Special Section

Fish, People, and Systems of Power: Understanding and Disrupting Feedback between Colonialism and Fisheries Science*

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ABSTRACT: This essay explores shifting scientific understandings of fish and the evolution of fisheries science, and it grapples with colonialism as a system of power. We trace the rise of fisheries science to a time when Western nation-states were industrializing fishing fleets and competing for access to distant fishing grounds. A theory of fishing called "maximum sustainable yield" (MSY) that understands fish species in aggregate was espoused. Although alternatives to MSY have been developed, decision-making continues to be informed by statistical models developed within fisheries science. A challenge for structured management systems now rests in attending to different systems of knowledge and addressing local objectives, values, and circumstances. To deepen and illustrate key points, we examine Pacific herring (*Clupea pallasii*) and the expansion of commercial herring fisheries and state-led management in British Columbia, Canada. A feedback between colonialism and fisheries science is evident: colonialism generated the initial conditions for expansion and has been reinforced through the implementation of approaches and tools from fisheries science that define and quantify conservation in particular ways. Some features may be unique to the herring illustration, but important aspects of the feedback are more broadly generalizable. We propose three interconnected goals: (*a*) transform the siloed institutions and practices of Western science, (*b*) reimagine and rebuild pathways between information (including diverse values and perspectives) and decision-making, and (*c*) devolve governance authority and broaden governance processes such that multiple ways of knowing share equal footing.

Keywords: geopolitics, governance, political economy, population modeling, scientific management.

Introduction: Science and Systems of Power

Science is not separate from or neutral to power. Questions are chosen and research is conducted in the context of political-economic structures and processes, often those built and shaped by nation-states. In turn, systems of power are established and reinforced as understandings of the world emanating from disciplines are adopted, espoused, and integrated into the institutions that claim authority to manage "the environment" and "natural resources" (Silver 2013; Todd 2018). In their book, *Pollution Is Colonialism*, Max Liboiron (2021) theorizes this in terms of sets of relations that humans have with each other, with other-than-human species, and the world around us: "land relations *always* already play a central role in *all* sciences, anticolonial and otherwise" (p. 6; italics ours).

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In this essay, we explore shifting scientific understandings of fish and the evolution of fisheries science, and we grapple with colonialism as a system of power. We trace the rise of fisheries science to a time when Western nation-states were industrializing fishing fleets and jostling competitively for access to distant fishing grounds. A theory of fishing called "maximum sustainable yield" (MSY) was espoused within international settings and institutionalized within state legislation. Today, alternative target and limit reference points (biological metrics to achieve, maintain, or avoid breaching) and harvest control rules (guidance that dictates when to/not to fish and how much to harvest) are often used in conjunction with or as alternatives to MSY. However, decision-making continues to be largely informed by statistical models developed within fisheries science. To deepen and illustrate key points, we examine Pacific herring (*Clupea pallasii*) in British Columbia. We argue that colonialism generated the initial conditions for commercial expansion and has been reinforced through the implementation of approaches and tools from fisheries science. In the "Discussion and Conclusion" section, we propose three interconnected goals and identify points of disruption where transformation is urgently needed.

Who Are We and How Do We Understand Colonialism?

Following Kim Tallbear's (2014) invitation to think about collaboration as being/holding accountable, we begin with a brief positionality statement. We are an interdisciplinary team composed of Indigenous and non-Indigenous scholars, scientists, and practitioners. We come from a variety of different academic disciplines and professional backgrounds. Collectively, we have many decades worth of experience with fisheries science and policy, marine ecology, and coastal communities. We are all actively involved in research and partnerships that aim to support Indigenous First Nations and other groups representing coastal communities, although we recognize that we are each differentially positioned and bring distinct experiences, privileges, and biases to the table as a result. Indigenous peoples have been traversing, relating to, cultivating, and harvesting from territorial lands and waters since time immemorial. Indigenous knowledges about the oceans—and the other-than-human species that live in them—combine breadth and depth in ways that are unparalleled in Western science and social science.

The term "colonialism" refers to the intended conquest and control of other territories. People and societies pre-exist colonial arrivers and settlers, so the appropriation of lands, waters, and "resources" is central to colonialism and to understanding it as a system of power (Alfred and Corntassel 2005; Wolfe 2006). Because of the intent to appropriate, dispossession is always involved; over time, physical violence and genocidal intent can then become sanctioned through laws, nation-state institutions, and dominant cultural norms and values (Wolfe 2006; Lloyd and Wolfe 2016). Histories and experiences of colonization are unique to place, and it is not possible to generalize a singular variety or perpetrator of colonialism (Harris 2004; Coulthard 2010). However, Western European colonialism is a globally impactful system of power and relevant to understanding contemporary dynamics because countries like Britain, France, and Spain aggressively expanded empires across multiple continents into the early to mid-1900s.

Indigenous thinkers and scholars of settler colonialism make many important observations in the context of Western industrialized settler-colonial states like Canada, the United States, New Zealand, and Australia. Several have informed our approach to this essay, especially points within the herring illustration. First, multigenerational and place-based histories inform complex Indigenous laws and hereditary governance systems (Menzies 2010; McGregor 2018; Todd 2018). Second, a key objective of colonialism is to sever Indigenous relationships with territorial lands and waters and usurp Indigenous laws and governance systems (Alfred and Corntassel 2005; Whyte 2018). Third, arbitrarily distinguishing a "colonial past" from a "postcolonial present" in Canada and other settler-colonial states is not useful because the present-day contours of law, society, and science are founded on ideas, practices, and institutions formative to European colonialization (Harris 2004; Wolfe 2006; Whyte 2018). Fourth, colonialization is and will always be incomplete because Indigenous peoples resist and persist (Simpson 2014, 2017; Atleo 2018; Todd 2018; M'sɨt No'kmaq et al. 2021).

