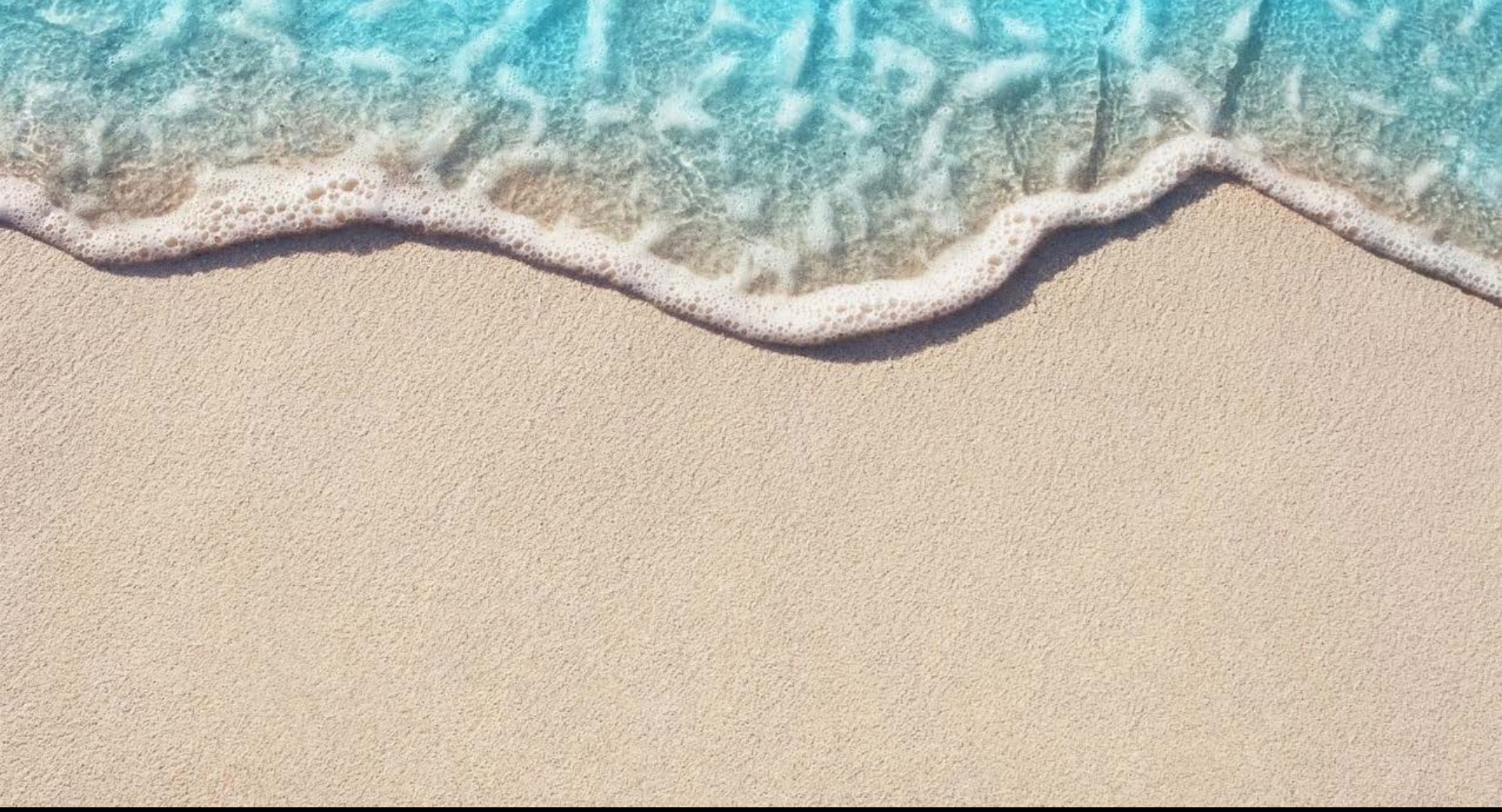


Driving Forces

Future of West Coast Fishing Communities

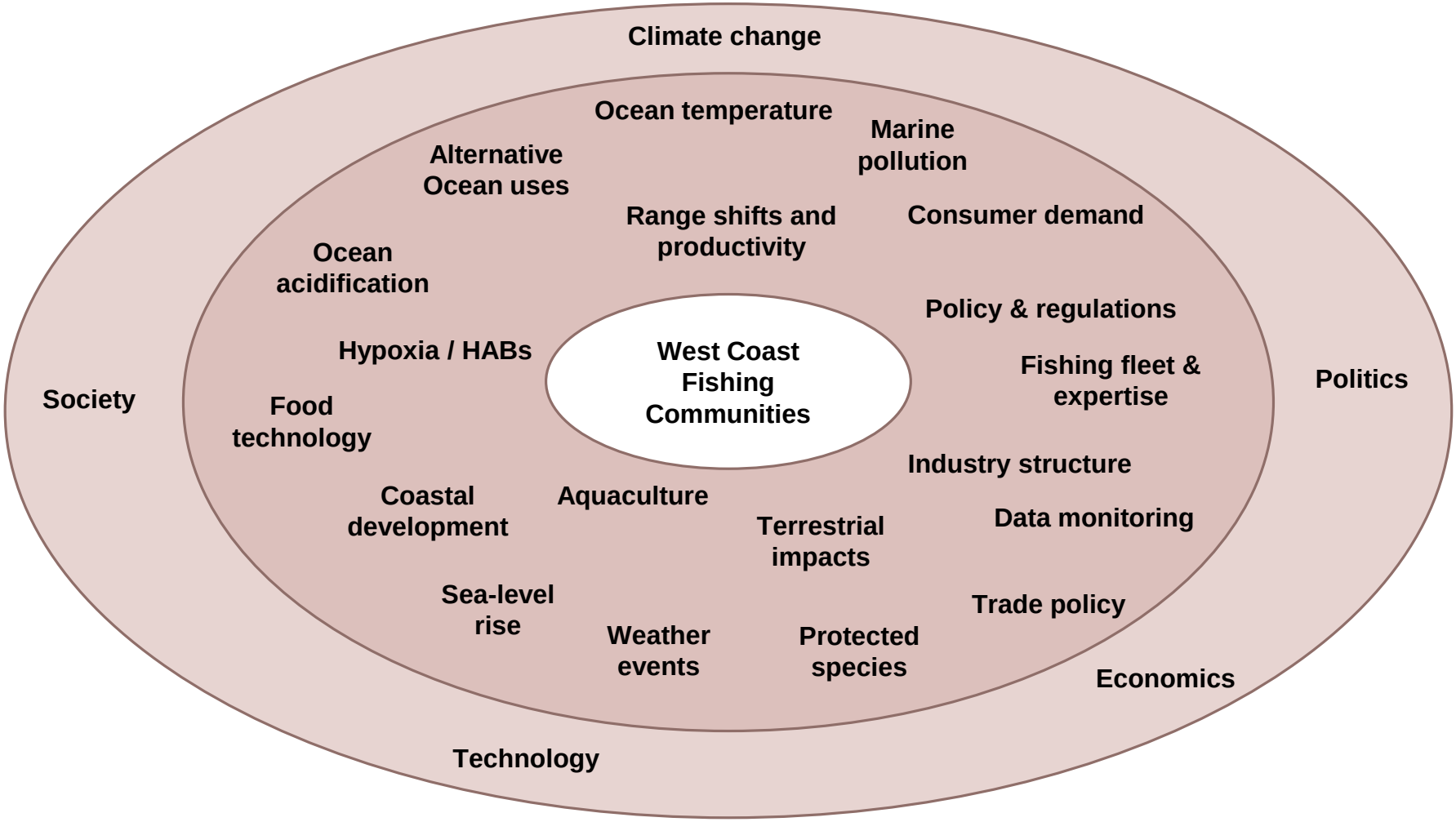
Introduction

As part of its Climate and Communities Initiative, the PFMC is undertaking a scenario planning process to prepare for future uncertainty. Over the next 20 years, climate change will create numerous biophysical changes that will impact fishing communities. It will also be a time of significant socio-economic and political change, partly driven by climate issues, but also driven by other factors.

