
Climate Change, the Oceans, and the Business of Seafood: A View from the World's Largest Food Fishery

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With the ocean covering 71 percent of the planet's surface, it is requisite that discussion of the marine world should be part of any greater dialogue on anthropogenic (or human-induced) environmental impacts. Understanding oceanic dynamics, particularly in light of climate change, is imperative. The oceans are an important source of food globally; over 1 billion people depend on fish as their sole protein source.¹ In addition to nutrition, people around the world rely on seafood for their livelihoods. In 2012, roughly 58.3 million people were directly employed in the fisheries and aquaculture sectors, with the vast majority living in developing countries.²

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But overfishing is of serious concern, and to some, the message of “eat fish” can seem counterintuitive when placed without context next to warnings of dwindling fish populations. The global wild capture of fish exceeds 90 million metric tons, which significantly impacts marine environments.³ Larger issues of climate change and variability further intensify these impacts. The harvest of seafood can be improved, however, and have an immediate reduction on these negative oceanic impacts.

Working toward this goal is not only critical to ensuring ocean health in the future, but it is also intricately linked to issues of global food security, poverty, and viable livelihoods. Yet, better fisheries management through improved rule-making can have only limited effectiveness in the face of global climate change—ultimately, businesses, who themselves are vulnerable to the impacts of a shifting climate, have a key leadership role in mitigating and adapting to such impacts. To this end, an examination of the threats and opportunities to seafood businesses from the perspective of the world’s largest food fishery, walleye pollock, offers a useful framework for considering these dynamics. In particular, this article will explore the need for businesses to demonstrate their leadership, by mobilizing the seafood industry to help mitigate and even overcome the challenges posed by climate change. In turn, this mobilization will secure a robust seafood supply and healthy oceans for future generations.

The first section of this paper outlines the impact of climate change on the oceanic environment. In the second section, this paper examines the dynamics of climate change and ocean acidification as applied to the walleye pollock fishery. Finally, the third section outlines potential strategies to be employed by the seafood industry for mitigating the anticipated impacts of acidification and climate change in the future.

I. CHANGING SEAS

Anthropogenic oceanic impacts are difficult to predict, and our ability to do so is further obfuscated when combined with the current and projected impacts of climate change. Climate change and climate variability can both affect marine organisms and ecosystems in many different ways. Climate change refers to human-influenced, long term climate trends having a different trajectory from the normal fluctuations that may occur over time. Currently, the planet is in an unprecedented warming trend, largely driven by the high amount of carbon dioxide (CO₂) and other greenhouse gases accumulating in the atmosphere from human activities such as transportation, electricity generation, industrial processes, and agriculture.⁴

Climate variability, on the other hand, refers to natural seasonal and inter-annual fluctuations in climate, often caused by patterns and oscillations in global weather. Climate variability increases in the face of climate change. Both climate change and climate variability depart from normal oceanic conditions including but not limited to fluctuations in temperature (including sea surface temperature), timing and extent of sea ice cover, precipitation, and zooplankton blooms. Recent figures estimate that ocean surface water has warmed by approximately 0.11 degrees Celsius per decade between 1971 and 2010, while the average yearly Arctic sea ice cover has decreased over roughly the same period at a rate of 3.5 to 4.1 percent per decade.⁵

It is important to note that these environmental dynamics do not exist independently of each other, and they may often affect ecosystems in concert with one another. Climate change and variability will affect the seafood industry both directly (extreme weather events, increased temperatures, and changes in fish stock locations, biomass, seasonality, or growth rates)⁶ and indirectly (rising fuel and energy costs, increased incidence of disease, and increased energy use).⁷ The nature and scale of these impacts has yet to be fully determined.

