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Comanagement in Maine: Integrating Fishermen's Ecological Knowledge into Government Oversight of Fisheries

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Abstract

Comanagement is the sharing of responsibility for management between fishermen and fisheries agencies. It shifts fishermen's incentives to include longer term conservation goals, generates fine-scale information for management that would not otherwise be available, and develops fishing strategies that are consistent with conservation. Analysis of comanaged fisheries in Maine, for lobster, clams, river herring, and scallops, indicates that comanagement improves fisheries productivity and is more effective than standard, top-down, broad-scale fisheries management.

INTRODUCTION

Maine is known for its high-quality seafood with good reason. Less well understood, and perhaps even more noteworthy, is the system of governance that has allowed several of Maine's fisheries to thrive. Known as *comanagement,* it is characterized by the sharing of responsibility for management between fishermen and fisheries agencies (Berkes et al. 1991). Comanagement can resolve the challenges that arise when fisheries are managed at a spatial scale inconsistent with the scale at which fish[1] populations grow. By creating incentives for fishermen to sustain harvests, comanagement generates the fine-scale information necessary for understanding the interaction of fishermen and fish populations and builds the capacity to adapt to threats such as climate change, use conflicts, and changing societal values.

Four fisheries in Maine—lobster, soft-shell clams, river herring, and scallops—are comanaged, and each has demonstrated success in enhancing fisheries productivity (Acheson et al. 2000; Cucuzza et al. 2021; Jansujwicz et al. 2021; McClenachan et al. 2015). Each benefits from observation by fishermen, which generates ecologically relevant information regarding the status of fish populations. Traditional, top-down, broad-scale management in other fisheries, such as in New England's groundfishery, has obscured the local, fine-scale processes that drive fisheries productivity and have generally fared much less well. This paper analyzes the capacity of Maine's four comanaged fisheries to avoid overharvesting and to cope with other challenges including climate change.

Wild fish in Maine constitute a commons, property managed by the state for the benefit of the people of Maine. Many commons, including many fisheries, have experienced the infamous "tragedy of the commons" (Hardin 1968). Maine's comanaged fisheries have avoided this fate. Elinor Ostrom's research revealed a series of conditions that can allow for successful commons management and are considered a framework for effective comanagement (Ostrom 1990). They include defining boundaries that limit where groups of fishermen can fish; limiting group membership; matching rules governing harvesting to local needs and conditions; ensuring those affected by the rules can help modify the rules, and that the group's rule-making rights are respected by outside authorities; developing a system for enforcing rules; and building responsibility for governing the common resource within nested tiers and from the lowest level up to the entire interconnected system (Ostrom 2008).

Ostrom also placed the use of commons within a broader setting that highlights the complex processes by which people (and their institutions) and organisms (and their ecosystems) interact (Ostrom 2009). This perspective expands the analysis of fisheries to incorporate their social drivers, such as fishermen's incentives and government policies, as well as their ecosystem context (Leslie et al. 2015). It informs this analysis of Maine's comanaged fisheries, which focuses on the importance of fine-scale information in understanding the interaction of humans and the natural system.[2]

In a range of forms, comanagement has a long history in fisheries (Berkes 2009); it is recognized as improving

fisheries outcomes (Smallhorn-West et al. 2022) and increasing fisheries' resilience (McCay et al. 2014). Comanagement is not a panacea for sustaining fisheries. It is most effective where fishing territories do not exceed the scale at which recruitment[3] and other drivers of productivity occur. Fisheries for migratory species that do not spawn in the Gulf of Maine are unlikely to benefit from comanagement in Maine. Comanagement can also be subject to conflicts among rival factions leading to inequitable outcomes. Adoption of conservation practices does not resolve all disagreements about management, but does suggest that sufficient consensus exists to support chosen strategies.

Fish populations are composed of a series of subpopulations that form hierarchies.[4] The growth of a fish population is driven by reproduction within individual subpopulations. The existence of subpopulations of shellfish is sustained by the local retention of a portion of the larvae they produced (Pineda et al. 2009). This arrangement allows such species to take advantage of locally productive and protective habitats and guards against catastrophic population loss since locally extirpated subpopulations can be repopulated from nearby survivors through adult migration or larval dispersal. Because vertebrate fish are social animals, adaptation to local conditions is a function of younger fish observing and learning from the behavior of older fish (Wilson and Giske 2023).[5] Anadromous fish, including river herring, spawn in freshwater lakes and ponds where their larvae are largely retained; the migration (or introduction through stocking) of some adults to non-natal spawning grounds allows for restoration of extirpated subpopulations if fish passage is not blocked.