To inform the early stages of this process, we asked a number of observers for their views on the future of West Coast fisheries to 2040 – and specifically about the factors and forces that are likely to shape change over that period. This document outlines 20 of the most significant **driving forces** that were identified**.**

This list of forces is a thought starter. It is not meant to be a complete list. You might think of other drivers that could be included, or you might have a different take on how any driving force is explained or positioned. The pages that follow contain very simple descriptions of complex phenomenon and there are clearly links and dependent relationships between many of these forces. There is a rough structure to each page; we outline which aspects of the driving force are predictable, which are uncertain, and also highlight the potential impact of future changes for each issue.

As you review these forces, ask: Have we captured the main factors that *you think will affect fish stocks and availability, and affect West Coast fishing communities* over the next 20 years? In our scenario building workshop, we will think about how these driving forces - and others that we identify - could interact to create future possibilities.

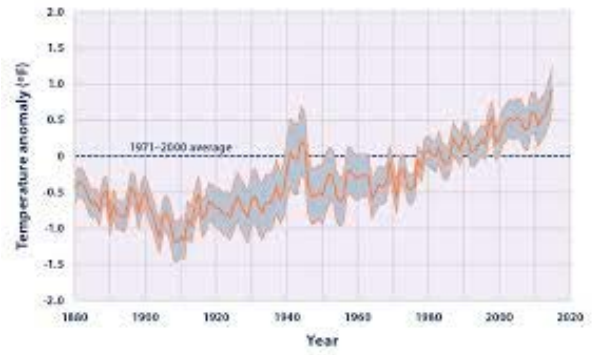

Climate change
Ocean temperature
Marine pollution
Alternative Ocean uses
Range shifts and productivity
Consumer demand
Ocean acidification
Policy & regulations
Hypoxia / HABs
West Coast Fishing Communities
Fishing fleet & expertise
Society
Politics
Food technology
Industry structure
Coastal development
Aquaculture
Terrestrial impacts
Data monitoring
Sea-level rise
Trade policy
Weather events
Protected species
Economics
Technology

Factors Shaping West Coast Fishing Communities to 2040

1. Ocean warming
2. Ocean acidification
3. Seal-level Rise
4. Hypoxia / HABs
5. Range shifts and productivity
6. Ecological surprises
7. Terrestrial climate impacts
8. Marine pollution
9. Alternative ocean uses
10. Aquaculture
11. Societal values
12. Consumer demand
13. Global trade / industry policy
14. Regulation and environmental policy
15. Protected species status
16. Food technology
17. Data and monitoring technology
18. Fishing industry structure
19. Aging of fleet and expertise
20. Coastal community development
21. Range shifts and productivity

1

Ocean warming



What's this driving force?

Globally, the ocean has continued to warm unabated and has absorbed ~90% of the excess atmospheric heat due to greenhouse gas (GG) emissions since the industrial revolution.

Year-on-year marine temperature in the California Current Ecosystem (CCE) is driven by regional wind speed and direction, and short- and long-term global processes such as El Niño and global warming.

What is predictable about ocean warming to 2040?

The ocean will continue to warm in future, with the magnitude of the warming dependent on current and future GG emissions. The surface ocean will continue to warm fastest and deep ocean more gradually.

Ocean warming has already increased stratification, and this is set to continue.

What is uncertain about ocean warming to 2040?

It's uncertain how severe future stratification will be and how warming will impact circulation within the CCE.

Increase stratification could increase the frequency of marine heatwaves, and warming oceans could also cause an intensification of El Niño events.

Timing of the upwelling season is also uncertain.

How might changes in this driving force affect the system?

Species have a narrow thermal range in which they prefer to live and are thus susceptible to ocean warming. It is predicted that ocean warming will cause a northward shift in marine species.

Marine heatwaves have significant negative effects on marine fisheries, and they can take years to recover. What happens to the CCE if marine heatwaves begin to occur faster than species can recover?

In general, the colder nutrient rich waters that are found in normal years are lipid rich—essential for the growth of many fish species. During El Niño years, warmer nutrient poor subtropical waters move up.

Sources:

IPCC, 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. In press

Cai, W., et al. 2018. Increased variability of eastern Pacific El Nino under greenhouse warming. Nature 564, 201-206, https://doi.org/10.1038/s41586-018-0776-9.

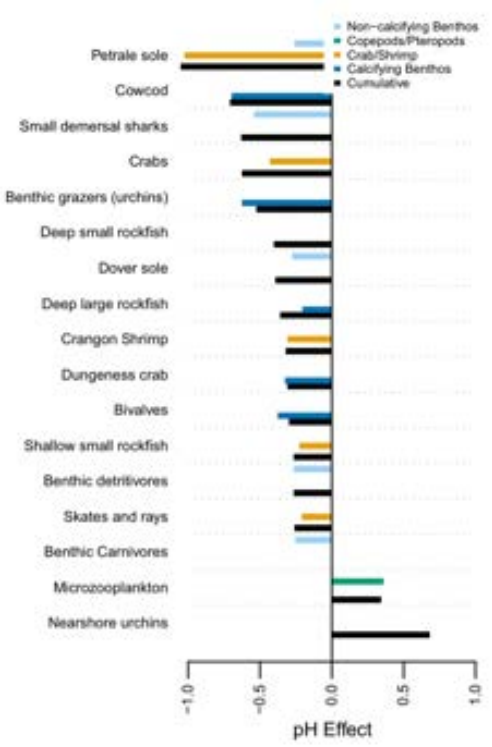
Morley J.W., et al. 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. PLoS ONE 13(5): e0196127. https://doi.org/10.1371/journal.pone.0196127.

Peterson, W. T., et al. 2017. The pelagic ecosystem in the Northern California Current off Oregon during the 2014–2016 warm anomalies within the context of the past 20 years, J. Geophys. Res. Oceans, 122, 7267–7290, doi:10.1002/2017JC012952.

Notes:

2

Ocean acidification



What's this driving force?

Globally, ocean acidification refers to the uptake of atmospheric carbon dioxide by the ocean.

Locally, ocean acidification is driven by respiration. Organic matter breaks down as it sinks through the water column and settles on the sea floor, consuming oxygen and releasing carbon dioxide.

What is predictable about ocean acidification to 2040?

Globally, oceans are becoming more acidic. Based on current emissions, this trend will continue through 2040 and beyond.

The CCE is acidifying more rapidly than the global average. The nearshore and northern and central regions of the CCE experience the most severe and persistent acidification.

In addition to the long-term increase, many parts of the CCE experience highly variable conditions, including the upwelling of highly acidified water, leading to extreme conditions.