Shifting Scientific Understandings of Fish and Fisheries

At the height of British imperialism, a number of prominent scientists asserted that fish were inexhaustible (e.g., British comparative anatomist T. H. Huxley, quoted in Sims and Southward 2006). Consensus that fishing directly impacted fish, perhaps altering population structure and behavior, began to build in the early twentieth century (Smith 1994; Hubbard 2014). Reproductive biology was a prevalent topic of study, and cutting-edge questions were emerging about the relationship between fishing practices (e.g., seasons, size selection) and fish population dynamics. Measures (e.g., of sexual maturity) and indices (e.g., growth rates, size at maturity) were benchmarks to compare between different populations and species.

By the 1940s, the idea that fisheries may have biological limits was gaining ground. At the same time, a handful of

Western countries were actively building and subsidizing industrial fishing fleets. These states sought to maximize annual catch close to home and to expand into distant waters perceived to be underutilized. Finley and Oreskes (2013) pinpoint the recognition of population-scale biological limits and expansionary interests as a critical moment in the emergence of fisheries science as a discipline and an ongoing source of contradiction in the management of fish. They summarize: "where [established fisheries biologists E. S. Russell and M. Graham] saw a biological problem, the British Foreign Office and the US State Department saw territorial ones. For both governments, fishing was tied to the freedom of the seas, historic patterns of use, and territorial claims" (Finley and Oreskes 2013, p. 246).

A landmark book, *On the Dynamics of Exploited Fish Populations*, was published by Raymond Beverton and Sidney Holt in 1957. It was lauded as the first comprehensive numerical treatment of the relationship between fish and fishing (Finley 2011; Raicevich et al. 2021). Hired by M. Graham "to devise improved fishing equations" (Hubbard 2014, p. 372), Beverton and Holt developed four variables to describe the dynamics of units called "fish stocks": recruitment, growth, capture, and natural death. Researchers pursued the statistical estimation of basic mathematical models that could be used to identify and project equilibria within single-species populations of fish. With this, fish were understood as a uniform aggregate and frequently discussed as stocks and in terms of biomass able to support consistent year-after-year "yields." Previously unfished stocks were asserted to respond positively to an initial level of fishing: "the faster and more intensively a virgin stock is fished, the faster the remaining fish grow and reproduce" (Parsons 1993, p. 43).

By the mid-1970s, fisheries science was burgeoning and understood as distinct from other ocean-oriented disciplines, such as oceanography and marine ecology. Through to the end of the twentieth century and into the early twenty-first, the focus was on refining and expanding statistical models for different species and circumstances, including integration of the ecological principle that populations may not be governed by equilibrium expectations (i.e., dynamics are stochastic, as in Kell et al. 2005; Fisheries and Oceans Canada [DFO] 2020). To address various complexities, the toolkit has expanded to include catch-at-age models (statistical models used to estimate dynamics from catch and/or survey data, as in Fournier and Archibald 1982; Deriso et al. 1985), state-space models (statistical models that disentangle trends in latent biological states over time, such as true population sizes, from observation error, as in Newman 1998), integrated analysis (models that statistically integrate multiple disparate data sets to simultaneously estimate dynamics, as reviewed in Maunder and Punt 2013), Bayesian methods (integration of prior knowledge and probabilistic uncertainties, as in Millar and Meyer 2000), spatial methods (as reviewed in Goethel et al. 2011), multispecies and ecosystem models (as in Plagányi et al. 2014; Heymans et al. 2016), and nonmechanistic or empirical forecasting methods (models that make no structural assumptions about population dynamics but are instead focused on short-term prediction, as in Ye et al. 2015).

Fisheries Industrialization and the Early Life of MSY

Historians have characterized fisheries industrialization as "frenzied" (Hubbard 2014, p. 374), driven after World War II by state subsidies, geopolitical desires, and the expansion of capitalism (Bavington 2011; Finley 2011; Campling and Havice 2018). In 1945, the United States unilaterally adopted the Truman Proclamation, "declaring that it had the right to establish conservation zones to protect fish in the high seas contiguous to the US coast" (Finley and Oreskes 2013, p. 246). This "reflected the intent of the US federal government to expand the American fishing fleet in the equatorial Pacific and in Alaska's Bering Sea" (ibid). A month after the proclamation was issued, Mexico announced an expanded domestic fishing territory; Argentina, Chile, Peru, and Costa Rica followed. Korea filed territorial claims in response to Japanese fishing, and the Soviet Union claimed extended domestic fishing territory in the Barents Sea.

Countries took different positions on governance as more and larger boats came online, onboard freezing capacity meant they could travel further, and global catch increased. In 1953, the International Law Commission recommended that each nation's territorial seas be expanded from three to six miles and that a new international organization be formed within the United Nations to generate science on transboundary fish stocks and settle fisheries disputes. Coastal countries in the global south agreed, calling for the extension of territorial seas even further than six miles to better protect their domestic fisheries. The United States objected to the recommendations, and they suggested other Western countries do the same (Finley 2011; Finley and Oreskes 2013). The US stance, expressed at an international technical conference in 1955, was that "freedom of the seas" was paramount (Finley 2011). Representatives asserted that this geopolitical position was supported scientifically by a theory of fishing called "maximum sustainable yield."

