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Why Is the Depletion of Our Important Fish Stocks so Persistent?

James A. Wilson
University of Maine, jwilson@maine.edu

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Cover Page Footnote

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Why Is the Depletion of Our Important Fish Stocks So Persistent?

by James A. Wilson

INTRODUCTION

My wife and I have the great fortune of living on Isle au Haut, an island on the southeastern edge of Penobscot Bay. Our house overlooks a small harbor. We bought the house (for what now seems like a song) in 1971. In the fifty-plus years we've been here, the natural system in and near the harbor has declined steadily. I used to be able to walk down to the flats in front of the house and dig enough clams for a meal for our family and guests in 20 minutes or half an hour. Mussels for the following evening could be gathered in 15 or 20 minutes. Flounders and young pollock were easily caught from a small skiff. A good-sized cod could be hooked with just a short row outside the harbor. Large schools of mackerel visited regularly. Several times each year, juvenile herring would flood the harbor and fill the nets of our neighbor who sold to the cannery in Stonington. Unfortunately, today, the abundance of the nearshore ocean has disappeared; the species we fished haven't been driven to extinction, just to rarity. Of the animals we like to eat, only lobster remains plentiful. Our experience has been shared by everyone on the coast of Maine, in the rest of New England and Atlantic Canada, and in almost all coastal places around the world (Jackson et al. 1998; Lotze et al. 2006).

Unfortunately, these changes don't appear to be temporary downturns. For example, herring and cod were once our dominant nearshore species (Goode 1887). Herring abundance collapsed in the mid-1980s, and cod shortly after that (Ames and Licther 2013). After nearly 40 years without fishing, coastal herring are still absent. Juvenile cod are found only occasionally on the Downeast coastal shelf (Maine Center for Coastal Fisheries, unpublished). They are probably the result of larval drift from places beyond the Maine coast (Clucas et al. 2019). When these cod mature, they die or leave the area. Mature fish, much less spawning fish, have not been observed for a long time.

The remaining herring and cod are found offshore. Their abundance is estimated at less than 10 percent of what it was 50 years ago. There may be a few places in the Gulf of Maine where spawning cod populations survive, e.g., in the Ipswich Bay area in Massachusetts. There are occasional reports of small schools of brit herring (juveniles) inshore. Menhaden are much more common. Overall, however, the coastal ecosystem is far less abundant, less organized, and less predictable than it was 75 years ago. The effort we have put into fisheries management has borne little fruit, except in the lobster fishery. Here, I argue that a view of the natural system that considers fish as social animals leads to a very different and more local idea of how we might successfully restore and sustain our marine fisheries.

PERSISTENT DEPLETION

The loss of local fish stocks appears recent to us, but what we've experienced may be simply the culmination of a long process. One hundred and fifty years ago, after an inspection of southern New England fisheries, Spencer Baird, the first US Commissioner of Fisheries, wrote: "It should ... be understood that the exhaustion of a local fishery is not like dipping water out of a bucket, where the vacancy is immediately filled from the surrounding body; but it is more like taking lard out of a keg, where there is a space left that does not become occupied by anything else" (Baird 1873).

Persistent local depletion is not consistent with the fish population theories that are the basis for standard fisheries management. Standard theory argues that fish populations inhabit extensive areas. The scientific basis for this argument rests on three well-established facts. (1) Marine fish are incredibly fertile. "Larger [cod] females can produce 3 to 9 million eggs when they spawn." (2) Those eggs or larvae usually float, may be viable for several weeks, and can travel long distances driven by wind and currents. (3) Adult fish typically face no barriers to their movement so long as they stay within their genetically determined habitat. For cod in New England, for example, these assumptions long ago led NOAA to conclude that in New England, there are probably two very broad-scale populations corresponding with the Gulf of Maine and Georges Bank.