Another outcome of increasing anthropogenic CO₂ emissions is the world's other major oceanic challenge: acidification. By absorbing about 30 percent of all anthropogenic CO₂ emissions from the atmosphere, oceans play a fundamental role in the earth's carbon cycle.⁸ As the amount of atmospheric CO₂ continues to increase from the combustion of fossil fuels and other anthropogenic activities, the amount of CO₂ dissolving in the oceans also increases. This drives a suite of well-studied changes in the ocean's chemistry collectively referred to as ocean acidification. Across the globe, the acidity of surface ocean waters today is 26 percent greater than in pre-industrial times, and surface ocean water acidity is expected to increase 170 percent from pre-industrial times by the end of this century if current CO₂ emission rates do not change.⁹

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Ocean acidification is anticipated to have major impacts on marine biodiversity by affecting the basic biological and physical processes of marine organisms. Through a loss in fishing and other basic uses of the ocean, one recent estimate places the potential cost of these impacts to the world's economy at over USD 1 trillion annually by 2100. This value is a

potentially conservative estimate, given that this figure does not account for the full range of ecosystem services provided by the ocean that could be impacted.¹⁰

II. THE SHIFTING LANDSCAPE OF FISH STICKS

With real economic and environmental costs on the line, the entire seafood industry has increasingly realized the need to take an active role in mitigating and adapting to the impacts of climate change and ocean acidification to protect the resources upon which they rely. Fishery managers have incorporated climate change and ecosystem considerations into management frameworks to varying degrees for some time. On the business side, there are risk management, reputation, and investment security perspectives to buffer their supply chains against the uncertainties of environmental volatility. These actions are foundational in developing and implementing a sustainability program. Yet the complex nature of these issues necessitates a multi-stakeholder approach to capitalize on the diverse expertise and skills of each group.

Increasingly, multi-party collaborations, especially corporate-NGO partnerships, have become an integral strategy in companies' corporate social responsibility and environmental sustainability policies. For example, the mission of the New England Aquarium in Boston, Massachusetts, is to address ocean challenges through education, research, and conservation initiatives. It partners with companies occupying unique positions in the supply chain—retailers, processors, importers, and food service providers—to help them develop, implement, and execute sustainable seafood policies and engage proactively to make positive changes in business practices.

Viewing these dynamics through the lens of the pollock fishery, the world's largest fishery for human consumption, provides an exceptionally informative model. Though perhaps not as well-known as the familiar canned tuna, bright pink salmon fillets, and imported shrimp the United States readily consumes, walleye pollock composes over 40 percent of the global whitefish production and consistently ranks as one of the top five species consumed in the United States.¹¹ A ubiquitous whitefish, pollock is transformed into a myriad of products, ranging from surimi (the source of imitation crab), to fish sticks, to the iconic McDonald's Filet-O-Fish sandwich.¹² The Bering Sea is a major fishing ground for pollock, stretching across both the U.S. and Russian exclusive economic zones. The Sea of Okhotsk in Russia offers another major pollock fishery.¹³ Harvesting around 3 billion pounds of fish annually in the last few years, the robust

pollock fishery in Alaska's eastern Bering Sea constitutes the largest fishery in the United States by volume.¹⁴

However, even this fishery is subject to a changing climate and fluctuating environmental variables. Though pollock fisheries in the North Pacific have been governed with sound management, they still display substantial interannual variability, largely due to fluctuating year classes in part caused by natural climate variability.¹⁵ Returning to the idea of climate variability, the Arctic Oscillation, Pacific Decadal Oscillation, and El Niño Southern Oscillation are all climate phenomena that have an effect on the North Pacific Ocean and the Bering Sea, affecting their ecosystems and inhabitants, including walleye pollock. The mechanisms behind these climate patterns are complex, but in general, they are thought to impact fish populations in many ways, including spawning and reproduction, abundance and recruitment (i.e., survival of juveniles until they enter the adult population), growth, distribution (i.e., where fish are) and migration, natural mortality, and catchability and availability.¹⁶

Box 1. *The Oscillating Control Hypothesis: A Deeper Dive on How Climate Variability Affects Walleye Pollock*

