temporal variability in their population dynamics is often indirectly driven by climate forces oscillating over the Pacific and Atlantic Oceans. Because forage fish and jellyfish respond to the same types of drivers, they often overlap in space and time in coastal ecosystems. This overlap can lead to predatory interactions and the potential for resource competition. Dietary overlaps can be often substantial as can be jellyfish predation on fish eggs and larvae (Purcell et al., 1994; Purcell and Sturdevant, 2001).

Stimulated ecosystem reach and footprint metrics for forage fish and jellyfish in the EBS, NCC, and GOM support the assertion jellyfish can be a production-loss pathway. Forage fish have a greater reach and smaller footprint than jellyfish in all three ecosystems, and are a much more important energy transfer pathway, measured by the ratio of reach to footprint (Fig. 1). Forage fish in the NCC, GOM, and EBS have similar levels of import in terms moving energy up the food web, indicated by the ratio of reach to footprint. However, jellyfish in the GOM play a larger role in energy transfer relative to NCC and EBS jellyfish (Fig. 1). The closure of all fisheries resulted in increased production in forage, pelagic, demersal, and apex predatory fishes, but did not affect jellyfish.



**Figure 1. System-wide reach and footprint metrics for (A) forage fish and (B) jellyfish in the three ecosystems. Green bars are the footprints and red bars are the reach.**

### An approach to ecosystem management using jellyfish

Building on recommendations to take a precautionary approach to the management of forage fish stock, we are developing a toolset using jellyfish as indicator for management targets. We suggest that fisheries management paradigm should be revised to include jellyfish, a seasonally abundant consumer of shared prey resources and fish early life stages.

### References

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