The genesis of MSY has been documented widely, including reflections written by Sidney Holt later in his life (also see Larkin 1977; Bavington 2011; Finley 2011; Hubbard 2014; Raicevich et al. 2021). Holt (2011) locates the initial idea to 1933 with three Norwegian biologists who were studying blue and fin whales. It was taken up by Milner Schaefer in the 1950s and developed for California sardine and yellowfin tuna of the central-eastern tropical Pacific (Schaefer 1954). Holt (2011) recounts: "Using—actually, mis-using—Verhulst's equation—which was specifically constructed to deal with numbers of humans or animals—he [Schaefer] fitted a symmetrical parabola to his data by a standard but simplistic statistical procedure and concluded that its peak—by definition at the centre of his graph long the x-axis going from zero to carrying capacity—was 'maximum sustainable yield'."

Schaefer's ideas took hold among fisheries scientists in Britain, Canada, and the United States. Estimating the parameters and calculating MSY for stocks around the world was a driving objective (Finley and Oreskes 2013, p. 247). More broadly, MSY influenced thinking about other harvested populations (e.g., trees, animals hunted for game or food) and became an early "central concept in population ecology" (Lundström et al. 2019, p. 373).

MSY was attractive from a managerial standpoint. This is because it could be derived irrespective of social and ecological context: estimate the equilibrium and exploit the "surplus production" of a stock about this equilibrium. Analysis of the 1955 technical conference (Finley and Oreskes 2013) demonstrates that it was quickly put to political work in support of Western access to distant fish stocks. One of the US State Department's main objectives for this meeting was to prevent international laws from curtailing access to "underexploited" stocks. The United States was successful, reflected in the conference outcome document's call for "countries to fish without restrictions until critical biological points had been reached" (Finley and Oreskes 2013, p. 248). Furthermore, "the burden of proof was on the nation requesting action to limit fishing, and that proof had to come from scientific studies. Since only the USA and Europe had the necessary scientific capability, this policy effectively excluded most nations—particularly the Latin American ones—from challenging the US" (ibid).

It would take roughly another 20 years for the UN Convention on the Law of the Seas to be negotiated and ratified, including extension of nation-state sovereignty to 200 nautical miles offshore (i.e., "exclusive economic zones" [EEZs]). By then, "the basic idea [of MSY] was enshrined in national policy documents, incorporated into international treaties, and, in effect, became synonymous in most people's minds with sound management" (Larkin 1977, p. 2).

Questions about the challenges and limitations of MSY grew in the 1970s (Larkin 1977; Holt 2011; Lundström et al. 2019). Alternative target and limit reference points and harvest control rules, a number of them derivatives of MSY, were developed. Fisheries science remained grounded in the statistical description of single species; the false sense that scientific management "could finally predict and control fishery fluctuations" flourished within academia and state agencies (Bavington 2011, p. 26). The scope of state-led fisheries science and bureaucracy expanded in many countries, including settler-colonial states such as Canada, Australia, the United States, and New Zealand. Issues like coastal jurisdiction, marine ecosystems and conservation, and the socioeconomic conditions of coastal communities were also recognized. However, they were often separated from fisheries and placed under different agency divisions and pieces of legislation (e.g., division between state and federal waters in the United States, tensions and gaps between the Fisheries Act, the Oceans Act, and the Species at Risk Act in Canada).

Advances in ecology and evolutionary biology over the last half century also raise questions about the potential for single-species models and objectives to underestimate the risks of harvesting on populations and ecosystems. From the population perspective, some examples include hyperallometry (i.e., older/bigger fish contribute more reproductively per gram, with higher mortality and size selectivity leading to lower productivity and resilience, as in Marshall et al. 2021), selective pressures on life history traits (e.g., effects of overall mortality and size-selectivity rates on evolution of maturation and growth characteristics, as in Heino et al. 2015; Hutchings and Kuparinen 2021; Pinsky et al. 2021), and the importance of spatial structure in affecting both perceived and realized productivity (e.g., Berkeley et al. 2004; Kerr et al. 2017). From the ecosystem perspective, some examples include an understanding of "excess production" as biomass available for other-than-human predators and human fisheries (Mangel and Levin 2005) and that accounting for community dynamics often suggests the need for different forms of management and conservation intervention, including the size and placement of marine protected areas (Mangel and Levin 2005; Kaplan and Marshall 2016; Townsend et al. 2019).