What is uncertain about ocean acidification to 2040?

Much of the uncertainty refers to the *impact* of ocean acidification on specific marine species and the marine food web.

Rising ocean temperatures might change the timing and intensity of upwelling, likely driving more intense upwelling in the spring and weaker upwelling in the summer.

This could make the negative impacts of upwelling events more severe and worsen conditions for benthic / deep water species.

How might changes in this driving force affect the system?

Ocean acidification will have impacts on organism survival, development and behavior. Negative impacts have already been observed in shellfish (e.g. oysters, mussels, crabs) and shell-forming organisms such as pteropods.

Observed behavioral impacts include decreased predator avoidance, impaired food detection, and impacts on spawning.

Sources:

Brady, R. X., et al. 2017. Emergent anthropogenic trends in California Current upwelling. Geophys. Res. Lett., 44, 5044–5052, doi:10.1002/2017GL072945.

Christian, J.R. and Ono, T. [Eds.] 2019. Ocean Acidification and Deoxygenation in the North Pacific Ocean. PICES Special Publication 5, 116 pp.

IPCC. 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. In press.

Marshall, K.N. et al. 2017. Risks of Ocean Acidification in the California Current Food Web and Fisheries: Ecosystem Model Projections. Global Change Biology, 23, 1525-1539, doi: 10.1111/gcb.13594.

Notes:

3

Sea level rise

What's this driving force?

Sea-level rise is an effect of climate change driven by melting glaciers, thermal expansion and increasingly, melting Greenland and Antarctic ice sheets.

What is predictable about sea level rise to 2040?

Sea-levels have been rising for decades, and virtually all models now show that this rise will accelerate in future years, especially under high emissions scenarios. Global mean sea level rise between 2006-2015 is 2.5 times the rate of 1901-1990.

Extreme sea level events that are historically rare (once per century in the recent past) are projected (with high confidence) to occur at least once a year at many locations by 2050.

Coastal California is already experiencing the early impacts of a rising sea level, including coastal flooding and erosion. Under high emissions scenarios, it is projected that sea levels could be 1m higher by 2100 compared to today.

What is uncertain about sea level rise to 2040?

There are minor differences in projections for sea level rise under different emissions scenarios up to 2050, but they diverge significantly in the later years of this century. The main sources of uncertainty relate to the core emissions scenarios, to model uncertainty, and also to other aspects of ocean / climate variability (such as oscillations and storms).

Along the Pacific coast, the net effects of sea level rise could be offset by tectonic processes (uplifting). Also, even though the long-term trend is towards rising levels, we can expect significant annual variability.

How might changes in this driving force affect the system?

Rising sea levels are a major contributor to increased coastal hazards (storm surges, flooding and erosion), so we can expect to see more destructive activity in coastal regions in the decades ahead. This will have a direct effect on fishing communities. Even without storm surges, rising sea levels will affect fishing port infrastructure, which might need to be relocated further inland.

Sources:

https://climate.nasa.gov/news/2680/new-study-finds-sea-level-rise-accelerating/

http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

https://www.ipcc.ch/site/assets/uploads/sites/3/2019/09/SROCC_SPM_HeadlineStatements.pdf

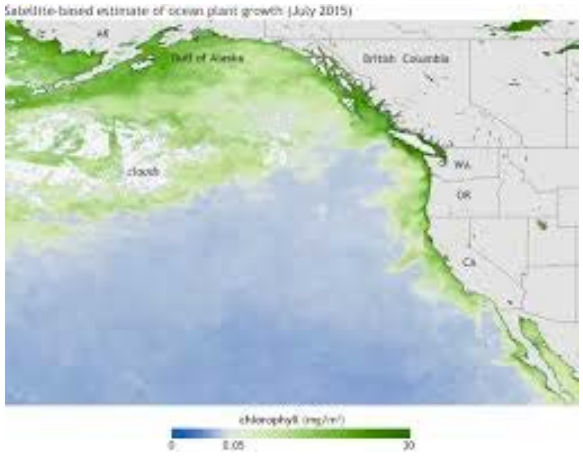
IPPC: Special Report on the Ocean and Cryosphere in a Changing Climate

---

Notes:

4

Hypoxia and harmful algal blooms



What's this driving force?

Hypoxia refers to low or depleted oxygen concentrations that can impair marine life.

Harmful algal blooms (HABs) occur when the rapid growth of marine algae is sufficient to impact fisheries and human health.

What is predictable about hypoxia / harmful algal blooms to 2040?

Hypoxia is caused by ocean warming. It is compounded by increased ocean stratification (which is also due to warming). Thus, we can expect hypoxia to increase given these underlying drivers. There is also evidence that, due to seasonal upwelling, the CCE has experienced—and will continue to — experience severe and persistent hypoxia.

HABs occur when conditions are right for rapid growth of marine algae (i.e. immediately after an upwelling event).

It's likely that the frequency and intensity of hypoxic events and HABs will increase, especially in the northern CCE

What is uncertain about hypoxia / HABs by 2040?

We cannot be sure about the magnitude of these events in the coming years.

The conditions that cause some algal blooms to produce toxic compounds is still poorly understood, but early evidence suggests temperature and nutrient limitations are key factors.

How might changes in this driving force affect the system?

Prolonged hypoxic events have been shown to displace local fish populations, which will lead to a restriction in fishable waters and habitat restrictions / competition in neighboring areas.

Short-term severe hypoxia (anoxia) can cause localized or widespread fish kills as well. Reduced oxygen concentrations can increase stress on fish, reducing growth rate and size. (Continued on next page)

Large scale algal blooms can increase or trigger hypoxic events and will also shade or smother immobile species (i.e. shellfish and seagrasses). Toxins produced by HABs routinely lead to the closure of some fisheries and can also impact other marine fauna such as marine mammals and seabirds.

Sources:

Brady, R. X., et al. 2017. Emergent anthropogenic trends in California Current upwelling. Geophys. Res. Lett., 44, 5044–5052, doi:10.1002/2017GL072945.

Chan et al. 2008. Emergence of Anoxia in the California Current Large Marine Ecosystem. Science, 319, pg 920.

Christian, J.R. and Ono, T. [Eds.] 2019. Ocean Acidification and Deoxygenation in the North Pacific Ocean. PICES Special Publication 5, 116 pp.

Feely et al. 2018. The combined effects of acidification and hypoxia on pH and aragonite saturation in the coastal waters of the California current ecosystem and the northern Gulf of Mexico. Continental Shelf Research, 152, 50-60.

Notes:

5 Ecological surprises

What's this driving force?

An ecological surprise is an unexpected and often dramatic shift in the environment. Examples of recent surprises in the CCE include the Humboldt squid invasion (2010-2012), the more recent pyrosome invasion, and the dramatic decline in sea star populations due to wasting disease.

What is predictable about ecological surprises to 2040?

Nothing is predictable about ecological surprises except that they are certain to occur. Doak et al classify them into three types:

- *Dynamic surprises*, where population numbers or community compositions change in unexpected ways, based on our prior knowledge (e.g. pyrosomes)
- *Pattern-based surprises*, where past patterns of abundance and spatial migration do not provide a reliable guide to current and future patterns (e.g. inshore feeding behavior of migrating humpback whales)
- *Intervention-based surprises*, which are unexpected changes arising from management actions or other human disturbances, such as the worldwide influence of agricultural nutrient runoff or the spread of marine dead zones.