One conceptual model relating climate variability to pollock and other groundfish recruitment in the Bering Sea is referred to as the oscillating control hypothesis (OCH).¹⁷ In its original form, the OCH model predicted alternating bottom-up control in cold years and top-down control in warm years.¹⁸ In cold years, late sea ice retreat and low water temperatures were thought to limit production of zooplankton (a prey source for fish) and recruitment of fish, including pollock, leading to bottom-up control.¹⁹ In warm years, warm temperatures and early sea ice retreat were thought to lead to abundant zooplankton and favorable conditions for successful groundfish recruitment; these favorable conditions eventually benefited the growth and survival of predatory fish as well, including cannibalistic adult pollock, leading to top-down feeding pressure on juvenile pollock.²⁰

However, a recent revision of this model suggests that despite the expectation for warmer years to lead to stronger recruitment, the composition of zooplankton consists of lower-quality, fat-poor species if warm temperatures persist into late summer and fall. Thus, pollock feeding on this prey may have fewer fat reserves at the end of the summer with which to survive over the winter.²¹ In other words, neither very high nor very low temperatures may benefit pollock recruitment.²²

Given the relationship between warm late summer temperatures, poor pollock feeding conditions, and reduced overwinter survival (see Box 1), scientists are keen to understand how dynamics may change and impact pollock stocks given the expected increasing trend in ocean temperatures. One study examined three Intergovernmental Panel on Climate Change (IPCC) climate scenarios with varying emissions projections to predict pollock recruitment through 2050.²³ It found that increased temperatures in the eastern Bering Sea would likely lead to reduced recruitment, biomass, and harvests of walleye pollock, with recruitment declining by as much as 32 to 58 percent.²⁴ Though uncertainties are inherent in these estimations, they concluded that there is a very high probability of future biomass and catches declining relative to historical figures.²⁵

Understanding these recruitment and survival dynamics requires a deeper dive into the technical aspects of climate science and fisheries biology than those outside the scientific community may find comfortable. The importance, however, lies in the ultimate implications for the ecosystem (pollock is a vital part of the food web as a key prey species for many organisms), food production, and seafood businesses. If the Bering

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Sea continues to experience periods of unusually warm waters, there is a potential for fishery managers to reduce quotas if associated recruitment is weak.²⁶ In other words, fishermen would be able to catch fewer fish, as fish populations would not be able to handle the same fishing pressure.²⁷ While management measures such as quota reductions are necessary to keep the resource viable, these actions can have an overall impact on the global seafood market, and the communities

dependent upon the fishery. Unfortunately, predicting recruitment (and, in turn, catches) will only become more challenging as climate change alters present interactions between environmental and biological drivers.²⁸

Ocean acidification has likewise prompted concerns for the future of the Bering Sea ecosystems. The sensitivity and tolerance of marine organisms to acidification varies considerably among taxonomic groups, species, and life-history stages. Different regions are affected differently as well. Some of the regions most vulnerable to ocean acidification include the Bering Sea and other high-latitude, North Pacific regions.²⁹ The vulner-

ability of these regions is due, in part, to naturally low concentrations of carbonate ions resulting from the upwelling of cold, CO₂-rich waters and the increased solubility of atmospheric CO₂ in cold surface waters.³⁰ The dissolution of anthropogenic CO₂ emissions further exacerbates the already relatively low levels of carbonate ions and pH in these areas, and thus has an overall greater relative impact than in tropical regions.³¹ In the North Pacific Ocean, scientists have already directly observed a 15 percent decrease in pH in the surface layers between 1991 and 2006, and more substantial declines in pH are expected in the next century if atmospheric CO₂ continues to rise.³²

Research on walleye pollock found that increased CO₂ levels in seawater had no significant impact on the growth or condition of juvenile pollock, aside from an unexpected increase in the growth rate of otoliths, or fish ear bones.³³ This suggests that pollock may be relatively resilient to direct physiological effects of acidification.³⁴ It is also difficult to directly translate laboratory-based results to how that species will respond in the wild. More critically, however, significant reductions in the mass and thickness of shells of pteropods (small snail-like organisms) have been observed along the U.S. West Coast, with up to 53 percent of onshore and 24 percent of offshore pteropods sampled showing signs of severely dissolved shells.³⁵ These organisms are an important food source for a variety of organisms in Arctic and sub-Arctic regions, including commercially important species such as pollock, salmon, and cod. Thus, in the next century the greatest impacts of acidification on finfish species, such as pollock, will likely be indirect, through impacts to key prey species such as pteropods.³⁶