A fundamental conservation concept built into standard theory is that if the boundaries of a population are known, we can carefully track our fishing activities and monitor the response of the harvested population within those boundaries. As fishing or other events alter the abundance of spawning fish, there should be a measurable change in the number of recruits, i.e., young fish, successfully entering the adult population. Knowing this, we should be able to control our fishing in a way that sustains the population. Unfortunately, our confidence in a reliable stock-recruit relationship is weak at best after more than 70 years of active monitoring and management of a wide variety of species here and throughout the world (Ludwig et al. 1993; Hauser and Carvalho 2008). Yet despite the weak evidence for a spawner/recruit relationship and the generally poor results from this approach to management, standard practice still assumes current spawning stock size is the primary determinant of future population size. Consequently, the ruling idea is that we can best affect the numbers of spawning fish by controlling our rate of harvest.

Furthermore, standard theory suggests fish in these broad populations should rapidly fill any locally depopulated place, like water in a bucket. Experience (going back at least to Baird) is that filling-in does not happen—at least among finfish; depletions tend to be localized and persistent. Furthermore, genetic evidence indicates multiple, relatively isolated, and smaller local populations (Bradbury et al. 2013; Riccioni et al. 2010), where standard theory expects only one. These anomalies suggest a finer-scale ecology with essential processes, such as recruitment, occurring at a much finer scale than standard theory assumes. At the same time, however, the assumptions leading to the idea of broad-scale populations, i.e., that fish are enormously fertile, that their larvae drift widely, and that the mobility of adult fish is relatively unrestricted, appear correct. These contradictory bits of evidence create a quandary and make it relevant to ask, "What mechanism might modify the standard idea of broad-scale adaptation? What might lead instead to persistent local adaptation?"

SOCIAL LEARNING AMONG FISH

In a recent paper, I and my coauthor, Jarl Giske from the University of Bergen, suggest that social learning among fish may be a behavioral mechanism that facilitates local adaptation (Wilson and Giske 2023). Our hypothesis builds on a growing body of science about social learning among animals, especially vertebrates (Brakes et al. 2019; Whiten 2021). Applied to a fishery, the idea is that fish can learn from one another and are more social than standard theory assumes. This idea is buttressed by solid laboratory evidence that shows that fish form persistent groups and learn from one another, primarily by imitating older fish (Brown 2023).

As Whiten (2021) and others suggest, social learning is an evolutionary mechanism that can lead to finer-scale adaptation. The barebones argument is this: only older fish whose behaviors have led to their survival can be imitated because fish that followed maladaptive behaviors have died. Consequently, simple imitation ensures that the learning passed on by older fish reflects the natural selection of good habits, i.e., a second form of evolution. However, the adaptive value of that learning is limited to the times and places older fish have experienced—a range far less extensive than the species' biological range. Learned knowledge particular to that limited range is valuable because it facilitates successful time- and place-based behavior, e.g., where and when to spawn, find prey, and avoid predators. Localization does not mean fish are sedentary; it means that they are habituated to the places frequented by their elders. In short, social learning among fish implies coherent local groups organized around an accumulated body of adaptive knowledge about particular times and places. Importantly, this includes the timing and routes of migration.

SUSTAINABILITY

The simultaneous operation of two evolutionary processes generates new ideas about managing fish populations with better results.

As mentioned earlier, the standard theory hypothesizes a predictable relationship between the number of spawners and the number of recruiting young fish. If this kind of quantitative relationship exists, even if it is highly variable, we only have to ensure the number of spawners is sufficient to maintain the population to sustain the fishery. This is the reason why current management puts such a heavy emphasis on quotas. In principle, quotas can ensure adequate spawners and produce optimum fishery yield while conserving the stock's reproductive capacity.

In contrast, the idea of learned adaptation argues that successful recruitment depends on a social environment (in the natural system) in which a group of older, experienced fish demonstrate to younger, maturing fish the behaviors appropriate to the particular environment they inhabit. From this perspective, recruitment is a relatively long learning process that provides fish with the local adaptive knowledge that complements their genetic endowment. This is strikingly different from genetic adaptations that are acquired in a single event at birth and are not dependent on social structure.

Consequently, the sustainability of a group of social learners requires preserving both the genetic and learned information necessary for successful adaptation. An example of when this does not seem to happen occurs in Downeast Maine. Currents and wind appear to deliver cod eggs and larvae to an area with no older fish; some of the larvae, operating only with the behaviors from their genetic endowment, reach maturity. However, without older fish to demonstrate local adaptive skills, successful recruitment does not happen (MCCF). The maturing fish leave or die.