The frequency and intensity of future ecological surprises will be exacerbated by climate anomalies and by climate variability and change. We are likely to see more surprises by 2040.

What is uncertain about ecological surprises to 2040?

While we should expect more surprises, it is difficult to predict the nature, location and effect of any particular ecological shock.

How might changes in ecological surprises affect the system?

By definition, an ecological surprise creates a shock to the ecosystem that can have serious and significant effects. Squid invasions delivered a new predator and affected fish stocks. The recent pyrosome invasion has clogged fishing gear, and there are concerns that a die-off of pyrosomes could lead to reduced oxygen levels.

Sources:

Diaz, R., and R. Rosenberg. 2008. Spreading Dead Zones and Consequences for Marine Ecosystems. Science 321: 929-929.

Doak, D., J. Estes, B. Halpern, U. Jacob, D. Lindberg, J. Lovvorn, D. Monson, T. Tinker, T. Williams, J. Wootton, I. Carroll, M. Emmerson, F. Micheli, and M. Novack. 2008. Understanding and Predicting Ecological Dynamics: Are Major Surprises Inevitable? Ecology 89: 952–961.

Filbee-Dexter, K., J. Pittman, H. Haig, S. Alexander, C. Symons, and M. Burke. 2017. Ecological surprise: concept, synthesis, and social dimensions. Ecosphere (12):e02005. 10.1002/

Ecosystem Status Report of the California Current for 2019: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment Team (CCEIA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-149.

National Fish, Wildlife and Plants Climate Adaptation Partnership. 2012. National Fish, Wildlife and Plants Climate Adaptation Strategy. Association of Fish and Wildlife Agencies, Council on Environmental Quality, Great Lakes Indian Fish and Wildlife Commission, National Oceanic and Atmospheric Administration, and U.S. Fish and Wildlife Service. Washington, DC.

:

https://www.nwfsc.noaa.gov/news/features/pyrosomes/

Notes
:

6

Extreme weather conditions

What's this driving force?

"Extreme weather conditions" refers to intense heat events, storms, rainfall / wind events that create disruption and damage to fishing operations and coastal communities

What is predictable about extreme weather conditions to 2040?

As the atmosphere warms and absorbs more heat, extreme storms will become more intense and more frequent, according to predictions from global climate models.

However, current models lack the precision to predict which local areas / fishing communities will be impacted the most from such storms.

What is uncertain about extreme weather conditions to 2040?

Will we be able to more accurately predict extreme weather events in future?

Could more frequent unsettled weather be followed by longer periods of calm, settled weather? If so, will this change the behavior of recreational and commercial fishermen?

How might changes in this driving force affect the system?

Increased storminess makes fishing more dangerous, putting lives at risk.

Intense storms can flood estuaries with saltwater and cause fish to evacuate large areas.

Storms can also benefit fish by strengthening upwelling, thus allowing phytoplankton and zooplankton to thrive.

Intense wind/rain events can cause structural and flooding damage to vulnerable coastal infrastructure.

Sources:

https://www.americanprogress.org/issues/green/reports/2018/09/10/457649/warming-seas-falling-fortunes/

https://nca2018.globalchange.gov/chapter/9/

Notes :

7 Terrestrial climate impacts

What's this driving force?

Terrestrial impacts from climate change directly affect anadromous species such as salmon and steelhead and species that depend on estuarine habitats for spawning and rearing young.

What is predictable about terrestrial climate change to 2040?

Climate change will affect freshwater and estuarine hydrological systems and habitats. Reduced snowfall and increased droughts will alter the magnitude and timing of stream flow, sediment loading, and nutrient loading.

Increased water and atmospheric temperatures will change animal and plant species compositions, degrading spawning and rearing habitats.

Sea level rise and changes to salinity in estuaries will have a detrimental affect on sea grasses.

What is uncertain about terrestrial climate change to 2040?

How quickly, and to what extent, will the terrestrial environment be impacted by climate change? How are river-estuary systems influenced by climate change effects in both watersheds and the oceans?

Changes to stream flow may result in changes to anadromous species spawning and outmigration timing. Habitat quality degradation will reduce the ability of species to identify suitable spawning and rearing habitat, thus reduce the ability of species to thrive. However, the changes to ecosystem communities are difficult to predict.

How might changes in this driving force affect the system?

Habitat restoration and conservation must be flexible and adaptive to adjust to increased understanding of impacts and mitigation strategies.

Land-use patterns may need to be modified, especially in urban areas, to reduce the impact on hydrological components such as runoff and streamflow.

Sources:

Bryant, M.D. 2009. Global climate change and potential effects on Pacific salmonids in freshwater ecosystems of southeast Alaska. Climatic Change 95: 169. https://doi.org/10.1007/s10584-008-9530-x

Marshall, E. & Randhir, T. 2008. Effect of climate change on watershed system: a regional analysis. Climatic Change 89: 263. https://doi.org/10.1007/s10584-007-9389-2

Frederick T.Short, Hilary A. Neckles. 1999. The effects of global climate change on seagrasses. Aquatic Botany. Vol. 63, Issues 3-4, pg 169-196.

Cloern J.E., Knowles N., Brown L.R., Cayan D., Dettinger M.D., Morgan T.L., et al. 2011 Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change. PLoS ONE 6(9): e24465. https://doi.org/10.1371/journal.pone.0024465

Lin, Y.-P.; Hong, N.-M.; Chiang, L.-C.; Liu, Y.-L.; Chu, H.-J. 2012. Adaptation of Land-Use Demands to the Impact of Climate Change on the Hydrological Processes of an Urbanized Watershed. Int. J. Environ. Res. Public Health 9:4083-4102.

Notes:

8

Marine pollution

What's this driving force?

Marine pollution is defined in the United Nations Conservation Law of the Sea as "the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities."

Marine pollution can be found in many forms, including plastics, light, noise, and chemicals. Globally, 80% of marine pollution comes from land-based activities, including oil, fertilizers, sewage, plastics, and toxic chemicals. These pollutants impact the health of the ocean, ocean organisms, and ocean systems by increasing algae production, reducing dissolved oxygen, and killing fish and wildlife due to ingestion. These impacts will only magnify climate change impacts to habitat and species.

What is predictable about marine pollution to 2040?

Pollutants will continue to affect the marine system into the foreseeable future. While there is considerable movement underway to reduce single-use plastics, it is expected that we will be producing three times as much plastic as we do today by 2050 (accounting for ~20% of petroleum consumption and 15% of annual carbon emissions), when there may be more plastic than fish in the world's oceans[2].

Non-point source pollution, such as oil from cars on the road, fertilizers, sewage, pesticides, and herbicides cannot be measured in the ocean; however, monitoring occurs in many river systems. These chemical pollutions can be damaging to individuals and habitats.

What is uncertain about marine pollution to 2040?

Most of the uncertainty around this driving force is related to the impact that it will have on the marine environment.

The future of microplastics in the marine environments is uncertain. Plastics break down into microplastics and can be found in nearly every environment on earth, with over 99% being microfibers from clothing and other artificial fabrics.

(Continued)

Microplastics have been found in many species, including bivalves, fish, birds, and marine mammals.

How might changes in this driving force affect the system?

Marine pollution affects the health of ocean ecosystems, so any reductions in marine pollution will improve the overall health, thus increasing the ability of the marine system to be resilient to the impacts from a changing ocean.