III. STRATEGIES FOR RESILIENT AND ADAPTIVE SEAFOOD BUSINESSES

What should a company that relies on fishery resources do in the face of the anticipated increase in acidification and climate change? Given the complexity of the situation, companies must accordingly adopt strategies that are multifaceted. Responses to climate change generally fall into three groups: research and monitoring, mitigation, and adaptation.³⁷ Mitigation refers to preventative actions taken to reduce rates of change, whereas adaptation refers to reactive actions taken in response to already-occurring changes.³⁸ Most of the efforts undertaken thus far related to climate change research, mitigation, and adaptation in the seafood industry have focused on the harvest sector, which is largely due to direct climate change impacts being more easily linked to the ocean environment in which fishers operate. However, actions along the entire seafood supply chain, including

by retailers, processors, foodservice companies, and others, and in conjunction with stakeholders outside the seafood sector, are critical to developing a robust industry-wide climate change strategy.³⁹

With regards to research and monitoring, seafood companies should support ongoing efforts of governmental, scientific, and fishery management agencies and stay abreast of the latest information to ensure awareness

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of, and thus preparedness for, future trends.⁴⁰ Companies can greatly benefit from collaborative partnerships with diverse stakeholder groups to maximize the technical knowledge and capacity needed to translate hard science into a business-oriented action plan.

For example, for its corporate partners who rely on the Alaska pollock fishery, the New England Aquarium monitors both in-season developments as well as the annual groundfish stock assessments produced by the Alaska Fisheries Science Center.⁴¹ In addition to providing species-specific information on stock trends and projections, the stock assessments include economic information and ecosystem indicators for stakeholders to better understand the context in which these trends are occurring.⁴² The New England Aquarium then interprets this information for companies in terms of any key environmental risks or vulnerabilities that may affect supply, considerations for purchasing decisions, and recommendations for engagement. As many companies and countries depend on the economic activities surrounding pollock fisheries, the ability to forecast future harvest trends is vitally important and helps companies better prepare for price fluctuations.⁴³

There are numerous organizations in addition to the Alaska Fisheries Science Center conducting extensive research on ocean acidification and climate change as they relate to pollock and the wider Bering Sea ecosystem. Besides offering financial assistance to research efforts, companies can engage in the political process to encourage prioritization of these research projects by state and federal governments. These kinds of research and monitoring efforts increase understanding of ecosystem dynamics and help reduce uncertainties surrounding the health, status, and availability of key fisheries. In turn, this reduced uncertainty can provide a more reliable

supply of key commodities, less financial insecurity, and less investment volatility.

Further, fisheries management is increasingly and necessarily transitioning from a single-species approach to an ecosystem-based approach.⁴⁴ This holistic approach, which seeks to account for ecosystem functions, variability, and uncertainty in the management process, is critical to better ensuring the sustainability and vitality of the ocean and its resources.⁴⁵ Strongly managed fisheries are much more likely to be resilient to climate change than those that are poorly managed.⁴⁶ Additionally, ecosystem-based management is expected to contribute to the stability of the fishing industry and associated economic activity.⁴⁷

Notably, Alaska is often at the forefront of taking into account an ecosystem perspective when it comes to its fisheries.⁴⁸ For example, Alaskan managers have been leaders in implementing a new concept in fisheries management known as fishery ecosystem plans (FEPs). FEPs have been identified as important tools for managers to use to better understand and explicitly account for the impacts of their decision-making on the ecosystem and, conversely, the impacts of ecosystem components on fisheries.⁴⁹ Recognizing the connection between resilient ecosystems and the productivity of key commercial fisheries, including Alaska pollock, businesses have started to develop policy engagement strategies to encourage precautionary management that accounts for holistic ecosystem considerations.

