**West coast climate-fisheries synthesis media pitch and selected case studies – April 2023**

**Title:** Impact of the 2014-2016 marine heatwave on U.S. and Canada west coast fisheries: surprises and lessons from key case studies

**Tag line:** A new collaborative study produced by multiple west coast marine research institutions and The Nature Conservancy (TNC) provides the most comprehensive coastwide synthesis to date of fisheries impacts resulting from the most intense marine heatwave on global record.

**Timing:** Accepted for publication on April 4th, publication very soon

**Target audience:**

* Fisheries policymakers – to elevate the importance of allocating new funding to climate-ready fisheries science and management
* Fisheries managers – to facilitate agency prioritization of frameworks, methods, and tools that advance climate-ready fisheries management
* Scientific community – to catalyze new scientific research focusing on linkages between climate, oceans, fisheries, and fishing communities
* Fishing industry/public – to communicate how impacts they’re experiencing are linked to climate change and the need for improved fisheries management

**Summary:** As symptoms of climate change, extreme environmental events (e.g., marine heatwaves) now represent the greatest global threat to the oceans, causing profound ecosystem and socioeconomic impacts worldwide. The recent 2014-2016 marine heatwave on the west coast of North America was the most intense heatwave event ever recorded globally, resulting in ecological changes that impacted fisheries management and human livelihoods ranging from Mexico to Alaska. Studies documenting the impacts of marine heatwaves are critical because they provide a window into the future of what may happen in ocean ecosystems and coastal communities as climate change continues. To address this, The Nature Conservancy (TNC), multiple research institutions, and NOAA Fisheries collaborated to conduct the most comprehensive case study synthesis to date of the impacts of the west coast marine heatwave on U.S. and Canadian fisheries, and to extract key lessons for preparing global fisheries science, management, and industries for the future. Using ten case studies of fisheries along the west coast, the collaborative research team found that extreme warming events result in negative impacts to some species but positive impacts to others. For instance, the heatwave and associated extreme drought conditions resulted in some of the lowest Chinook salmon run sizes on record, leading to federal fishery disaster declarations and fishery closures. We also documented an unexpected reversal of known anchovy and sardine populations, with sardine population health declining during the heatwave (causing closure of the fishery) while anchovy abundance exploded to a near-record high, possibly due to shifting diets.  We can learn from scientific studies of marine heatwaves by viewing them as “stress tests” that can expose vulnerabilities – and resilience – both in terms of impacts to the environment and to food systems and coastal economies. We found that relying only on historical fisheries trends to inform management decisions will lead to continued fishery impacts in the future, while forecasting and evaluating fishery responses and management decisions under expected climate scenarios can lead to proactive solutions that mitigate or minimize future fishery impacts.

**Call to action:** Fisheries science and management institutions need to:

1. Improve fisheries and ecosystem monitoring to enhance mechanistic understanding, provide early warning signals, and improve predictions of impacts
2. Increase the flexibility, adaptiveness, and inclusiveness of management where possible
3. Use climate-fishery forecasting models to estimate impacts of future marine heatwaves and proactively guide management decisions
4. Enhance the adaptive capacity of fishing communities by promoting engagement, flexibility, experimentation, and fail-safes