Pacific Herring: Indigenous Fishing, Industrialization, and Scientific Management in British Columbia, Canada

Indigenous peoples have lived in the place now known as "British Columbia, Canada" for more than 14,000 years. Multigenerational and place-based histories inform Indigenous laws and hereditary governance systems (Menzies 2010; Atlas et al. 2021). A wide range of coastal and ocean cultivation, fishing, and management techniques existed, including (but not limited to) weirs and traps that work with tides and seasons (Atlas et al. 2017, 2021), estuarine root gardens (Deur et al. 2013), juvenile fish transplant (Thornton 2015), and terraced rock walls that extend intertidal clam habitat (Groesbeck et al. 2014). Pacific herring were, and continue to be, critical to Indigenous trade, food, nutrition, social relationships, and ceremony (Gauvreau et al. 2017). An important resource form is herring "roe-on-kelp" or "roe-on-branch." Named after the harvest technique, kelp strands, cedar, or hemlock branches are laid out during spring spawning events and removed after several herring egg layers have been deposited. Herring themselves were caught using dip nets and fish rakes (Newell 1993). The remainder of this section deepens and illustrates points from earlier parts of the essay by tracing key moments in the colonization of British Columbia, detailing the expansion of commercial herring fisheries and describing some important and contested aspects of state-led herring management.

European explorers began arriving in the mid- to late 1700s, Britain established the colonies of "Vancouver Island" and "British Columbia" in the mid-1800s, and British Columbia officially entered Canada as a new province in 1871. Outside a couple of instances, colonial officials did not pursue treaties that articulated agreements with Indigenous peoples (Harris 2004). Systems of "Indian reserves" (hereafter, "reserves") and "Indian residential schools" expanded throughout this period (ibid). To usurp Indigenous laws and hereditary governance systems, agents of the Canadian government were empowered to install elected "band councils" on each reserve. An important Indigenous governance practice called the potlatch was banned in 1885; the ban was not lifted until 1951. Canadian government officials planned the network of small and remote land-based reserves in British Columbia based in part on the false premise that "Native Peoples on the Pacific coast were primarily fishing peoples who did not need a large land base" (Harris 2009, p. 6). However, federal interest in developing a commercial fishing economy intensified quickly. Skill in fishing and the location of many reserves near productive fishing grounds meant that many Indigenous peoples participated in nascent commercial fisheries for salmon, herring, and halibut (Newell 1993). Involvement necessitated capital investment in European-style vessels and gear because Indigenous techniques were criminalized: "the state and its administrative agencies and courts" characterized "Pacific Coast Indian fishing traditions as destructive" (Newell 1993, p. 4; also see Silver 2013).

Across the north Pacific rim, large-scale herring reduction fisheries operated between the late 1800s and 1960s. In 1955, the Canadian Fisheries Act was amended to prohibit Indigenous peoples from harvesting roe-on-kelp/branch for commercial sale: "[p]rohibiting the harvest and sale of herring spawn, [DFO] officials argued, was essential to conserve herring stocks" (Harris 2000, p. 205). Yet between 1948 and 1962, annual landings from the Canadian Pacific herring reduction fishery increased from 1.5 to 11.9 million tonnes (Newell 1993), and the fishery is estimated to have removed 60% of the stock on average each year (Taylor 1964; Schweigert 1993). Herring stock collapses occurred from Japan to Alaska and down the US West Coast; collapse off of British Columbia led DFO to close herring reduction fishing in 1968 (Hourston 1980; Schweigert 1993; Trochta et al. 2020). Although many herring populations rebounded, some smaller subpopulations never recovered (e.g., Skidegate Inlet within the traditional territory of the Haida First Nation, as discussed in Jones 2000). Commercial roe herring fisheries using seine nets and gillnets were permitted to open in 1973 in response to demand from Japan for "sac roe" (i.e., full egg sacs removed from harvested female fish).

There are three important time lines to consider at this juncture (fig. 1). Given the troubling details of British Columbia's early history, including direct actions to usurp Indigenous governance, assimilate Indigenous children, and criminalize Indigenous fishing, we contend that it is erroneous to understand colonialism as separate from commercial fishing and management in British Columbia (in orange). In the case of Pacific herring specifically, large volumes of herring biomass were harvested each year during the reduction fishery at the same time that laws and policies criminalized Indigenous fishing practices as a conservation threat and oppositional to industrialization and "modernizing" the marine economy. Colonial acts severed Indigenous relationships with territorial lands/waters and restricted Indigenous access to herring and other fish. These were critical keys to the initial expansion of commercial fisheries. As we will show through the rest of this section, colonialism has not simply disappeared. Although more nuanced in some ways, colonial processes and inequities have entrenched as fisheries have industrialized and approaches and tools from fisheries science have been implemented (in green and blue).

Corresponding with the broader history of fisheries industrialization and science from the last two sections, the late 1960s marked a transition in Canadian fisheries management where "government became increasingly involved in determining who could fish, where, when and how" (Parsons 1993, p. 2). In 1976, Canada announced that MSY would no longer be the guiding management principle and that the "best use" of society's resources would guide decisions: "While it lacked specificity, the 1976 Policy was the first comprehensive attempt to propose objectives for the entire fisheries system" (Parsons 1993, p. 67). Fisheries had been managed federally since the late 1800s, but DFO was now empowered and publicly accountable for articulating objectives, conducting science, and answering for the social, economic, and conservation outcomes of fisheries management. Government scientists were charged with generating evidence and providing advice to the federal fisheries minister, who in turn signed off on decisions

