Quantifying the benefits of spatial fisheries management

One of the most pressing challenges fisheries managers face is when the biology of the species they are managing does not align with the way they manage it. An example is the Pacific herring. Herring populations are known to have spatial structure: they are made up of sub-stocks that use their own nearshore spawning grounds, and those grounds have little or no connectivity. Often, though, managers simply do not know how individual sub-stocks are faring—information is not available at that fine of a scale. Therefore, they set harvest rules on the basis of how the herring appear to be doing in aggregate. However, this mismatch between biology and management has consequences.

Voss et al. built a model that combined ecological and economic parameters for a fish whose life history mimics the spatial structure of Pacific herring. They used the model to ask what happens when a) a management plan accounts for a fish's recruitment strategy or does not; b) different sub-stocks have different levels of productivity; and c) management plans either consider the stock as an undifferentiated whole or attempt to tailor catch quotas to particular sub-stocks.

Voss et al. compared two recruitment strategies for the fish: diffusion, in which recruits spread themselves in fixed proportions among spawning sites and return to those same sites each year; and "Go With Older Fish," or GWOF, in which recruits join schools of older fish and adopt their migration behaviors. Traditional and other knowledge show that Pacific herring use the GWOF strategy.

They considered the implications of these different recruitment strategies under three additional scenarios: (1) spawning sites all have the same level of productivity, and the management plan does not differentiate between them; (2) productivity differs among the spawning sites, but the management plan does not differentiate between them; and (3) productivity differs by spawning site and the management plan *does* account for those differences – so-called "fully spatially-explicit management."

When does migration behavior matter? In the first scenario, knowing the behavior the fish follows does not matter: all the sites are equally productive, so treating them as a single entity from a management perspective did not lead to local extinction. Under the second scenario, where sites are differently productive but the management plant does not consider this, the results differed depending on the strategy the fish followed. If managers treated the fish like they followed the diffusion strategy, but the fish really followed the GWOF strategy, some sub-stocks were overexploited. "Assuming incorrect recruitment behavior might either lead to overfishing, or to underutilization, of the resource," Voss et al. write. Lastly, under fully spatially-explicit management, migration strategy also does not matter, because managers have almost complete knowledge of how a particular site is doing and can manage accordingly.

"Despite the appearance of large-scale sustainability, local depletion and related losses in potential catch" can occur, write Voss et al. What managers need, they argue, are better spatial management tools, guided by a detailed knowledge of herring recruitment patterns at particular sites or sub-stocks. However, with greater data needs come increased monitoring and enforcement costs. In the face of imperfect knowledge, then, how best to proceed? Making the correct assumption about the migratory and recruitment behavior of the fish becomes vital. For herring, the model showed that the lowest management risk is associated with assuming a GWOF migration strategy. When crucial information is unknown, a cautious or precautionary management approach is in order.

Voss R., et al. 2018. *Ecological Modelling* 385:165-172