There are several campaigns to educate the public about the impacts of single-use plastics and new awareness of the wide-spread impacts of microplastics in high-profit countries. However, more needs to be done to reduce use globally and identify effective alternatives.

Sources:

Luís Gabriel A. Barboza, Andrés Cózar, Barbara C.G. Gimenez, Thayanne Lima Barros, Peter J. Kershaw, Lúcia Guilhermino. 2019. Chapter 17: Macroplastics Pollution in the Marine Environment. Editor(s): Charles Sheppard, World Seas: An Environmental Evaluation (Second Edition), Academic Press, pp 305-328.

https://www.futureagenda.org/foresights/plastic-oceans/

Jenny Howard. National Geographic. Marine pollution, explained.

https://www.nationalgeographic.com/environment/oceans/critical-issues-marine-pollution/

Lebreton, L., Andrady, A. 2019. Future scenarios of global plastic waste generation and disposal. Palgrave Commun 5, 6 doi:10.1057/s41599-018-0212-7

Britta R. Baechler, Elise F. Granek, Matthew V. Hunter, Kathleen E. Conn. 2019. Microplastic concentrations in two Oregon bivalve species: Spatial, temporal, and species variability.

Notes
:

9

Alternative ocean uses

What's this driving force?

Technology advances and a growing human population have created proposals for new and alternative uses of ocean space including submarine cable installation, water desalination, offshore mining, renewable energy, intensive waste disposal and aquaculture.

What is predictable about alternative ocean uses to 2040?

The basic underlying drivers will lead to increased demand and more intensive use of ocean waters.

Under a future of climate change, scarce fresh water supplies are likely to increase demand for desalination plants. Wind energy technology will also increase in popularity as finding alternatives to fossil fuels become more urgent.

However, the topography of the U.S. West Coast (a narrow continental shelf) makes permanent ocean installations more challenging far offshore.

What is uncertain about alternative ocean uses to 2040?

Will ocean energy development become viable for all areas of the West Coast, or will it be focused mainly closer to densely settled urban areas?

Will regulatory and legal hurdles be overcome to enable offshore aquaculture? Will state and tribal interest in nearshore aquaculture grow enough to support significant new installations?

Will alternative ocean use work in concert with existing ocean resources (e.g. devising systems to deal with marine waste), or will alternative uses further contribute to ecosystem damage?

How might changes in this driving force affect the system?

Alternative ocean uses will cause disturbances (e.g. sound, pollution) that will affect marine life and fisheries.

New uses could also provide new and different economic and employment opportunities to coastal communities. As the industries and skill sets are different, new investments could change the character and socio-economic make up of coastal communities. (Continued)

Interactions between fisheries and alternative uses have been occurring off the West Coast for many years, with some promising indications of success (e.g. submarine cable installation).

Sources:

http://www.ofcc.com/about_ofcc.htm

https://nca2014.globalchange.gov/highlights/regions/southwest

https://e360.yale.edu/features/as-water-scarcity-increases-desalination-plants-are-on-the-rise

---

Notes:

10
Aquaculture

What's this driving force?

Aquaculture is defined in U.S. law as "the propagation and rearing of aquatic species in controlled or selected environments, including, but not limited to, ocean ranching..."

The United Nations Food and Agriculture Organization define it as "The farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated."

Aquaculture includes shellfish and finfish in both fresh and saltwater environments, in either contained or open systems.

What is predictable about aquaculture to 2040?

Aquaculture will remain a global tool of seafood production across multiple types and geographies.

What is uncertain about aquaculture to 2040?

The U.S. currently has a fragmented legal and regulatory management system for aquaculture. What will it look like in 2040?

What will global aquaculture look like? What pressures will it put on wild U.S. fisheries and aquaculture?

What will our cultural attitudes towards aquaculture be?

Can finfish aquaculture and wild capture fisheries thrive economically and socially on the U.S. West Coast at the same time?

How might changes in this driving force affect the system?

If finfish aquaculture continues to grow globally and in the U.S., we could see market pressures challenge U.S. wild fisheries.

If aquaculture grows off the U.S. West Coast, we could see environmental damage to coastal areas as well as federally-managed areas.

Sources:

National Aquaculture Act of 1980 (P.L 96-362)

NOAA: What is Aquaculture? https://www.noaa.gov/stories/what-is-aquaculture

Naylor, Rosamond L., et al. 2000. "Effect of aquaculture on world fish supplies." Nature 405.6790: 1017.

Notes:

11

Societal values

What's this driving force?

Societal values represents the standards and preferences that groups of humans hold in common. This is a fundamental set of forces, and changes can lead to consequential political, economic and technological change. For our purposes, we will focus mainly on societal values in relation to climate change.

What is predictable about societal values to 2040?

Societal values change over time. Values held on the U.S. West Coast may shift to reflect changing demographics. (e.g. an aging population, or movements into / out of coastal communities).

At present, societal values regarding concern about the state of the environment remain low relative to other public policy priorities. However, opinions on climate change are shifting towards a greater acceptance of the realities and a recognition of the challenges that it brings. (Public concern tends to rise in association with large-scale natural disasters).

What is uncertain about societal values to 2040?

Will rising awareness of the impacts of climate change lead to a societal pressure for fundamental changes in how economic, regulatory and business systems operate?

Will rising awareness of the impacts of climate change lead to meaningful shifts in human behavior (e.g. what we eat, where and how we travel, what we consume)?

Will society conceive of oceans and ocean resources differently by 2040? Could this lead to more attention placed on protection and preservation? Or will our values encourage more commercial exploitation?

How might changes in this driving force affect the system?

Shifts in societal values can affect all aspects of the fishery system. Changing demographics and attitudes toward healthy living can drive consumer preferences towards wild-caught seafood.

Greater awareness of environmental concerns could lead to public policies that encourage protection of species.

Societal values could also emphasize commercial growth or national security, which could in turn create pressures on stocks, or international cooperation.

Sources:

Capstick, S., L. Whitmarsh, W. Poortinga, N. Pidgeon, and P. Upham. 2015. International trends in public perceptions of climate change over the past quarter century. WIRE's Climate Change 6: 35-61. doi: 10.1002/wcc.321.

Cusack, L., E. Smit, M. Kile, and A. Harding. 2017. Regional and temporal trends in blood mercury concentrations and fish consumption in women of child bearing age in the United States using NHANES data from 1999-2010. Environ Health 16:10.

Honkanen, P., S. Olsen, B. Verplanken. 2005. Intention to consume seafood – the importance of habit. Appetite 45: 161-168. https://doi.org/10.1016/j.appet.2005.04.005.

Potera, C. 2018. Catch of the Decade: Change in U.S. Seafood Consumption and MeHG Intake over Time. Environ Health Perspect 126: 044004. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6071810/

Rokeach, M. 1973. Understanding Human Values: Individual and Societal. New York, NY: The Free Press, Macmillan.

Notes:

12

Consumer demand

What's this driving force?

This driver captures major changes in the demand for seafood over the next 20 years and explores the underlying causes of such changes.

What is predictable about consumer demand to 2040?

There will be more mouths to feed. Global demographic trends paint a picture of a growing global population, from 7.7bn in 2020 to 9.1bn by 2040. Much of this growth will be concentrated in Africa and South East Asia. A growing middle class is likely to demand higher quality proteins. In richer nations, we already see an emerging trend towards demand for seafood and plant-based proteins, and away from animal-based.