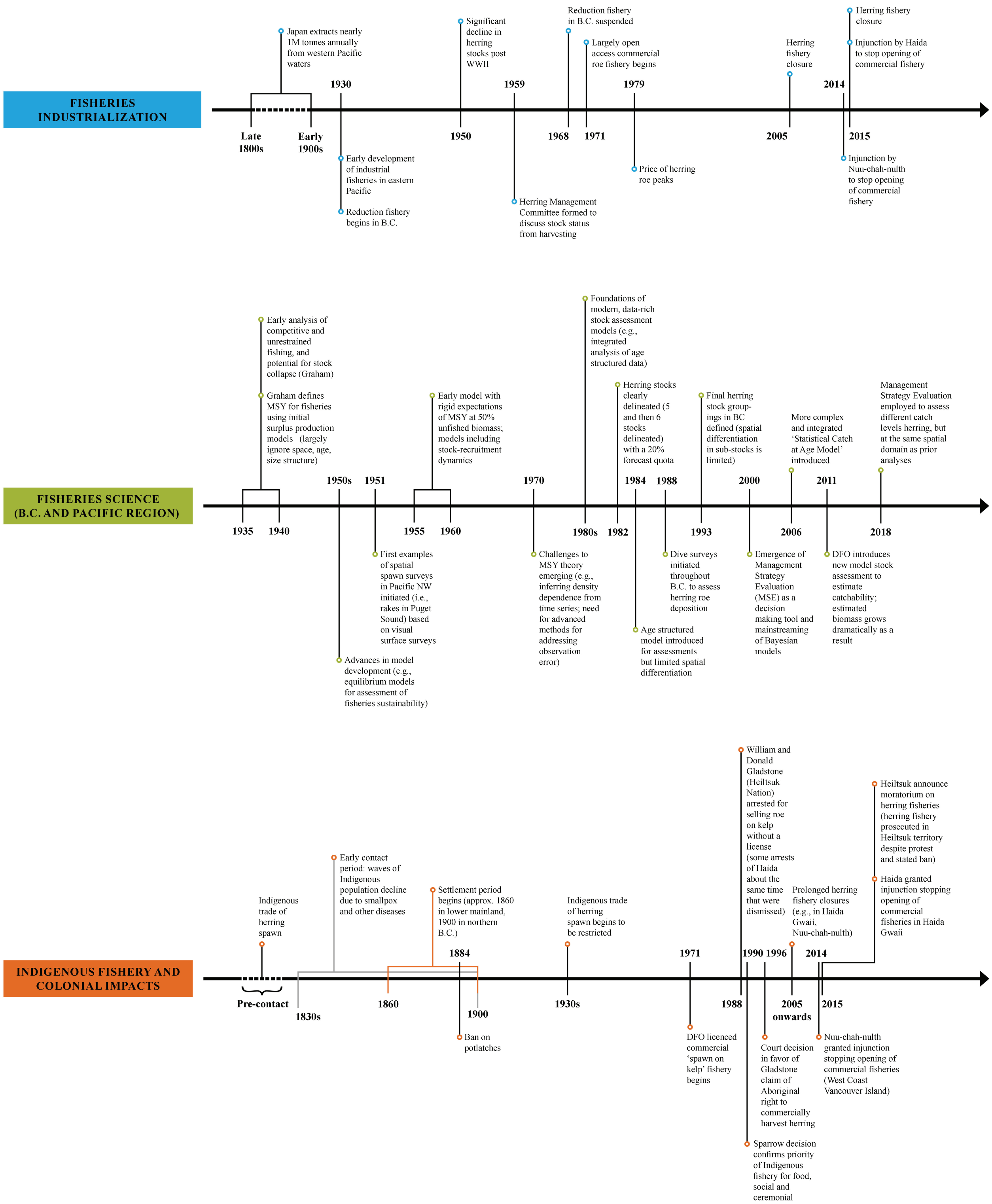

Figure 1: Three time lines critical to understanding feedback between colonialism and fisheries science in the Pacific herring illustration. In orange, we see moments in Indigenous histories, fisheries, and colonial acts. In green, we see broad developments in fisheries science and approaches and tools implemented in Pacific herring management. In blue, we see key moments in the industrialization of Pacific herring fisheries. Illustrated by Sevil Bernji. B.C. = British Columbia; DFO = Fisheries and Oceans Canada; MSY = maximum sustainable yield; WWII = World War II.

such as openings and total annual allowable catch for each fishery. Science and management were centralized and hierarchical.

Restructuring fisheries to reduce the number of participants and sustain harvests and profitability for those who remained was equated with best use. In pursuit of this objective, DFO adopted limited entry policies for several key fisheries, including Pacific herring throughout the 1970s. This meant that no new licenses would be issued and that existing ones were not necessarily replaced when license holders exited (Brown and Joyce 1994). Like many fisheries, limited entry and pooling of licenses is a key mechanism employed to try and prevent overfishing, reduce the number of vessels, minimize conflict among those that remain, and improve aggregate economic efficiency. At the same time, it serves to exclude individuals from commercial fishing and make it challenging for young and other new entrants (Silver and Stoll 2019). Commercial roe herring licenses have concentrated into fewer hands, especially since the 1990s (Haas et al. 2016).

With reference to conservation concerns, DFO began to revise the Pacific herring management framework in the 1980s. Fournier and Archibald's (1982) integrated catch-at-age analyses (i.e., statistical models that integrate age and biomass data from both fishery-independent surveys and catch statistics) were adopted, which eventually evolved into the current state-of-the-art modeling framework used across a number of fisheries (Quinn and Deriso 1999; Methot and Wetzel 2013). The system moved from a constant escapement strategy (i.e., ensuring at least a minimum number of fish spawn) to a target fishing mortality rate for each stock (harvesting 20% of forecast biomass, well below estimates for fishing mortality associated with MSY; Martell et al. 2011). Five spawning areas (and later six) were defined as broad-scale management areas (Stocker et al. 1983). In 1986, a cutoff was adopted to close the fishery if forecasts fell below 25% of estimated "unfished biomass" (B_0 [Haist et al. 1986]; adjusted to 30% in 2019 [Kronlund et al. 2018]). These changes were deemed biologically conservative via simulation testing (Hall et al. 1988) and are now evaluated using management strategy evaluation, where harvest strategies are compared through computer simulation (e.g., as in Punt et al. 2016). At face value, this structured system presents as precautionary and adherent to best practices in fisheries science.

Yet numerous concerns about Pacific herring science and management are expressed by Indigenous First Nations and others along the British Columbia coast. First is the assertion that roe herring fisheries affect important species that depend on them as prey, including salmon and halibut (Levin et al. 2016; Gauvreau et al. 2017; Jones et al. 2017). This issue has been broadly acknowledged by DFO, but roe herring harvest control rules do not formally consider ecosystem dynamics. Second, despite many technical advances in science and the management system, Pacific herring stock declines led to prolonged commercial closures in the traditional territories of many First Nations during the 2000s. A rebuilding plan for Pacific herring in Haida territory is being collaboratively developed by the Haida Nation and Canada, and the process has highlighted numerous Haida concerns about the structure of models and risk assessments. For example, impacts on Indigenous fisheries for food and livelihood receive no explicit treatment in models and management. Finally, Pacific herring models and management have not historically accounted for spatial dynamics at the scales at which traditional knowledge suggests populations are structured demographically (Jones et al. 2017; Gauvreau et al. 2017) and behaviorally (Rogers et al. 2018; MacCall et al. 2019). Risks of ignoring fine-scale spatial structure are shouldered uniquely by Indigenous nations and other coastal communities: commercial roe herring fisheries frequently concentrate herring removals from spawning areas important to local harvest and use (Okamoto et al. 2020*a*; Stier et al. 2020; also, recall the example of Skidegate Inlet earlier in this section). While the commercial fleet is mobile and may choose different areas from year to year, place-based communities rely on and have long-standing relationships with the same local and adjacent sites (Okamoto et al. 2020*b*).

Governance authority, particularly related to high-level decisions about fisheries, is another critical concern in British Columbia (as well as other regions in Canada; e.g., Piper 2009; Denny and Fanning 2016). The fisheries minister, who is federally elected and appointed directly by the prime minister, has considerable leeway to sign off on decisions even if they (*a*) contradict advice coming from agency scientists and/or (*b*) appear to contravene Supreme Court decisions that have found in favor of constitutionally protected rights held by some Indigenous nations to fish, lead management, and/or share in management of certain species or fishing areas (see Healey 1997; Harris 2000; Jones et al. 2017). For example, the federal fisheries minister opened roe herring fisheries in 2014 against evidence and advice generated by DFO scientists (reported in Secher 2014). The minister opted to open roe herring fisheries the next year, this time against the request of multiple First Nations, including the Heiltsuk First Nation, which had declared their traditional waters closed to the roe herring fishery. The opening sparked protests, including a multiday occupation of DFO buildings by Heiltsuk leaders and community members (Harper et al. 2018). The implementation of approaches and tools from fisheries science since the 1970s have helped to rebuild some British Columbia fisheries. However, an unequal burden of risks, top-down governance authority, and limited Indigenous access to herring for food and livelihood have entrenched.

Discussion and Conclusion

As fisheries industrialized around the world, countries clamored to extend their geopolitical reach, secure access to distant stocks, and protect domestic fisheries and fleets. For political-economic reasons, the United States and other Western countries strongly favored knowing and representing fish in aggregate and/or as biomass. Understandings and approaches from fisheries science developed and evolved, were taken up, and are now institutionalized within state-led agencies—notably, single-species models that feed into structured decision-making and evaluation processes. These outcomes are typically described as a matter of the best available science being eagerly adopted by state agencies concerned with economic development and responsible for conservation. However, following Liboiron (2021), it is vitally important to understand them as direct reflections of particular outlooks (i.e., hubristic and techno-optimist postwar ideas about "modernization"), sets of relations (i.e., capitalist), and objectives (i.e., the globalization and neoliberalization of food systems). All of this, as Liboiron persuasively argues, is underlain by the colonial and common Western scientific presumption of unfettered access to Indigenous lands and waters (also see McGregor 2018; Todd 2018).

The herring illustration echoes these points and reinforces that it is not meaningful or useful to distinguish between a "colonial past" and "postcolonial present" (Harris 2004; Wolfe 2006; Whyte 2018). Colonialism generated initial conditions for rapid fisheries expansion and has been reinforced through the implementation of approaches and tools from fisheries science that define and quantify conservation in particular ways and at particular (generally larger) social-ecological scales. The Western science–based management system now in place struggles to recognize and incorporate place-based observations, objectives, and values. Indigenous fishing techniques, several of them documented to have beneficial social and ecological advantages (e.g., Groesbeck et al. 2014; Atlas et al. 2021), are not generally permitted under the fisheries management system, which means that practicing them can lead to penalty and even arrest under Canadian law. Indigenous nations and others who relate to and rely on fish adjacent to their home communities shoulder unique risks, an issue that is persistently underacknowledged and deprioritized.