The coast of Maine has a wide variety of habitats, at various scales, as tides and coastal currents swirl among its many islands, peninsulas, estuaries, and embayments. The overall result is fish populations that are patchy in both time and space. Boundaries that limit where fishermen can fish prevent them from leaving an overfished area to exploit less depleted stocks elsewhere. Such boundaries lead to an important change in fishermen's incentives. Without access to other fishing areas, incentives shift from maximizing harvests in the short term to maintaining harvests over the long term. Controlling access to a territory by limiting the number of fishermen who can fish there is a first step in preventing overharvesting within the territory. Aligning territories with the local ecology increases the likelihood that fishermen will be able to monitor subpopulation dynamics, develop new information about the local ecology, and generate conservation strategies to match local conditions. Failure to monitor subpopulations masks loss due to overharvesting; the impact of overharvesting may not be evident until the population as a whole collapses (Hayden et al. 2015).

Fishermen and fisheries managers also form groups and subgroups: informal groups of fishermen, various councils and committees in which fishermen have roles, and government agencies. Ideally, such groups are hierarchically arranged in nested tiers aligning scales of management with those of ecological processes. Fishermen must learn where and when to fish, searching for patchy populations of fish in diverse environments. Acquiring useful information by interacting with or observing others can be more efficient than searching on one's own.

Information observed by fishermen is least ambiguous when the scale of the territory does not exceed the scale of a fish subpopulation or small group of subpopulations. The sharing of observations among a group fishing the same territory increases the likelihood of discerning meaningful signals and generates a progressively more precise understanding of the ecological and population dynamics within territories. This process contrasts with traditional science-based research, which is most often conducted at a broad scale and overlooks fine-scale information essential for accurately monitoring the health of fish populations.

Working together to track the status of fish subpopulations within a territory can lead to cooperation among group members and the capacity to address a range of threats to their fisheries, including declining harvests due to overharvesting and the negative impacts of climate change. As fishermen work together to address threats, social learning facilitates adaptation through an evolutionary process that reinforces those strategies that work and weeds out those that don't (Wilson 2017). Social learning at the group level requires a collective understanding of local conditions and the right to test a range of strategies. Group efforts are often limited to those allowed under existing governance regimes (which generally resist the establishment of new, finer-scale fishing territories) and often focus on those that might directly result in changes to local conditions.

Government oversight of fisheries often operates at a much broader scale than that at which fishermen can detect changes in abundance and productivity (Scott 1998). Government agencies often rely on broad-scale monitoring

that obscures such changes (Hauser and Carvalho 2008). In contrast, fishermen trust a collective and qualitative understanding of what contributes to a species' reproductive success based on observation at a much finer scale (Wilson 2002). Comanagement provides an opportunity for resolving this tension as it allows for more useful information on population dynamics to be incorporated into the management process. It also allows for local action that government agencies cannot manage.

In summary, comanagement can improve fisheries outcomes because it shifts fishermen's incentives to include longer term conservation goals, generates fine scale information for management that would not otherwise be available, and develops fishing strategies that are consistent with conservation.

CASE STUDIES

Here, I examine Maine's four comanaged fisheries (lobsters, soft-shell clams, river herring, and scallops) are analyzed to compare the degree to which they meet the conditions established by Ostrom (Table 1). I also examined each fishery regarding its capacity to address both internal and external threats.

Lobster Fishery

The lobster fishery is the most valuable single-species fishery in the country (NMFS 2022). In 2022, it accounted for 68 percent of the value of Maine's commercial fisheries landings. The fishery is managed by the Maine Department of Marine Resources (DMR), subject to oversight by the Atlantic States Marine Fisheries Commission (ASMFC), a state-federal partnership with jurisdiction over coastal fisheries on the eastern seaboard.