**Ten Case studies (13 species: 7 negative, 6 positive):**

* 1. **Pacific cod (-)** – Ranked among the top three fisheries by volume and revenue in Alaska, this species also historically represents the 3rd highest volume commercial fishery nationwide, but it experienced a sudden and severe decline in biomass in 2017, which was due to heatwave-induced mortality of age classes ranging from eggs to adults. Heatwave conditions then returned in 2019, further impacting recruitment and delaying stock recovery. Catch limits were severely reduced in 2018 and 2019, but the declines continued, prompting a fishery closure and a federally declared fishery disaster in 2020. The stock began showing signs of rebuilding in 2022, but additional management improvements are needed: 1) precautionary buffers used in combination with environmental indicators can allow managers to act proactively, 2) forward-looking perspectives that include early warning indicators, and 3) adoption of climate-linked stock assessments will allow managers to plan for and respond to future heatwave events.
  2. **Kelp, urchin, abalone (-)** – In 2015, the marine heatwave caused a perfect storm of events in California, increasing ocean temperature and reducing nutrient availability, causing kelp forests to decline by over 90% statewide. Because kelp is the primary food source for many herbivores, the loss of kelp forests led to starvation of commercially harvested red urchin and recreationally harvested red abalone. Red urchin became unmarketable due to severely reduced gonads (marketed as ‘uni’ in sushi restaurants), leading to a fishery collapse and federally declared fishery disaster. Red abalone starvation resulted in a mass mortality event for this species, prompting a 2018 statewide recreational fishery closure in California and Oregon that remains in place today. Management improvements could include: 1) encouraging new fisheries and improving marketability for the purple urchin, a species which exploded in population during the heatwave, or 2) development of kelp forest restoration programs.
  3. **Chinook salmon (-)** – Ranging from California to Alaska, this species has uniquely strong commercial, recreational, ecological, subsistence, and cultural value. Chinook salmon are anadromous, spending their adult lives in the ocean before migrating up rivers to spawn, after which recently hatched juveniles migrate back down rivers into the ocean to become adults. This makes them vulnerable to ocean stressors, and especially vulnerable to stressors in rivers where salmon experience population bottlenecks. Unfortunately, impacts were not only documented with adult salmon in the oceans during the marine heatwave, but also simultaneously in rivers during a concurrent period of extreme drought. Salmon run sizes ended up being some of the lowest on record during this period, which led to overfishing declarations and several federal disaster declarations, impacting commercial fishing communities and Native American communities across the Pacific Northwest. To address this, we need improved climate, ecosystem, fisheries, and communities data/model integration that will allow improved forecasts, precautionary control rules, and improvements in model uncertainty estimation. We also need improved freshwater and estuarine habitat restoration, and more opportunities for fishing communities to switch to alternative fisheries when needed.
  4. **Dungeness crab (-)** – The Dungeness crab represents the single most valuable commercial fishery on the west coast, but the marine heatwave significantly impacted this fishery. The heatwave led to the formation of Harmful Algal Blooms, which produce domoic acid, a marine biotoxin that crabs bioaccumulate, posing a human health risk to consumers. These elevated domoic acid levels in Dungeness crabs led to numerous west coast fishing season delays and closures, including a federally declared fishery disaster in 2015-16 that represented over $43M in lost fishery income and a federal assistance disbursement of $25.8M to fishing communities. Concurrently, the marine heatwave also created anomalous oceanographic changes that shifted humpback whale migrations, creating a strong overlap between whale distribution and the statewide Dungeness crab fishing footprint. This overlap led to a spike in entanglements of whales in crab trap fishing gear that impacted both the whales and the fishery. These events collectively prompted the creation of California’s entanglement risk management program, leading to both delayed openings and early closures of the last four crab fishing seasons to prevent humpback whale entanglements. Additional improvements needed are: 1) improve the spatio-temporal scale of biotoxin monitoring to enable more targeted closures that minimize both public health risks and impacts to fishing communities, 2) continue to advance entanglement prevention strategies that are co-developed with stakeholders, 3) reform the federal fishery disaster assistance program, and 4) improve access to alternative fisheries as a means of providing other options during extreme environmental events.
  5. **Pacific sardine (-) and northern anchovy (+)** – Sardine and anchovy are two of the most abundant and ecologically important species in the California Current because they are both prey species for numerous marine fishes, seabirds, and mammals. Sardine and anchovy are generally known to follow “boom-and-bust” cycles that are not related to fishing, but rather to decadal oceanographic regime shifts that represent either cold or warm periods. For decades, the scientific and management consensus was that cool periods favored anchovy populations while warm periods favored sardine populations, but this dynamic has mysteriously begun to change during recent warm periods, especially during the west coast marine heatwave. During this extreme warming event, counter to expectations sardines declined, leading to a closure of the fishery in 2015 and a federally declared fishery disaster. Meanwhile, anchovy abundance exploded to a near-record population high, possibly due to shifting their diet leading up to the heatwave. This reversal of expected population impacts illustrates the risks of relying on historical correlations during immediate and extreme environmental events. Successful management of these species into the future should include improving our understanding of the links between environmental change, foraging ecology, and stock productivity, as well as management strategies that integrate environmental change and reduce impacts on marine seabirds, mammals, and other species.
  6. **Pacific bluefin tuna (+)** – Targeted by numerous countries across the entire Pacific as one of the most sought-after species for global sushi markets, Pacific bluefin tuna are considered overfished, but increased in both size and availability in U.S. waters during the west coast marine heatwave. Prior to the heatwave, 77% of annual recreational catch occurred off Mexico, but during and after the heatwave, 75% of annual recreational catch shifted northward to California waters. Average bluefin ‘trophy’ sizes also tripled from 25kg to 75kg, with fish reaching sizes of almost 180kg reported. Extended periods of warm water also meant that bluefin fishing seasons lasted much longer, resulting in greater annual catch than previous years. This led to the U.S. exceeding its catch limit in 2017 by 50 metric tons due to the combined effects of improved recreational fishing, an increase in commercial purse seine effort, and lags in catch reporting, which resulted in a precautionary closure of the fishery that year. While the improved fishery represented an economic boon to California recreational fisheries, improving climate resilience of this fishery requires new science focusing on ecology, distribution, and Pacific-wide migrations of the species.
  7. **California market squid (+)** – California market squid represent the single highest-volume fishery annually in the state (and sometimes the highest revenue fishery), marketed as a variety of products ranging from fishing bait to restaurant calamari. The fishery has historically operated primarily in Mexico and California, but the marine heatwave caused a significant northward shift into Oregon waters, with spawning observed as far north as Kodiak Island, Alaska. The new fishery in Oregon (and proposed fishery in Alaska) represented new economic opportunities for coastal communities while also highlighting the need for improved science focusing on bycatch, conflicts with other fishing gears, and potential benthic habitat impacts. In anticipation of future squid fisheries farther north, fisheries scientists and managers need to evaluate novel conflicts in rapidly emerging fisheries, and improved monitor and short-term forecasting for short-lived species like squid.
  8. California shrimp species (+)
  9. Bocaccio (+)
  10. Shortbelly rockfish (+)