What is uncertain about consumer demand to 2040?

Will the demand for healthier proteins move beyond seafood? Will consumers embrace plant-based proteins as the best route towards healthy proteins, or will seafood demand remain strong?

Will there be sufficient demand for wild-caught seafood, driven by consumers who value supporting local providers and emphasizing sustainable practices? Or will consumers opt more for farmed seafood for price, value and/or safety reasons?

Will wild-caught seafood be seen as a healthy, sustainable alternative in 20 years? Could microplastics, mercury or other contaminants damage consumer demand for the product?

Will there be significant changes in the type of species that consumers choose to eat—either because of changing tastes, availability, sustainability or safety concerns?

How might changes in this driving force affect the system?

Major shifts in consumer demand will have a profound effect on all parts of the seafood industry and ecosystem. If consumer demand shifts towards aquaculture, this will force significant changes on the traditional practices of fishing communities. Demand for different species could affect stocks in specific areas. The nature of consumer demand will affect fishing practices (e.g. encouragement of sustainable practices).

Sources:

https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html

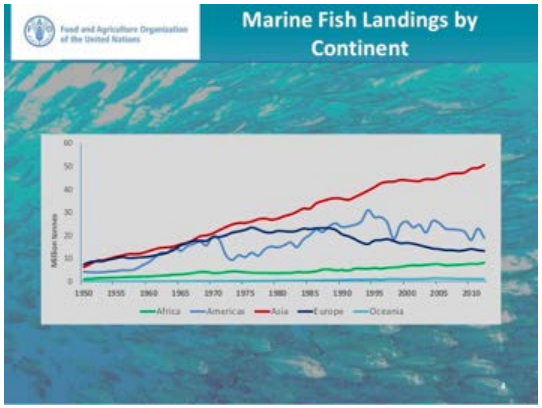
http://www.alaskafishradio.com/us-millennials-eating-seafood-ever-aim-healthier-natural-products/

https://www.forbes.com/sites/margotwilsterman/2019/03/01/specialty-diets-on-the-rise-with-seafood-as-a-major-player/#7c35471267a4

Notes:

13

Trade/ industry policy



What's this driving force?

Trade in fish and fishery products is extensive, and hence changes to trade (and industrial support) policies have the potential to shape the global fishing industry. Trade measures can include tariffs, subsidies, safety and sustainability requirements.

What is predictable about trade & industry policy to 2040?

Changes to international agreements over trade usually take many years to negotiate and come into effect, so change typically happens slowly. The global trading regime is currently experiencing relatively low tariffs, and there are increased measures in the pipeline to further lower tariff levels.

Many advocate for additional reform of fishery subsidies to prevent overfishing, but change is politically and economically difficult, thanks to powerful players and vested interests in the status quo.

What is uncertain about trade policy to 2040?

While trade policy tends to move slowly, a more volatile and uncertain geopolitical environment could herald more dynamic changes in the years ahead. Currently, there is unpredictability around the future of the World Trade Organization and in many trade relationships, e.g. U.S. raising tariff levels on goods in trade disputes with China and the European Union, and China imposing 25% tariffs on U.S. lobster. Could fish and fishery products become caught up in some new trading dispute?

It is also uncertain what will constitute trade policy and other forms of support / assurance in future. To what extent will concepts of sustainability and safety become essential requirements to trade with other nations? If U.S. policy becomes more progressive, concepts like the "Blue New Deal" might rise in prominence, providing incentives to favor U.S. fish rather than imports.

More generally, will we see more unification and multi-lateral collaboration with larger trading blocs (e.g. the EU), or will we see the collapse of multi-lateral agreements and the rise of bilateral deals, or no deals at all?

(Continued)

How might changes in this driving force affect the system?

Removal of fishing subsidies for developing countries could deliver a more advantageous environment for U.S. fishing.

New sustainability and safety requirements could make seafood more expensive but could also favor quality U.S. products.

Sources:

http://e15initiative.org/publications/fishing-for-the-future-trends-and-issues-in-global-fisheries-trade/

http://filesforprogress.org/memos/blue-jobs.pdf

Notes:

14

Regulation and environmental policies

What's this driving force?

This force describes the nature of policies and regulations that are designed to protect various aspects of the natural environment. In this summary, we focus primarily on U.S. policy (e.g. NEPA, Endangered Species Act).

What is predictable about regulation and environmental policies to 2040?

Public support for existing environmental protection is relatively strong.

Major federal environmental legislation is unlikely to be rolled back, nor will major new legislation get passed in the short/medium term.

State and local actions will continue but can only be partially effective. Large-scale environmental concerns will require concerted federal action.

What is uncertain about regulation and environmental policies?

Will the current drive for deregulation regarding environmental protection continue in the U.S.? This largely depends upon the political environment and the nature of the administration in power.

Will environmental problems (e.g. climate impacts, air and water quality) become sufficiently visible and concerning to shift public attitudes and political will in a meaningful way?

Will demographic changes in the U.S.—as younger generations become more influential—bring about changes in environmental attitudes and political preferences?

Will environmental protection and economic growth be seen as competing goals, or will new technologies/approaches/regulations allow us to see the pursuit of both as complementary?

How might changes in this driving force affect the system?

Policy and regulation has a pervasive effect on the ecosystem by influencing/controlling behavior that ultimately affects the environment.

Deregulation could affect water quality; changes to the Endangered Species Act could affect the scope of fishing grounds and the timing of seasons.

Sources:

Robinson Meyer, How the U.S. Protects the Environment, From Nixon to Trump, The Atlantic Magazine, March 29, 2017. https://tinyurl.com/ya5qtnke

Gallup, Americans Want Government to Do More on Environment, March 29, 2018 https://tinyurl.com/sd3ml6p

Generational replacement is what shifts public opinion, The Economist, Oct 31, 2019. https://tinyurl.com/ye7u634d

---

Notes :

15. Protected species status

What's this driving force?

This driver captures major changes in the number, condition, and relationship to harvested species of legally-protected species over the next 20 years and explores the underlying causes of such changes.

What is predictable about protected species status to 2040?

Declining global biodiversity and changes in ecosystem productivity will continue, increasing stress on most food webs, including those that protected species depend on. At the same time, recovery of some protected species will likely continue, impacting fisheries through increased predation on target stocks and in other ways. These impacts will manifest differently across geographies — globally and within the California Current—and across protected species.

What is uncertain about protected species status to 2040?

What will the legal framework for protected species look like? How will it relate to fisheries management?

What biophysical drivers will most impact protected species? What anthropogenic drivers?

What will protected species and fishery target species interactions look like?

What will our societal relationship with protected species be?

What protected species populations will be healthy and which will be declining?

How might changes in this driving force affect the system?

Recovery of some species will put additional competing pressure on target stocks, furthering current management challenges around balancing the needs of protected species and fishing.

Food web degradation will continue adding pressure on the entire ecosystem, likely further affecting populations of some protected species, both target stocks (such as salmon) and non-target species (such as birds).

(Continued)

Both recovery and decline will create challenges for managers; sometimes these species are the same (ex sea lions) creating complex questions even without the additional stressor of climate change. We will likely see an increase in these challenges.

Sources:

Bellard, Céline, et al. 2012. “Impacts of climate change on the future of biodiversity.” Ecology letters 15(4): 365-377.