Ostrom's conditions for the emergence of local adaptive capacity are largely met in the Maine lobster fishery. The fishery is divided into seven fishing zones. Fishermen are limited to fishing in their home zones (with an allowance for fishing in adjacent zones). Fishermen within each zone have the authority to manage certain aspects of the fishery within their zone, subject to approval by DMR. Each zone has the right to set (1) the number of licenses and the ratio of new licenses granted to licenses retired, (2) trap limits, (3) the number of traps on a trawl, and (4) fishing hours. Requests for rule changes within the zones are generally approved by DMR and attest to the department's respect for the role of fishermen in the management of the fishery (Acheson 2013). Governance of the fishery forms a nested hierarchy with fishermen's participation in decision-making occurring at every level. Decision-making within zones is overseen by zone councils, comprised of fishermen elected from local districts within each zone. Zone councils, in turn, appoint a member to serve on the statewide Lobster Advisory Council, which advises DMR on lobster policy.

ASMFC is comprised of an administrator, legislator, and gubernatorial appointee from each of the participating states; these individuals also sit on each of the boards that oversee individual fisheries. Reflecting the value of the lobster fishery to the state, a lobster fisherman is often appointed as Maine's gubernatorial appointee to the commission. As a member of ASMFC's American Lobster Board, this appointee has a direct role in lobster management decision-making at the highest scale of governance.

Challenges met

Unfettered harvesting of juvenile and adult lobsters in the early 20th century led to the collapse of the fishery in the 1920s, with a drop from 20 million pounds in 1910 to 5.5 million pounds in 1924 (Maine DMR 2023). Fishermen worked together to test strategies for recovering and sustaining catches, laying the groundwork for emergent organization and the capacity for adapting fishing practices to local conditions. For several decades, industry leaders worked to develop and implement statewide regulations, including prohibitions on harvesting pre-reproductive and over-sized lobsters, the marking of reproductive females, escape vents (to prevent cannibalism of small lobsters), and strategies to limit ghost fishing (Acheson 2003). The effectiveness of industry-led strategies in sustaining and growing harvests is often attributed to a conservation ethic among lobster fishermen, and the scale at which their conservation practices are implemented is important.

In the 1980s, dramatic growth in the number of traps being fished created a problem that the industry was unable to solve on its own. Fishermen wanted to limit overall trap numbers, but couldn't reach a consensus on an individual trap limit given the widely differing conditions faced by fishermen along the coast. The solution, developed by Robin Alden, commissioner of DMR at the time, scientists at the University of Maine, and leaders in the lobster fishery, was to establish a regional level of governance that would allow fishermen in different areas to develop rules specific to local conditions. It was codified in 1995 by the passage of the Maine lobster comanagement law (Acheson et al. 2000). The

TABLE 1: **Four Comanaged Fisheries in Maine and Conditions Necessary for the Emergence of Local Adaptive Capacity**

Ostrom conditions	Lobster	Clams	River herring	Scallops
Territorial boundaries	Fishery is divided into 7 zones. Fishermen must fish a majority of their traps in one zone.	Fishermen are limited to fishing within municipal boundaries (in 2 cases, within boundaries of several municipalities).	Fishermen are limited to fishing a single river or stream within municipal boundaries.	Informally enforced exclusion of nonlocal fishermen from Zone 3.
Limits on group membership at local level	Each zone limits entry.	Slightly more than half of participating municipalities limit entry.	Fishing rights within a municipality are granted to individuals.	No formal limits.
Rules fit local circumstances	Each zone limits entry, number of traps, number of traps on a trawl, and sets time of day for fishing.	Most municipalities adjust number of licenses to reflect changes in shellfish abundance. They also adopt various strategies to sustain harvests.	Fishing is primarily regulated at the state level. Fishermen often clear impediments to fish passage to improve productivity.	Management is based on local conditions within 2 of 3 scallop fishing zones. In Zone 2, rules reflect circumstances with subzones.
Harvester participation in rulemaking	Formal and effective role in rulemaking at local, state and regional levels.	Formal and effective role in rulemaking at local level.	Very limited role, at local level.	Informal and effective role within Zones 2 and 3.
Respect by authorities	High	Low	Low	Moderate
Enforcement	The advent of comanagement in each fishery has reduced fishermen's role in punishment and dispute resolution. Responsibility for these activities was shifted to the Marine Patrol when zone management was implemented. Monitoring by fishermen and others occurs in all four fisheries. Information about illegal activity is shared with the Marine Patrol. As a result, enforcement is more effective and the costs of enforcement for, and the number of violent conflicts among, fishermen has been reduced. In the clam fishery, municipalities ensure compliance with state and local regulations by hiring clam wardens to monitor local flats, which reflects both the number of flats that need to be monitored and the importance of the fishery to municipalities.			
Participation by fishermen in nested tiers of governance	**Hyperlocal:** Election districts **Local:** Zone councils **State:** Lobster Advisory Council **Regional:** Atlantic States Marine Fisheries Commission	**Local:** Municipal shellfish management **State:** Shellfish Advisory Council	**Local:** Municipal river herring management **Regional:** None	**Hyperlocal:** Informal fishermen-state cooperation in subzones of Zones 2. **Local:** Informal fishermen-state cooperation in Zones 2 and 3. **State:** Scallop Advisory Council **Federal:** Limited

law established formal zones that have prevented coastwide expansion of fishing effort as vessel range increased.