The difference between social and nonsocial animals would appear to have important ecosystem implications. When faced with heavy fishing pressure, the recruitment and resilience of nonsocial learners should not be affected by the absence of older individuals. Thus, heavy fishing across the ecosystem might generate a long-term shift in relative abundance, favoring nonsocial species such as lobster and crabs.

For social species, learning might be expected to generate population attributes that are significantly different from those usually assumed (Wilson and Giske 2023):

1. Social learning generates localized subpopulations because fish only acquire the adaptive benefits of learning if they remain in the area of their learned adaptation. (This contrasts with the usual assumption of uniform, genetically determined, broad-scale adaptation.)
2. Learning from one to the next generation is a relatively fast, fine-scale, nongenetic evolutionary process that allows fish to adapt to (some) changing local conditions, lending persistence but not permanence to locally adapted groups. (There is no similar idea in standard theory.)
3. Social learning tends to isolate groups of the same species, adapting them to different places and enabling but not assuring minor genetic differentiation (Whiten 2021). (Usually, the isolation necessary for genetic differentiation is only attributed to geographical factors.)
4. Most significant, successful recruitment (survival to maturity) depends on a continuing social environment among fish that allows young adults to acquire from more experienced fish the knowledge necessary for local adaptation. (Traditional theory assumes that adaptive knowledge is only genetic, that it transfers entirely at birth, and that recruitment and sustainability are a function of the number of spawners. It does not consider social structure or learning.)

Furthermore, because many social learners are significant predators, removing them from local ecosystems can generate substantial changes throughout the ecosystem. For example, the clams and mussels that used to feed our family and friends may have been affected by the long, complex causal chains resulting from the removal of many of the predators, i.e., the social learners, at the top of the ecosystem.

FISHING

Good fishers learn the time and place patterns generated by social learning among fish in their area. Unfortunately, the way we fish now—the kinds of gear we use and the times and places where we target fish—seems designed to impair the adaptation of social learners. In nearly every fishery, we target large fish and social aggregations. Large fish are preferred because they tend to provide a better yield and often a more desirable product (Pauly et al. 1998). If social learning is necessary for the local adaptation of fish, the perverse effect of fishing is that it damages social structure and removes the older fish whose memories record the behaviors needed for successful local adaptation. The principal conclusion is that the long-term decline of broad-scale populations of social learners results from the loss of the recruitment potential of multiple local populations.

Occasionally, a fishery for social learners does not focus on large fish. For example, juvenile herring are found in schools that retreat nightly to nearshore coves and bays along the coast. For more than 140 years the sardine, i.e., juvenile herring, fishery in Maine and Atlantic Canada, was sustained at a high level using weirs and stop seines at fixed locations in coves and bays. There was only a small, incidental catch of adults. When markets for adult fish opened up in the 1960s and 1970s, fishing effort (by newly introduced purse seiners) was directed at adults in addition to juveniles. Soon after, the spawning groups of herring associated with various bays disappeared (personal communication, C. Stinson). The entire sardine industry evaporated by the mid-1980s. Shortly after that, coastal cod populations also disappeared (Ames and Licther 2013). Populations of herring and cod still exist offshore.

IMPLICATIONS FOR MANAGEMENT

A complex-systems perspective (e.g., Holland 2012; Ostrom 1990) strongly emphasizes the need to organize management in a way that mirrors or parallels, as much as possible, the organization of the managed system. At first, this configuration may seem to make fisheries management more complicated than it already is. However, the great advantage of congruent organization is that it reduces the ambiguity of spatial and temporal signals from the natural system, which gives us a clearer sense of how the natural system responds to our actions. Congruent organization makes it easier for us to learn and puts us in a better position to manage for sustainability.