While some specifics may be unique to the herring illustration (e.g., harvest techniques and gear types, resource forms preferred in different markets, spatial dynamics of herring and different fisheries), at least three feedbacks between colonialism and fisheries science are more broadly generalizable. First, an implicit assumption appears to be built into the discipline of fisheries science, especially evident in modeling approaches and tools: the state is the appropriate authority to manage and articulate objectives for fisheries. This assumption is easy to appreciate because nation states are responsible for 200 nautical mile EEZs and are incentivized to support and subsidize fisheries that generate employment and income. At the same time, the assumption has implications for the scale at which fisheries scientists typically build, test, and refine models and for the reference points and performance metrics developed and recommended for decision-making and evaluation. Approaches and best practices straddle into (and, as in the illustration, are often formally housed within) state-led management.

Second, state-led fisheries management exacerbates colonial legacies and entrenches inequities, often in the name of best use and/or conservation. Research suggests this to be the case for other fisheries in Canada (e.g., Piper 2009; Denny and Fanning 2016), along with fisheries in countries like the United States (e.g., Richmond 2013), New Zealand (e.g., Bodwitch 2017), Australia (e.g., Lalancette 2017), and South Africa (e.g., Nielsen and Hara 2006). Inequities take common forms, including license and quota holdings concentrated with large vessels and/or nonfishing investors, the criminalization and/or marginalization of Indigenous fishers and fisheries (which, in turn, diminishes access to traditional and nutritious foods), and science and management processes that are inattentive or inaccessible to localized harvests, ecosystem dynamics, and other forms of knowledge. We have also seen that state agencies in many jurisdictions were established and have continued to evolve under shared political-economic and geopolitical circumstances. Countries with active domestic and distant-water fleets were and remain in competition with one another for access to fisheries and export markets, seek to enable and maintain high-volume fisheries, and often must rationalize negotiating positions in international settings and domestic management decisions to citizens. Therefore, the third and final generalizable point about feedbacks between colonialism and fisheries science is that the history and evolution of fisheries science cannot be understood separately from industrialization and neoliberalization as driven by colonial states/statecraft.

Perhaps the best way to describe the overarching "problem" is that practices of knowing, using, and governing other-than-human species and ecosystems become accepted only when formally enshrined through and culturally embedded within Western scientific disciplines, management agencies, and legal regimes. This is hegemony, and unfortunately a single-step "solution" does not exist. Although not an exhaustive list, we propose three urgent and interconnected goals: (*a*) transform the siloed institutions, practices, and culture of Western science; (*b*) reimagine and rebuild pathways between information (including

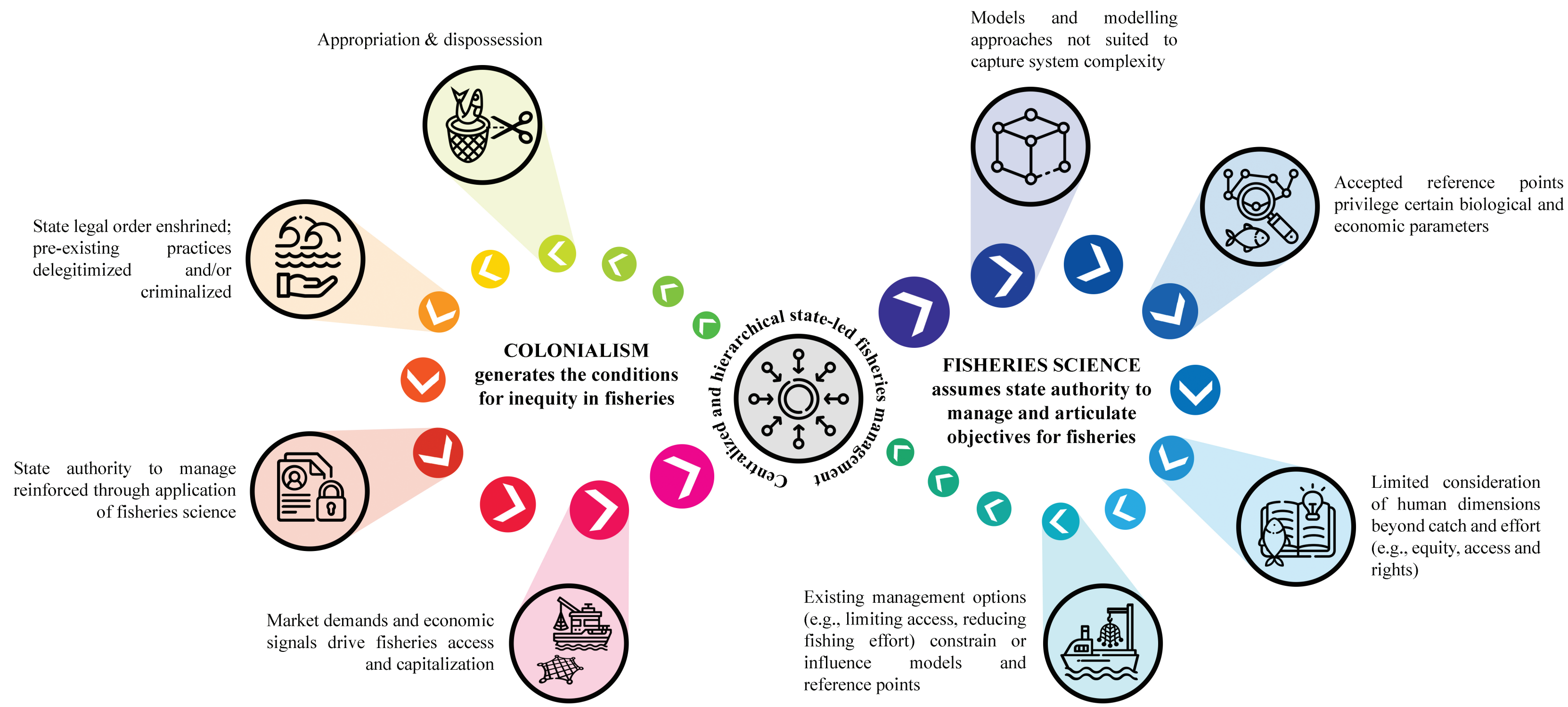

Figure 2: Feedback between colonialism and fisheries science, mediated through management led by a colonial state. Arrows trace generalizable aspects of the feedback, and small circles identify points of disruption. Illustrated by Sevil Bernji.

diverse values and perspectives) and decision-making; and (*c*) devolve governance authority and broaden governance processes such that multiple ways of knowing share equal footing. In figure 2, we illustrate the generalizable feedbacks between colonialism and fisheries science just summarized and identify points of disruption where work toward one or more of the three goals is needed.

We briefly discuss two of the small circles for illustrative purposes. "Appropriation and dispossession" calls attention to the central role of private property within colonialism and the tendency for non-Indigenous environmental governance regimes to prioritize privatization (e.g., license limitation and quota programs within fisheries). Efforts to design and implement devolved governance arrangements (e.g., comanagement) thus need to confront privatization, specifically the ways in which it redistributes access and often leads to concentrated ownership among a few. One opportunity is to consider how alternative and collective property models (Ostrom 1990) and Indigenous notions and practices of community economy (Atleo 2018) might be represented within models and better supported by adopting more diverse measures of success/well-being. "Models and modeling approaches not suited to capture system complexity" calls attention to the limited extent to which single-species models reflect ecological, evolutionary, and sociocultural properties. Efforts to develop ecosystem approaches and "braid" Western and Indigenous knowledges in the context of fisheries decision-making are underway (e.g., Levin et al. 2018; Reid et al. 2021). However, there are important institutional considerations if/as new types of models and modeling processes are adopted by state agencies (e.g., see Armitage et al. 2019). Three include shifting from "engagement" to "co-production" with a wider range of knowledge holders (Cooke et al. 2021), incorporating understandings and responding to criticisms from a broader range of disciplines and types of experts, and hiring new sorts of staff (e.g., community liaison persons, ecologists, evolutionary biologists, social scientists).

It is our hope that this essay reinforces the need for critical introspection and subsequent transformation across not just fisheries science but all Western scientific disciplines. A great deal of complexity rests in the fact that other-than-human species and ecosystems are important to people in place and that these people are embedded within genealogies, histories, and structures that shape their very experiences of "the state," "management," and "science." Building toward something different requires reimagining relationships and systems, in this case those that connect fish, people, and place. Engaging entrenched assumptions about what the appropriate scale of research and management is, who is the appropriate management authority, and what constitutes the best use of other-than-human species must be central to this work.

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Statement of Authorship

J.J.S.: conceptualization, funding acquisition, visualization, writing—original draft, writing—review and editing. D.K.O.: conceptualization, visualization, writing—original draft, writing—review and editing. D.A.: conceptualization, funding acquisition, visualization, writing—original draft, writing—review and editing. S.M.A.: conceptualization, visualization, writing—review and editing. C.A.: conceptualization, visualization, writing—review and editing. J.M.B.: conceptualization, visualization, writing—review and editing. R.J.: conceptualization, visualization, writing—review and editing. L.C.L.: conceptualization, visualization, writing—review and editing. E.-K.M.: conceptualization, visualization, writing—review and editing. A.K.S.: conceptualization, visualization, writing—review and editing. J.S.S.: conceptualization, visualization, writing—review and editing.

Data and Code Availability

No new data or code were generated for this essay.

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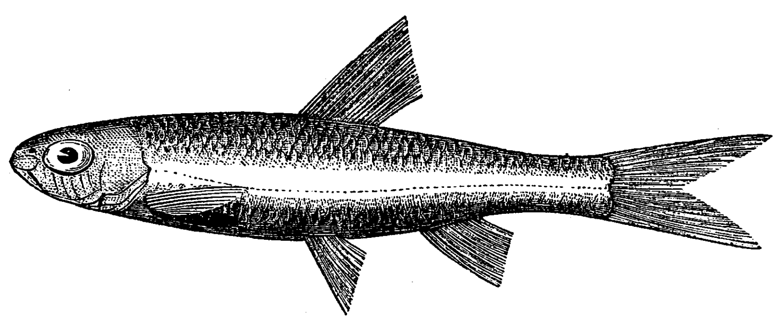

"During the past summer the author had no opportunity of fishing in the Raritan River, at or about New Brunswick, at which point the specimen was taken; but among a number of small collections from that river, no specimen of this cyprinoid occurred." Figured: "*Hybognathus*." From "Further Notes on New Jersey Fishes" by Charles C. Abbott (*The American Naturalist*, 1871, 4:717–720).