The major benefit of boundaries that do not exceed the scale of lobster subpopulations has been the ability of each zone to manage effort as the market value of lobster has remained strong and their relative abundance has led to increased fishing pressure. The ability of the lobster population to support fishing livelihoods varies from zone to zone as a function of fishing conditions, the availability of lobster's preferred habitat, and local retention of lobster larvae (Incze et al. 2010; Xue et al. 2008). Each zone limits new entrants to a percentage of those exiting the fishery, which reduced the number of commercial licenses held by fishermen between the ages of 18 and 70 by 28 percent between 1997 and 2018. The number of licenses varies by zone; in 2018 they ranged from 291 to 853.[6]

DMR and industry leaders have to some degree been able to develop comanagement that generates fine-scale information and individual incentives that complement the top-down management mandated by the Magnuson Act and the Atlantic Coastal Fisheries Cooperative Management Act on Maine's fishery (Acheson 2003). In the early 2000s, DMR and the industry also negotiated manageable changes to the fishery to lessen perceived threats to the federally endangered right whale population.

Ongoing challenges

Lobster landings rose dramatically beginning in the late 1980s peaking at 132 million pounds (live weight) in 2016.

Increasing value has offset a decline in landings since 2016, but many in the industry are concerned about the future of the fishery. The industry is also facing several challenges that arise outside the fishery, including (1) renewed regulatory pressure to limit potential impact on the endangered right whale, (2) changing spatial dynamics in lobster populations as lobsters avoid warmer, shallow waters, (3) rising bait and fuel costs, and (4) potential use conflicts with offshore wind farms and aquaculture. Some members of the fishery recognize that the lobster population has benefited from the overharvesting of cod and worry that efforts to restore cod could affect lobster abundance; others are willing to see cod restored if they are allowed to fish for them.

Soft-Shell Clam Fishery

The soft-shell clam fishery is the third-most valuable in the state, representing 3 percent of the value of Maine's commercial fisheries landings. Oversight of the industry occurs at the state level, through DMR, and at the municipal level. There is indirect federal oversight of the fishery through the National Shellfish Sanitation Program, which permits interstate sales of shellfish by those states with effective public-health-monitoring programs. The soft-shell clam fishery takes place mainly in intertidal habitats and has been comanaged by the state and municipalities in some way since statehood. As of 2023, 55 out of 145 coastal towns exercise a right to local management subject to state oversight; an additional 12 towns, in 2 regional programs, manage shellfish resources collectively. The Passamaquoddy tribe manages the clam fishery in Sipayik, and Washington County manages the clam fishery within unorganized territories within the county.

Ostrom's conditions for effective comanagement are partially met in the soft-shell clam fishery. Municipal boundaries establish territorial limits on fishing activity. Licenses are limited to residents except for a 10 percent allocation to nonresidents required by the state. Approximately half of municipal shellfish management programs otherwise limit entry in the fishery. Harvesters participate in rulemaking through their roles on municipal shellfish management committees, which allows management strategies to be tailored to local conditions on a flat-by-flat basis. For example, shellfish management committees close flats when necessary to prevent overharvesting and seed flats to enhance productivity.

DMR has had a mixed record in respecting local shellfish management programs. Harvesters share a perception that protecting consumers from the risks of shellfish-borne toxins and pathogens is a higher priority at DMR than supporting comanagement through collaborative research and monitoring. This contention is supported by DMR's statement that public health monitoring constitutes its support for the industry (Waller et al. 2023). It remains to be seen whether a recent DMR effort to engage shellfish harvesters in improving Maine's municipal shellfish management program shifts the dynamic between the department and the industry (Singer 2022).

Municipal management programs form the base of a two-tier system of governance. A statewide Shellfish Advisory Council advises DMR on the status of the soft-shell clam fisheries and to recommend updates to statewide regulations; four of its fourteen seats are reserved for commercial shellfish harvesters. The advisory council has been subject to regulatory capture affecting fishermen's participation in decision-making. It is actively engaged in DMR's current initiative regarding shellfish management and has developed its own set of recommendations, addressing improved access to flats for harvesters and increased support for conservation activities, management, technical assistance, data management, municipal committees, improved water quality, and enforcement (ShAC 2023).

Challenges met

The soft-shell clam fishery exhibits only a moderate degree of alignment with Ostrom's conditions and a relative inability to affect state policy and regulations. Despite a long-term decline in landings, the fishery remains the third-most valuable in the state. Support for active management in many coastal communities remains high, an indication that shellfishermen value comanagement and that the scale of local management aligns with drivers of recruitment, which, in this case, are likely to be hyperlocal.

Municipal shellfish committees are also testing adaptations to external changes that affect the fishery. For example, several committees have worked with their boards of selectmen or town councils and DMR (1) to eliminate sources of pollution causing closures, (2) to increase water quality monitoring to reduce rainfall closures, (3) to diversify their harvests to include other bivalves such as quahogs, razor clams, and oysters, and (4) to allow harvesters to retain their licenses if they move inland due to housing costs.

With rare exceptions, the industry has generally lacked the political capital to affect state-level shellfish policy and suffers from a strained relationship with DMR managers.

Ongoing challenges

The greatest threat to the fishery is predation by the invasive green crab whose populations have expanded dramatically with climate-driven increases in water temperature (Beal et al. 2018). Other external challenges facing the fishery include an increase in public-health-related habitat closures, the loss of access to intertidal shellfish habitat (Genter 2022), restrictions on the use of airboats (O'Brien 2021), and rising housing costs in coastal communities.

River Herring

Commercial river herring fisheries are prosecuted in over 20 municipalities in Maine (Maine DMR 2020), but constitute less than 1 percent of the value of Maine's commercial fisheries landings. The river herring fishery is managed by DMR subject to oversight by ASMFC. Highly productive in Maine's early history, these fisheries declined dramatically over time, primarily due to the construction of dams and other obstructions to fish passage (Hall et al. 2012). Maine's tribes are focused on restoring river herring as a means of re-establishing Wabanaki sustenance lifeways practices (MITSC 2022). In partial alignment with this goal, commercial fishermen and environmental groups are engaged in river herring restoration for its ecological benefits and for sustenance and commercial fishing. Recent restoration projects have led to dramatic increases in the abundance of adult and juvenile fish within restored runs; to date, such efforts have addressed a small number of the obstructions affecting river herring runs. Maine's river herring fisheries are comanaged by municipalities and DMR. Municipalities are granted harvest rights if a sustainable fisheries management plan is submitted to DMR that conforms with the state's river herring fisheries management plan. Municipalities may appoint a river herring management committee to oversee the fishery.

Maine's river herring fisheries meet Ostrom's conditions in only limited ways. Territorial and group boundaries and the alignment of fishing territories with subpopulations are clear: commercial fishing rights are sold annually to individual harvesters who often hold the rights for several years. A short fishing season and strict state control on harvests have left harvesters with little opportunity to adjust harvesting rules to local conditions. Some harvesters focus instead on clearing debris and notching beaver dams to enhance migration and productivity. If harvesters fish within a community with a river herring management committee, they may have a say in local management decisions. DMR's respect for municipal river herring fisheries is mixed. Disputes have arisen between DMR and municipalities seeking to re-establish commercial river herring fisheries over monitoring and sample collection methods as well as analysis and interpretation of resulting data.

While river herring management by state actors is comprised of a nested hierarchy from municipal to multistate levels, there are few ways for fishermen to participate in decision-making at every level. Fishermen participation on municipal river herring management committees varies from community to community. At the state level, there is no state advisory council. Because Maine's gubernatorial appointee to ASMFC is most often filled by a lobster fisherman, there is little prospect of a river herring fisherman participating in ASMFC's Shad and River Herring Management Board.

Challenges met

River herring fishermen have had little success in addressing threats to their fisheries. Because harvest rights are auctioned to an individual harvester, there is limited opportunity to share information with other harvesters or to collectively develop a more detailed understanding of run dynamics. However, commercial harvesters, supported by the Maine Center for Coastal Fisheries, were successful in 2019 in petitioning DMR and ASMFC to establish an experimental fishery program, an example of changing river herring fishery policy, which is a challenge in Maine's comanaged fisheries. Three provisional fisheries in Maine were approved, providing fishermen interested in restoring a river herring run an opportunity to harvest fish while collecting the 10-year data record required for full approval of a commercial fishery (ASMFC 2019).

Ongoing challenges

Changes in rainfall patterns related to climate change affect both the upstream migration of adults and the downstream migration of juveniles. Bycatch in Gulf of Maine pelagic fisheries affects to some degree the abundance of adult river herring. The restoration of additional river herring runs and expansion of commercial river herring fishing face challenges including resistance from dam owners and owners of shorefront property on impoundments. In addition, dam removal or installation of a fish ladder can be expensive.

Scallop Fishery

The scallop fishery in Maine waters represents 1.5 percent of the value of Maine's commercial fisheries

landings. Scallops are primarily harvested by towing a drag along the bottom; a small percentage of landings are from a dive fishery. DMR provides oversight of the fishery within state waters and the New England Fisheries Management Council oversees scallop fishing in federal waters.

Maine waters are divided into three scallop management zones, reflecting differences in scallop habitat and productivity. Zone 1, from the New Hampshire border to Penobscot Bay, is the least productive; Zone 2, from Penobscot Bay to Lubec, further subdivided into 24 subzones, is more productive; Zone 3 includes Cobscook Bay, the most productive scallop habitat in the state, which generates approximately half of Maine's total scallop landings. Informal comanagement is evident in Zones 2 and 3. Management of Zone 2 is divided into a series of small subzones. Local larval retention is likely given genetic analysis that indicates distinct subpopulations of scallops (Owen 2008). The subzones are managed on a rotational basis; a subset of the subzones is open each year and divided between the drag and diver fisheries. Fishermen develop a collective, fine-scale understanding of the status of the scallop resource as they fish within each subzone. As the fishing season progresses, fishermen inform DMR when they detect declining catch rates and request that the subzone be closed for the remainder of the fishing season, which DMR implements in real time.[7] Local harvesters in Zone 3 have informally limited access for nonlocal fishermen to their fishery.

Management of the state fishery meets Ostrom's conditions to a degree, but it lacks formal territorial limits on where scallop fishermen can fish. Entry is limited in the fishery at the state level; lotteries are held for licenses that become available. Comanagement in the fishery fits local circumstances. Cobscook Bay fishermen have indirectly limited nonlocal fishermen by lobbying for a low daily harvest limit and restricting the number of moorings available to fishermen from other parts of the coast (scallop value and abundance would otherwise make travel to and from Cobscook Bay worth the time and expense). The Zone 2 rotational management program curbs overharvesting within its subzones.

Scallop comanagement forms a three-tier hierarchy: the most local level, in effect in Zones 2 and 3, is informal. The Scallop Advisory Council advises DMR on scallop management. Nine out of thirteen seats are reserved for scallop fishermen, so it is an influential voice for fishermen. There is limited scallop habitat seaward of Maine waters, which is managed by the National Marine Fisheries Service and the New England Fishery Management Council. Maine fishermen struggle to compete with an industrial scallop fleet that operates out of southern New England. They have limited influence in federal scallop management, but recently won a set-aside of a portion of the northern Gulf of Maine scallop quota for the small-boat fleet.[8]

Challenges met

In 2009, the fishery in Zone 2 was closed, following a dramatic decline in landings. In cooperation with DMR, the Maine Center for Coastal Fisheries solicited management suggestions from fishermen that led to the implementation of the rotational management scheme in 2012. Landings recovered, and comanagement has been effective; however, it is more vulnerable to change than if codified in law or regulation. Like the advent of the zone system in the lobster fishery and an experimental fisheries policy in the river herring fishery, the development of rotational management in Zone 2 is another example of outside groups working with fishermen to change fisheries policy at a higher level of governance.