Crozier, Lisa G., et al. 2019. “Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem.” PloS ONE 14(7).

Grémillet, David, and Thierry Boulinier. 2009. “Spatial ecology and conservation of seabirds facing global climate change: a review.” Marine Ecology Progress Series 391: 121-137.

NOAA Fisheries, Marine Mammal Stock Assessment Reports by Stock: https://www.fisheries.noaa.gov/national/marine-mammal-protection/marine-mammal-stock-assessment-reports-species-stock

Paleczny M., Hammill E., Karpouzi V., and D. Pauly. 2015. “Population Trend of the World’s Monitored Seabirds, 1950-2010.” PLoS ONE 10(6): e0129342.

Chasco, B.E., Kaplan, I.C., Thomas, A.C. et al. 2017. Competing tradeoffs between increasing marine mammal predation and fisheries harvest of Chinook salmon. Sci Rep 7, 15439.

Tulloch, V.J.D., Plagányi, É.E., Brown, C., Richardson, A.J., Matear, R., 2019. Future recovery of baleen whales is imperiled by climate change. Global Change Biology 25, 1263–1281.

Magera, A.M., Mills Flemming, J.E., Kaschner, K., Christensen, L.B., Lotze, H.K., 2013. Recovery Trends in Marine Mammal Populations. PLoS ONE 8, e77908.

16

Food technology

What's this driving force?

This force describes how the world will use technology to satisfy our need / desire for food in the next 20 years.

What is predictable about food technology to 2040?

Given demographic trends, some estimates suggest that the world will need 60% more food by 2050. And this needs to be made available at a time when existing food production practices are causing environmental damage.

There is little doubt that we need — and will experience — innovation in food production. This will include lab-grown meat, vertical farming, insect proteins, aquaculture, drought-resistant crops, use of data for more effective tracking and farming.

What is uncertain about food technology to 2040?

How important will new technology advances be in the fishing industry over the next 20 years? Will they transform aspects of the industry, or be of marginal importance?

Which new technologies will rise to the fore and become influential or transformative in how we grow/manufacture food?

How will consumers respond to new food technologies, and will there be unintended consequences (e.g. safety concerns)?

Examples of Innovation

TRUfish (www.trufish.org) offers DNA testing of sample fish from batches, allowing resellers and consumers to verify that the species on offer are what the seller says they are

In the fish feed industry, there is a hunt for nutritious fish feeds that don't require other fish. Algae, soybeans, oil seed, insects and bacteria are all getting trials.

Waste byproducts could be turned into valuable co-products. People are making leather out of fish skins. Fish scales, which are highly conductive, could be useful in solar cells and other applications. (Continued)

Seafood entrepreneurs are looking at upcycled food uses for what's often treated as waste, such as bottarga (cured grey mullet roe) and salmon jerky made from flesh that is typically discarded.

How might changes in this driving force affect the system?

Advances in food production technology could mean that seafood demand is moderated (as alternative sources of protein come on stream).

New technology and processes could increase the quality, safety and sustainability of seafood, thus boosting demand.

New technologies will change the nature of the industry, as new investments and different capabilities become essential for success.

Sources:

https://worldpositive.com/your-relationship-with-seafood-is-about-to-change-86383e7ff82d

---

Notes :

17

Data and monitoring technology

What's this driving force?

This driving force captures major changes in the types of data, data availability, and monitoring capabilities available to support fisheries management over the next 20 years.

What is predictable about data and monitoring technology to 2040?

NOAA has identified four strategies to keep pace with emerging data capabilities and technologies, including artificial intelligence, unmanned systems, 'omics (a suite of advanced methods used to analyze material such as DNA, RNA, or proteins), and cloud computing. It is likely that the use of these strategies will increase over the coming decades in the context of fisheries management.

New surveillance technologies like electronic monitoring and vessel monitoring systems will enable better data collection on fisheries catch and vessel behaviors. Remotely-sensed data from unmanned systems and tagging of living marine resources will improve surveys available to support fisheries assessment. New understanding of stock structure will facilitate more accurate assessments. The use of cloud computing will allow all these new data sources to be processed more efficiently, providing closer to real time information to decision makers.

What is uncertain about data and monitoring technology to 2040?

What new technologies will develop in the next 20 years that are not available today?

What will the legal framework for data and monitoring technology look like? How will it relate to fisheries management?

How will public and stakeholder support for the use of new technologies and data change?

How might changes in this driving force affect the system?

Rapid advances in data and monitoring technology will challenge the ability of legal frameworks, fisheries managers, and scientists to use them in a timely, ethical, and rigorous manner to support fisheries management. (Continued)

New data and monitoring technology could replace the need for certain jobs associated with fisheries and create opportunities for new jobs that require different skill sets.

The costs of R&D and purchasing new data and monitoring technology are enormous initially and decline as they scale. It is unclear how these costs can and should be borne by government, industry, and others.

Sources:

Hazen, E.L., Abrahms, B., Brodie, S., Carroll, G., Jacox, M.G., Savoca, M.S., Scales, K.L., Sydeman, W.J., Bograd, S.J., n.d. Marine top predators as climate and ecosystem sentinels. Frontiers in Ecology and the Environment.

https://doi.org/10.1002/fee.2125

Kroodsma, D.A., Mayorga, J., Hochberg, T., Miller, N.A., Boerder, K., Ferretti, F., Wilson, A., Bergman, B., White, T.D., Block, B.A., Woods, P., Sullivan, B., Costello, C., Worm, B., 2018. Tracking the global footprint of fisheries. Science 359, 904–908. https://doi.org/10.1126/science.aao5646

NOAA Strategies for Emerging Science and Technology https://tinyurl.com/yeqxlg82

NOAA Electronic Monitoring https://tinyurl.com/yggcszzy

Werner, F. 2019. “On the Next Generation Stock Assessment Improvement Plan (SAIP).” Presentation to the Gulf States Marine Fisheries Commission. https://tinyurl.com/yjf58njk

18

Fishing industry structure

What's this driving force?

Over the past 40 years, a combination of technology, regulatory and consumer trends has led to significant changes in the structure of the fishing industry, leading to greater concentration and less diversity amongst operators.

What is predictable about fishing industry structure to 2040?

Most observers expect these trends to continue, resulting in more concentration, agglomeration and less diversification—in a similar way to trends in agriculture over the past century.

Consolidation is evident in catch. In the 1980s, 22,000 vessels averaged $20k in revenue. By 2011, 5,600 vessels averaged $86,000 in revenue. Similar trends are also present in processing.

What is uncertain about fishing industry structure to 2040?

How far will consolidation go? Could we see a future where there are just a handful of large operators and processors, and very few independent operators in existence?

While consolidation is expected to be the main theme, there are still some significant pockets of diversification and specialization. Where will these occur?

Will societal attitudes, consumer demand and technology lead to a reversal of concentration trends, and a renewal of smaller operators who bypass the main industry players and sell more directly to restaurants and consumers?

How might changes in this driving force affect the system?

Greater industry consolidation and efficiency is likely to affect fishing community employment, and the character of fishing communities. In such situations, fishing continues, but fishing communities themselves are hard hit.

In more rural and isolated communities, there may be few comparable employment opportunities as concentration increases (although this could change if new sectors such as offshore energy and aquaculture grow).