We currently manage fish populations on a single broad scale, which is *not* congruent with the different scales important to the natural system. Because of this incongruity, the information we receive and generate about the system's state is fundamentally ambiguous, and our ability to learn from our actions, i.e., fishing, is significantly diminished. For example, suppose we operate as if each targeted species is composed of one large, homogeneous population when, in fact, it is characterized by multiple subpopulations. Our assumptions (and budget constraints) will lead (have led) us to design data sampling protocols and fishing constraints as if each population were homogeneous over broad spatial and temporal scales. This approach hides changes in the finer-scale structure of a more complex natural system and reduces our ability to learn how we impact the system.

Significant unintended consequences have probably resulted. For instance, large mesh nets are intended to allow more spawning by newly mature fish. However, larger mesh makes it easier to catch older fish, thereby eroding the group's memory and the likelihood of successful recruitment. In another instance, quotas applied to a population that is assumed to be broad-scale do not restrain fishing on local subpopulations. Fishers are efficient and tend to target convenient subpopulations. As a result, entire local, especially coastal, populations of social learners might be fished out without individual fishers or the fleet violating assigned quotas. The resulting reduction in local recruitment tends to be undetected in aggregated data because it often falls within the normal variability of a broad-scale population. As more local populations are fished out, aggregate recruitment potential declines and temporary downturns become permanent.

THE IMPLICATIONS FOR MAINE

If social learning complements genetics as sketched here, population structure is much finer-grained than usually assumed. Consequently, learning how we affect the resource will require much finer-scale monitoring than is currently carried out. The strong implication is that Maine and other localities need to acquire and exercise responsibility for local management of social learners. Circumstances like this are commonly termed comanagement, where the "co" refers to a broader-scale authority, such as the state, which has the ability to stop beggar-thy-neighbor local policies, i.e., policies that benefit a locality at the expense of its neighbors. For example, in a migratory fishery, a local area might benefit greatly by reducing the mesh size used in its area, allowing large numbers of fish to be caught as they pass through the area. But that local benefit only comes at the expense of neighbors who have fewer fish to catch. In a heterogeneous fishery, there are many ways that adjacent and not-so-adjacent areas interact. A multilevel governance system is needed to forestall beggar-thy-neighbor local policies. This is not an unusual requirement of governance; it's a large part of the rationale for multilevel governance, i.e., town, county, state, and federal. It is a prominent aspect of international trade and governance arrangements. It is worth noting that comanagement, or multilevel governance, is less necessary when fish populations are homogeneous over a broad scale.

As noted earlier, governance organization that mirrors the natural system as much as possible reduces the ambiguity of information about the resource. Significantly, fishers' descriptions of *any* fishery are *always* expressed in terms of the relatively local timing and movements of fish—a critical aspect of localization. Nowadays, those descriptions almost invariably use the past tense: "You used to be able to find species S, in season X, at time of day Y, near place Z." Even though the depletion of our local stocks occurred 30+ years ago, the knowledge held by older fishers is essential for understanding the regular patterns of the fish stocks that comprised the coastal ecosystem. This local knowledge is certainly not everything we need, but it is critical. There will be a need to acquire the fine-grained observations of users, to document the time and place patterns of the local system, to develop protocols for the consistent collection of data, and to build the analytical methods that make sense of local observation.

Comanagement can bring this information to the table and combine it with information from other community stakeholders. For example, the success of the lobster fishery is critically dependent on comanagement in the seven lobster zones. This system of mutual restraint is based on practical and scientific knowledge of the resource; mutual restraint limits the places and ways lobstermen can operate; it is close to self-enforcing and has prevented the sequential depletion and broad-scale collapse as has happened in so many other fisheries. It is probably not responsible for the explosion of the lobster population, but it has maintained the robust population necessary for that growth. Significantly, the mutual restraint and the boundaries of the zones are the result of an open and democratic process that gives lobstermen a self-interested reason to respect the requirements of comanagement. In this volume, papers by Robin Alden and Anne Hayden elaborate on the history and capabilities of comanagement in Maine.

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James A. Wilson is emeritus profssor of marine science and economics at the University of Maine. He served for two years in the Peace Corps in Ethiopia where he learned the value of local knowledge. He and his wife, Sharen, live in an old house on Isle au Haut.