Ongoing challenges

The 10-year rotational management plan is up for renewal, creating the potential for elimination or weakening of informal comanagement. Some harvesters are concerned that the expansion of scallop aquaculture in Maine could negatively affect the market for wild-caught scallops and lead to the protection of wild stocks that are the source of seed for scallop farmers.[9]

SUMMARY OF FINDINGS

Analysis of the case studies suggests that comanagement has contributed to improving fisheries productivity. The lobster, scallop, and river herring fisheries support increasing or sustained landings. Landings in the soft-shell clam fishery are declining, with predation by the invasive green crab being a major factor. Anecdotal evidence of the overharvesting of clams in a community with no shellfish management program suggests that landings may have declined more sharply without comanagement. Harvesting of other species of shellfish has helped compensate for losses due to green crab predation. The apparent effect of comanagement on landings implies that territorial limits on fishing are no larger than naturally occurring boundaries in

TABLE 2: **Comparison of Local Actions to Restrain Harvests and Improve Natural Productivity**

	Lobster	Clams	River Herring	Scallops
Constraints on fishing activity	Local limits on entry	Local limits on entry	Local limits on entry	De facto exclusion of at least some nonlocal fishermen from Zone 3
Constraints on fishing activity	Trap limits	Flat closures		Rotational management of subzones within Zone 2
				Daily limit lower than state daily limit in Zone 3
Improving local productivity		Seeding	Maintenance of stream flows	

fish populations and that the opportunity to observe fine-scale ecological and fisheries phenomena has fostered the local adaptive capacity necessary to address threats to these fisheries.

Management strategies supported and adopted at the most local level of governance vary from fishery to fishery (Table 2). In the lobster, shellfish, and scallop fisheries, strategies include constraint on local fishing activity, such as limits on local entry and trap limits. In the shellfish and river herring fisheries, strategies include improving local productivity; clam fishermen seed flats and river herring harvesters remove obstructions to stream flow to enhance migration. None of these fisheries rely on model-driven estimates of fisheries abundance or set limits on total catch. The right to make changes at the local level allows action that would be difficult to administer at the state level. That municipalities hire clam wardens indicates the challenge the state faces in managing local fisheries and demonstrates the value that towns place on local shellfish management.

These fisheries also adjust rules to address issues unrelated to the population dynamics of the target species. The number of licenses within a fishery can be adjusted to ensure a meaningful level of income for license holders. Shellfish harvesters support closures that prevent harvesting until the summer months when market demand increases, and lobster zone councils can determine the time of day during which fishing can occur, most likely to prevent night fishing, which is more difficult to monitor for noncompliance.

Each fishery is also subject to state-level conservation rules. The lobster fishery is subject to conservation practices for which the industry is well known including prohibitions on harvesting large, reproductive lobsters and juvenile lobsters. The soft-shell clam and scallop fisheries are subject to minimum size limits, and the river herring fishery is limited to fishing four days per week. Each of the four fisheries includes an owner-operator requirement; fishing activity cannot be delegated and must be conducted by the license holder. In addition, the selling or transfer of licenses is prohibited. Both policies prevent consolidation of fishing activity into larger businesses with different incentives than owner-operators,[10] and also help ensure the retention of local knowledge in the fishery. Such statewide measures likely contribute to the sustainability of these fisheries; a link between statewide regulations and upper levels in the hierarchy of subpopulations can only be assumed.

While a range of factors may have contributed to the dramatic rise in lobster abundance and landings since the 1980s, the conservation strategies of the lobster industry have likely had a significant impact (Acheson and Gardner 2010). The restoration of fish passage has had a dramatic and clear impact on the productivity of river herring runs. In the soft-shell clam and scallop fisheries, the relationship between local management strategies and fisheries productivity is less obvious and has not been as closely studied. The support of harvesters in these fisheries, however, is indirect evidence of management effectiveness.

The layering of state and local strategies appears to mirror the hierarchies of interconnected subpopulations and may reflect a combination of local larval retention, affected by local strategies, and larval delivery from adjacent areas, affected by statewide policies.

The lobster fishery meets all the conditions described by Ostrom as necessary for effective comanagement.[11] The soft-shell clam, river herring, and scallop fisheries appear to benefit from comanagement even though they meet Ostrom's conditions only to varying degrees. The scallop fishery lacks the most basic of Ostrom's conditions: territorial boundaries. Long travel times from one zone to the next

and barriers to fishing for nonlocals in Cobscook Bay may effectively confine scallop fishermen to one of the three zones. The management of stream flows by river herring fishermen may make up for their lack of a role in decision-making at state and regional levels. A greater degree of local larval retention may allow local shellfish conservation practices to be particularly effective. Despite the high value of both soft-shell clams and scallops, and with some exceptions in the soft-shell clam fishery, the river herring, soft-shell clam, and scallop fisheries contribute to but don't solely support full-time individual fishing livelihoods for fishermen. The growth of these fisheries to support larger numbers of fishermen could create more pressure to sustain harvests and lead to the further refinement of comanagement practices.