If trends combine in favor of more independent operators, there might be new opportunities in marketing. Other non-consumptive services (recreational fishing, charters, wildlife viewing) could also be sources of revenue and employment.

Sources:

PacFIN fishery landings database, 11/21/19

2019 Annual State of the California Current Report, Section 6.2 and Appendix N

Notes:

19

Aging of expertise and fleet

What's this driving force?

The average age of fishermen is increasing as retirement ages and lifespans increase, while fewer young people are entering into fishing.

What is predictable about the aging of expertise & fleet to 2040?

2012 data (from West Coast groundfish trawl fishery) showed that over 27% of fishermen were over 61 years old, and this proportion has increased by five percentage points in two years. Conversely, the number of fishermen under 30 fell by 5 percentage points to 6% over the same two-year period.

These trends are typically attributed to changes in policy (e.g. rationalization), resulting in fleet consolidation and increased cost to enter the industry. There are fewer family-owned fishing businesses as younger generations choose to move away from coastal communities.

What is uncertain about the aging of expertise & fleet to 2040?

How quickly, and to what extent, will the graying of the fleet continue?

Global studies have shown more "climate losers" than "climate winners" in terms of impact to fish stocks from climate change. The increased uncertainty of what fisheries will look like as our ocean experiences changes will exacerbate this issue. Recruits to the fishing industry may be less likely to enter fishing due to such uncertainty.

However, an aging industry can often provide space for new, innovative entrants and ideas to thrive. Could this happen in an important way on the West Coast?

How might changes in this driving force affect the system?

An aging fleet will find it more difficult to cope with unpredictable changes in stock availability and other shocks to the system.

An older workforce might have less incentive to invest in new gear and new technology, leaving the industry more likely to be influenced by larger vessels.

Aging expertise and fleet might also be associated with a declining sense of community vibrancy.

Sources:

Silva, A., A. Pitts, M. Van Oostenburg, J. Morris-Terez, P. Clay, S.M. Russell, L. Colburn. Draft-In Progress. A Bi-Coastal Exploration of Greying of the Fleet Using Oral Histories.

Russell, S. M., Sparks, K., & Arias-Arthur, A. 2014. The Pacific Groundfish Fishery Social Study: An Initial Theme Based Report.

Donkersloot, R., and C. Carothers. 2016. The Graying of the Alaskan Fishing Fleet, Environment: Science and Policy for Sustainable Development, 58:3, 30-42, DOI: 10.1080/00139157.2016.1162011

The Resilient Fisheries Rhode Island project (with support from the Rhode Island Natural History Survey.) 2018. Rhode Island Commercial Fisheries Blueprint for Resilience. Available at: www.resilientfisheriesri.org

University of California Santa Barbara. 2019. “Climate change is shifting productivity of fisheries worldwide.” ScienceDaily. ScienceDaily, 28 February.

Free, C.M., Thorson, J.T., Pinsky, M.L., Oken, K.L., Wiedenmann, J., and O.P. Jensen. 2019. Impacts of historical warming on marine fisheries production. Science, 01 March : 979-983

Notes :

20

Coastal community development

What's this driving force?

Coastal community development refers to the social and economic evolution of communities along the U.S. West Coast.

What is predictable about coastal community development to 2040?

Social and economic forces will change the characteristics of all communities. Coastal communities worldwide continue to see upwards trends in in-migration; this is true for the West Coast, where total migration rates are positive coastwide. These trends differ by individual community.

The impacts of climate change, for example sea level rise and increased storm surge, will have direct impacts on community development. Existing governmental frameworks—federal, state, local — are likely not well designed to address the multiple, competing, and changing needs of coastal communities given expected population growth and increased demand on natural resources.

What is uncertain about coastal community development to 2040?

Which communities will see development and to what degree?

To what degree will commercial, recreational, subsistence, and/or cultural fishing be included in development? How and for whom?

Will important ecological areas be protected and/or restored to ensure sustainable fishing and other natural resource goods are maintained?

Will development occur equitably for different members of coastal communities?

How might changes in this driving force affect the system?

Increased development without sufficient planning for fishing needs could result in unintentional loss of fishing opportunities of all types.

Changing social fabrics of coastal communities could change the way fishing is viewed and valued societally, positively or negatively, impacting how development occurs.

Increased development poses additional pressure on natural resources, particularly sensitive coastal habitats.

Sources:

Bagstad, Kenneth J., Kevin Stapleton, and John R. D'Agostino. 2007. "Taxes, subsidies, and insurance as drivers of United States coastal development." Ecological Economics 63.2-3: 285-298.

US Census Bureau. www.census.gov

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. 2019. https://www.ipcc.ch/srocc/home/

Dolan, A. Holly, and Ian J. Walker. 2006. "Understanding vulnerability of coastal communities to climate change related risks." Journal of Coastal Research: 1316-1323.

Notes:

21

Range shifts and productivity

What's this driving force?

Range shifts and productivity capture the predicted changes in geographic location of stocks and the changes in amount of fish that a stock can support removal of.

What is predictable about range shifts and productivity to 2040?

Climate is altering where species are physically located due to changing temperature and other oceanographic conditions. Some stocks may move north-south, east-west, or deeper, and some may expand or contract. Compared to other North American regions, the expected shifts in distribution on the US West Coast are relatively high, certain, and predominantly northwest. These shifts create a suite of challenges as existing management is designed to assume static location of stocks. These conditions also impact habitat and bycatch, further complicating meeting management goals.

Oceanographic conditions greatly influence the productivity of stocks, for example habitat suitability like temperature, ecosystem dynamics like predator-prey relationships, and recruitment success. As these conditions change, productivity of some stocks will change. The most comprehensive study to date for the California Current suggests that warming is having relatively weak effects on our stocks, compared to other systems.

What is uncertain about range shifts and productivity to 2040?

What range shifts will occur, for which species, and in what direction/s?

Which stocks will experience changes in productivity and to what magnitude?

What associated management concerns—protected species, habitat preservation, social and economic goals—will be most impacted?

How might changes in this driving force affect the system?

Shifting stocks will create challenges for managers as adaptation from a geographically static system to one that incorporates moving stocks is required. These challenges will be mirrored by fishermen and industry as they not only navigate a changing management system, but the on-the-water realities of capturing stocks.

Changing productivity creates challenges for fisherman by adding variability. Although changing productivity and subsequent quotas are part of management today, the challenges that new conditions place on traditional stock assessment will additionally increase uncertainty around these assessments.

Sources:

Free, C.M., Thorson, J.T., Pinsky, M.L., Oken, K.L., Wiedenmann, J., Jensen, O.P., 2019. Impacts of historical warming on marine fisheries production. Science 363, 979–983. https://doi.org/10.1126/science.aau1758

Karp, Melissa A., et al. 2018. “Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process: From Detection to Management Action.” NOAA Technical Memorandum NMFS-F/SPO-188.

Link, Jason S., Janet A. Nye, and Jonathan A. Hare. 2011. “Guidelines for incorporating fish distribution shifts into a fisheries management context.” Fish and Fisheries 12.4: 461-469.

Morley, J.W., Selden, R.L., Latour, R.J., Frölicher, T.L., Seagraves, R.J., Pinsky, M.L., 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. PLOS ONE 13, e0196127. https://doi.org/10.1371/journal.pone.0196127

Pinsky, Malin L., et al. 2018. “Preparing ocean governance for species on the move.” Science 360.6394: 1189-1191.

Notes: