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Editorial

Ecosystem-Based Fishery Management in the Bering Sea

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1. Introduction

The waters of the Bering Sea are among the most productive on earth, having supported major commercial fisheries for up to ~60 years and First Nations cultures for millennia. Relatively lax initial management of these virgin fish stocks resulted in high and possibly unsustainable catches in the eastern Bering Sea until the US asserted jurisdiction within its exclusive economic zone in 1977. Concurrent with the rise of these commercial fisheries, there has been a continuing decline in the northern fur seal (*Callorhinus ursinus*) population on the Pribilof Islands in the Bering Sea, where nearly 80% of this species once congregated to reproduce. The population was designated as "depleted" by the US National Marine Fisheries Service in 1988 because it had declined to <50% of its 1950s peak of ~1.6 million, without evidence of a change in habitat carrying capacity [1]. In the early 1990s, interest in ways to incorporate the effects of fisheries on the ecosystems that support them increased [2]. Since then, accelerating environmental changes from global warming have intensified these concerns. The exploration and definition of ecosystem considerations with respect to fisheries management remain active fields of research and discussion, and incorporating these concerns into formal fisheries management actions is a continuing challenge [3]. With commercial fisheries being by far the greatest human-related perturbation, apart from climate change, in the Bering Sea, the effects of these fisheries on the marine ecosystem of the eastern Bering Sea are especially clear, with other perturbations from human activities likely negligible in comparison. Yet, even here, while ecosystem considerations are now routinely presented in fishery stock assessments, consensus on what constitutes ecosystem-based fishery management (EBFM) remains elusive [3]. In recognition, the primary goal of this Special Issue entitled "Ecosystem-Based Fishery Management in the Bering Sea" was to provide a discussion forum to further develop and promote EBFM in the Bering Sea.

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2. An Overview of Published Articles

The five articles included in this Special Issue present new scientific findings, a review of how the Bering Sea marine ecosystem responded to recent warming events, and a policy recommendation for advancing EBFM in the eastern Bering Sea. The article by Short et al. (contribution 1) presents evidence, for the first time, of an inverse correlation between the first-year survival of Pribilof northern fur seals and commercial catches of walleye pollock (*Gadus chalcogrammus*), the largest fishery in US waters. They suggest that competition between lactating fur seals and the commercial fishery for pollock reduces the nourishment available to fur seal pups, thereby lowering their survival probability during their first year of life, a view supported by bioenergetic considerations [4]. This correlation had previously been suspected but remained obscure owing to time delays between first-year mortality and subsequent effects on population size estimation. These findings are further supported by Divine et al. (contribution 2) who, using an Indigenous and local knowledge-based approach in conjunction with Western science methods, conclude that ecosystem changes and nutritional limitation are important drivers of recent declines in the Pribilof northern fur seal population. In particular, they note that pollock catch data indicate that there are concentrated areas of pollock harvest over time near the Pribilof Islands, where female northern fur seals forage. These observations provide additional support to the view that competition for pollock between the commercial fishery and lactating fur seals substantially contributes to lower pup survival. More broadly, they demonstrate the high value of Indigenous and local knowledge for a more general understanding of ecosystem processes.

The Pribilof northern fur seal population is far from the only commercially, economically, and socially important species with declining populations in the Bering Sea. Poor Chinook, chum, and coho escapements in recent years have had serious adverse socioeconomic effects on the First Nations peoples who depend on them as subsistence food sources. The article by Miller and Weiss (contribution 3) examines the influence of temperature and river discharge within the Yukon River basin on intra- and inter-annual variation in juvenile salmon phenology. Understanding how variations in phenology change with environmental heterogeneity is a critical first step in evaluating how the future climate may affect salmon, especially in high-latitude rivers, where the pace of climate change is nearly twice that of rivers in more temperate regions. They identified species-specific differences in the factors affecting migration duration, concentration, and skew in the time-distribution of migrating cohorts. This provides a starting point for a more detailed examination of how phenological variability may affect the temporal matching of juvenile salmon with the biological resources and environmental conditions required for optimal survival. A better understanding of these factors will be critical to determining the causes of recent declines in the survival or escapements of these species. Concurrently, the review of the marine heat wave that appeared in the Northeast Pacific Ocean in 2013 and its ecological effects as it passed through the Bering Sea by Belkin and Short (contribution 4) suggests that warm conditions lowered primary production during spring, increased the production of small copepods and jellyfish, and reduced the efficiency of energy transfer to higher trophic levels through the second half of the 2010s. These effects are consistent with other studies finding an escalation in the loss of sea ice during spring as global warming intensifies may dramatically decrease the overall productivity of the marine ecosystem of the Bering Sea within the next two to three decades.

Recognizing that such changes will challenge how managers balance the effects of fishery harvests and management adaptability with the resilience of the ecosystem, Wiese and Nelson (contribution 5) introduce a new conceptual framework to visualize and integrate the various aspects of the Bering Sea ecosystem into a holistic, socio-ecological management framework. They summarize their approach in a “Star Diagram”, which presents a conceptual model of a seasonally ice-covered marine ecosystem, linking climate policy and resource management to fishes and fisheries. The core of the approach comprises five linked factors: atmosphere, bottom-up processes, species interactions, fishes, and fisheries, each of which is characterized by attributes that interact across factors that may mechanistically combine to form drivers that act on other factors. Linked to the core system are three policy/management factors (climate policy, non-fish species management, and fisheries management), which enter the system at different points in the star diagram as top-down controls. This scheme provides a comprehensive context for dialogue and the management of complex ecosystems that support major commercial fisheries. Importantly, they provide concrete examples of how their management framework may be used to manage three important fisheries in the Bering Sea (pollock, benthic crab species, and sockeye salmon), which will all but certainly be adversely affected by continued warming in the region.

3. Conclusions

More holistic management frameworks are currently needed, and they will become even more necessary in the near future, as attempts to define and implement EBFM in the Bering Sea thus far have clearly been inadequate in terms of mitigating the adverse effects associated with the scale and pace of the warming climate. Early efforts characterized EBFM as “essentially reversing the order of management priorities to start with the ecosystem rather than the target species”, along with useful proposals to develop community and system-level standards, reference points, and control rules analogous to single-species criteria, as well as to embrace a precautionary approach wherein greater uncertainty would elicit more stringent management measures [5]. The failure to find general consensus on how these proposals could be defined, developed, and adopted has led to more recent suggestions that EBFM should be understood as a collection of management tools that can be selectively applied to better address the unique circumstances of particular fisheries and ecosystems [4]. However, it is unclear how such an empirical approach, unmoored to any foundational principles, could successfully justify, let alone implement, reductions in catches that might meaningfully promote species and community resilience in the face of increasing environmental uncertainty and accelerating warming.

As warming continues, the productivity of most harvested species in the Bering Sea is predicted to decline [6], and how best to manage these harvests in the face of such secular decline and associated community restructuring is the paramount management issue. Currently, EBFM measures applied to fisheries in the eastern Bering Sea include limited control of directed and incidental catches; prohibiting fisheries that target forage fish; the protection of habitat for fish, crabs, and marine mammals; temporal and spatial fishing controls; and a two-million metric ton cap on the combined catches of walleye pollock, Pacific cod (*Gadus macrocephalus*), and other groundfish. Yet, while prudent and welcome, these measures have not led to the recovery of the walleye pollock population in the international waters of the Bering Sea (aka the "Donut Hole") that was all but extirpated by overfishing by 1993 and has yet to recover, nor have they noticeably mitigated the abrupt collapse of the eastern Bering Sea snow crab fishery in 2021. Despite closures of subsistence fisheries for chum and Chinook salmon across Western Alaska in 2021 and 2022, salmon populations remain near all-time lows, with serious consequences for regional food security and traditional First Nations' ways of life. There have been no commensurate EBFM actions for reducing the lethal impacts of the commercial fishing on these stocks beyond limited efforts to reduce salmonid bycatch.

Looking forward, escalating warming may prompt consideration of management scenarios ranging from continuing or even increasing harvest levels across fisheries, to closing commercial fishing entirely. Justifications for increased harvest-level scenarios might note that since the economic viability of these commercial fisheries may be limited to the next few decades and extinguished thereafter, these resources should be exploited aggressively now while there are still economically viable stocks to exploit. Conversely, closing commercial fisheries would maximize the availability of exploited stocks for subsistence uses, prioritizing access by and support for First Nations peoples in the region, but it would forego commercial fisheries that generate billions of dollars of revenue, employ thousands of workers, and provide protein for millions of consumers. Clearly, neither of these extremes equitably balance the burdens that would result from lowered ecosystem productivity among stakeholder groups, nor are they consistent with prudent EBFM principles.

Finding an equitable balance of burdens borne by stakeholder groups affected by declining fishery resource availability of an uncertain magnitude and rate is fundamentally a risk-management problem. Here, prior experience and practice of managing these fisheries provides invaluable guidance regarding the application of the precautionary principle, an essential element of EBFM, as noted above [5]. Fisheries management in US waters of the Bering Sea has embraced this principle by adopting a tiered approach to setting catch limits, wherein target fishery stocks are assigned to tiers depending on the quality and quantity of information available regarding the population status and productivity of each stock [7]. Catch limits for stocks with lower quality or less information available are progressively restricted. This approach could be usefully generalized to manage risks and uncertainties associated with climate change. Specifically, the cap on total catches of groundfish could be further reduced to promote greater resilience of these stocks as warming proceeds, and similar caps introduced for other exploited species as well. In the case of groundfish, the implementation of the cap reductions could be achieved through time and area closures that would have the greatest effect on reducing the bycatch of salmonids, thereby leveraging efficacy across these species groups. The conceptual framework presented by Wiess and Nelson (contribution 5) provides an especially appropriate approach for achieving these management goals.

Conflicts of Interest: The author declares no conflict of interest.

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