The collapse of significant components of the lobster, scallop, and river herring fisheries created incentives to rebuild these fisheries, and the overharvesting of clam flats had a similar effect at the local level. Recovery in each case has led to the establishment or renewal of comanagement and has reinforced its value. Fishermen support local and statewide rules when they fit their understanding of stock dynamics because they perceive that such measures correlate with greater success in their fisheries.

Comanagement facilitates cooperative research, which plays an important role in resolving conflicts over the different ways that fishermen and scientists view fish population dynamics and ecosystem processes (Ebel et al. 2018). DMR recognizes the vital importance of cooperative research in improving fisheries outcomes and addressing climate impacts. The department has developed trusted partnerships with members of the fishing industry that support long-running programs such as lobster sea sampling and the Maine-New Hampshire Trawl Survey (Waller et al. 2023). Cooperative research has also been facilitated by the University of Maine and nongovernmental organizations, including Manomet and the Maine Center for Coastal Fisheries.

These and other organizations support fishermen's efforts to engage in management and often act as bridging organizations between DMR and industry groups (e.g., Gulf of Maine River Herring Network and Maine Shellfish Learning Network).[12] Such efforts support changes in fisheries policies at higher levels of governance and align comanagement more closely with Ostrom's conditions.

CONCLUSION

Four fisheries in Maine suggest that comanagement is an effective approach to conservation. Comanagement helps integrate fine-scale information on fisheries population dynamics with government responsibility for oversight of fisheries at a broader scale. Limits on fishermen's ability to expand their territories shift incentives from maximizing harvests in the short term (by moving to another place) to ensuring that local harvests can be sustained over the long term. The lack of boundaries on fishing territories has dominated overfishing in almost all cases around the world. Limits on group membership and other constraints on effort limit the risk of overharvesting. Sharing of information among fishermen results in a collective understanding of fish subpopulation dynamics and allows for testing the effectiveness of conservation strategies. Granting even limited authority for decision-making to the local level allows for local action, such as clam flat closures based on local knowledge, that would be difficult for the state to manage. The emergence of local adaptive capacity also allows groups of fishermen to respond to a range of external threats including climate change, use conflicts with offshore wind power projects, and efforts to protect endangered species. Collaboration with nonprofit organizations and other policy entrepreneurs facilitates changes to fisheries policy that enable the expansion of comanagement practices. Comanagement does two important things that top-down management does not: it creates incentives for conservation and sustainability and generates the required information.

Looking ahead, comanagement could be explored as a tool for improving other Maine fisheries, such as for urchins (Ovitz and Johnson 2019); resolving tensions between the market-based approach of traditional fisheries management and Wabanaki sustenance lifeways practices (MITSC 2022); incorporating an ecosystem-based approach to management (Cucuzza et al. 2021); and transitioning from a single-species, broad-scale management to a multispecies management approach within areas congruent with population and ecosystem structure (Nguyen Thi Quynh et al. 2017).

While there is no guarantee that comanagement will allow the lobster, soft-shell clam, river herring, and scallop fisheries to weather the challenges they face, such efforts to date make clear that this approach is more effective than the top-down, model-driven approach of standard broad-scale fisheries management.

NOTES

1 In this article, references to fish refer to both fish and shellfish.

2 The use of a socio-ecological systems framework is now pervasive in the study of natural resources.

3 Recruitment is the process by which fish reproduce and mature.

4 Ecologists refer to such populations as metapopulations.

5 See article by James Wilson in this volume: https://doi.org/10.53558/LEPX2678.

6 https://www.maine.gov/dmr/fisheries/commercial/fisheries-by-species/lobsters/maine-lobster-fishing-license-and-trap-tag-counts

7 https://coastalfisheries.org/collaborative-management/scallops/

8 https://www.fisheries.noaa.gov/bulletin/noaa-fisheries-announces-final-rule-amendment-21-atlantic-sea-scallop-fishery

9 Scallop comanagement in Japan includes both a wild fishery and aquaculture (Kosaka 2016).

10 For example, the captain of a fleet fishing vessel whose job and reimbursement depend on consistently generating profits for the owner has shorter term incentives than an owner-operator in a co-managed fishery.

11 This is not surprising given the role that the lobster fishery played in Ostrom's findings regarding commons more generally.

12 https://www.gomriverherringnetwork.org/; https://themudflat.org/the-msln-team/

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