By making a commitment to adopt environmentally friendly practices, taking concrete actions toward these commitments, and reaching out to customers about efforts, seafood businesses can build trust with customers, who are increasingly demanding corporate social responsibility and transparency.

Seafood businesses must also go beyond engaging policymakers and fisheries managers. The conversations surrounding seafood sustainability consistently return to both end consumers and the need for marketing efforts to engage and educate this key audience. By making a commitment to adopt environmentally friendly practices, taking concrete actions toward these commitments, and reaching out to customers about efforts, seafood businesses can build trust with customers, who are increasingly demanding corporate social responsibility and transparency.⁵⁰ This trust can increase brand value and encourage customer brand loyalty, potentially making a

company more resilient in the long term through increased competitiveness and profitability.⁵¹

The movement toward seafood sustainability is also now increasingly demanding a more holistic approach to assessing industry impacts. There is a growing body of literature on the full life-cycle assessment of seafood products and the fishing industry, particularly related to studies of greenhouse gas emissions.⁵² The range of the carbon footprint for seafood as a whole can be large.⁵³ However, one study examining the life-cycle assessment of walleye pollock from Alaska to supermarkets in the Netherlands found that the fishery had a carbon footprint of 2.4 to 2.5 kg CO₂-eq kg⁻¹ protein,⁵⁴ which was relatively small compared to other fisheries as well as the terrestrial proteins (for example, other fisheries ranged from 4-540 kg CO₂-eq kg⁻¹ protein, and beef had a carbon footprint ranging from 45 to 640 kg CO₂-eq kg⁻¹ protein).⁵⁵ A key action step for seafood companies tackling climate change issues will be to improve energy efficiency and mitigate greenhouse gas emissions throughout the supply chain,⁵⁶ and particularly at the vessel level, which contribute a large portion of fisheries' carbon footprint.⁵⁷ Such improvements may even increase a company's public sustainability reputation and lead to increased end user sales.⁵⁸

Ultimately, businesses will likely have to contend with shifts in species distributions and abundance—and many already are—which in turn affects catch distributions.⁵⁹ This may result in both positive and negative effects for fishers.⁶⁰ Considering the potential described above for pollock stocks to decline in the next few decades⁶¹ and for the distribution of pollock to shift in response to climate changes,⁶² other species may become more dominant. Addressing species distribution shifts will require strategies of adaptation, in contrast with some of the mitigation strategies listed above.

Moving forward, businesses must continue to push the edge of innovation to tackle the biggest challenges for seafood and the oceans.

The companies that are best able to diversify sources and exploit and effectively market new species will be most resilient against such shifts.⁶³

Moving forward, businesses must continue to push the edge of innovation to tackle the biggest challenges for seafood and the oceans. There are numerous additional issues that must

be addressed along with those discussed above, ranging from illegal, unreported, and unregulated fishing, to social concerns such as human rights and labor issues. Additionally, there are perhaps even more barriers to overcome before these issues can be solved, including transitional costs, public

demand, and restrictive regulation.⁶⁴ However, if businesses embrace their role as leaders in mitigating and adapting to the impacts of climate change and other ocean threats, they, in conjunction with the numerous stakeholders that have a vested interest in seafood, will be better poised to secure a robust and productive seafood supply in perpetuity.

In summary, the ocean environment is changing in unprecedented ways. The dynamics of human-induced climate change and ocean acidification further obscure an already complex picture of climate variability and ecosystem interactions in the marine environment. From rising ocean surface temperatures to reduced sea ice cover and beyond, the environmental consequences of climate change are expected to be substantial, with cascading effects that will result in real economic, ecological, and social costs. The global seafood industry in particular is vulnerable to these impacts, even in fisheries as robust as that of walleye pollock. However, companies can capitalize on proactive strategies to build resilience and adaptive capacity within fisheries. It is critical that businesses accept their leadership role in these issues and actively pursue effecting positive change in the world's oceans. *f*

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