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Sweating the Small Stuff: Managing Fisheries and Fostering Marine Ecosystem Resilience in the Face of Climate Change

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Erratum
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SWEATING THE SMALL STUFF: MANAGING FISHERIES AND FOSTERING MARINE ECOSYSTEM RESILIENCE IN THE FACE OF CLIMATE CHANGE

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I. INTRODUCTION

Since 2013, thousands of emaciated California sea lion pups have washed ashore along the United States West Coast ("U.S. West Coast" or "West Coast"), leading concerned scientists and members of the public to wonder what's happening off our shores. In March 2016, researchers concluded that California sea lions have been suffering from mass malnutrition because their main food sources, sardine and anchovy, are scarce.[1] Why are these fish so scarce? Scientists say that the combination of unusually warm ocean conditions and fishing for sardine and anchovy has depleted the food supply for these animals. And sea lions are simply the most visible victims. The health of the entire California Current Large Marine Ecosystem (CCE), the productive swath of the Pacific Ocean that runs from southern British Columbia south along the West Coast of the United States to Baja California, Mexico, is at stake.

Sometimes called the "Blue Serengeti," the CCE hosts an astonishing array of fish and wildlife that support commercial and recreational fisheries, tourism, and research. The CCE's vibrant fish, sea bird, and marine mammal populations are fueled by species known as forage fish – seemingly unglamorous, small, oily fish like sardine and anchovy that provide the essential food source of dozens of marine predator species. These fish are targets of one of the largest commercial fisheries on the U.S. West Coast: the Coastal Pelagic Species fishery. They are also vul-

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[1] Karen Kaplan, *Why are so many sea lion pups starving? Scientists find the answer off the central California coast*, LOS ANGELES TIMES, Mar. 1, 2016.

nerable to climate change effects, which can suppress their populations and cause them to shift to different geographic areas.

United States' fishery managers must modernize their approach to fishery management to ensure that fishing does not deprive ocean predators of crucial food sources, especially as climate change makes those food sources more scarce and uncertain. Arresting the effects of climate change is obviously a long-term project. In the meantime, we must take immediate action to build the resilience of forage fish populations and the CCE as a whole to address climate change effects. One thing we can do right away to promote resilient forage fish populations is to adapt the way we manage the commercial fisheries that target these ecologically vital species. The decision-makers in charge of managing the Coastal Pelagic Species fishery, the National Marine Fisheries Service and Pacific Fishery Management Council, have been slow to implement changes based on the scientific evidence of recent declines in forage fish populations and concomitant declines in their predators. Fortunately, existing federal law offers the necessary tools to manage forage fisheries in a way that will build resilience to climate change effects.

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) already requires federal fishery managers to ensure that fishery management measures account for ecosystem needs like adequate forage and to base management decisions on the best available scientific information. However, rather than accounting for the effects of removing ecologically important fish on the rest of the food web, fishery managers have implemented the law with a narrow view towards protecting fish stocks only to the extent necessary to support fishing.

To bring forage fishery management into the modern era, we must align management with the best available scientific information on the biology and ecology of forage species like anchovy, and implement the MSA's requirement to account for ecosystem needs. This would compel several fundamental changes in the way decision-makers apply the law to manage the Coastal Pelagic Species fishery. It would require moving away from management that focuses narrowly on setting catch limits on a species-by-species basis to a system that explicitly accounts for predator needs. This system would be implemented through both catch limits and restrictions on the times and places where fishing can take place to protect breeding predators. It would also require fishery managers to closely monitor the abundance of targeted forage species, build in management mechanisms to ensure that enough spawning age fish are left in the water to allow the species to rebound, and include a buffer in catch-setting mechanisms to account for the considerable scientific uncertainty involved in setting protective catch levels. In addition to protecting forage fish and predators from the combined pressure of fishing and climate change, accounting for the value of forage fish to the ecosystem and the uncertainty associated with managing these fisheries should result in more transparent, thoughtful, and informed decision-making as to how we use this crucial public resource.

This article explores the fundamental changes in fishery management necessary to build the resilience of forage fish populations and the ecosystem as a whole in the face of climate change. After presenting an overview of the role and vulnerability of forage fish, the article describes the current management framework for forage species in the federal Coastal Pelagic Species fishery, the current status of those species, and management responses. We then present an overview of key MSA provisions and offer recommendations for using these provisions to align forage fishery management with biology and ecology of these species, including specific recommendations for protecting forage fish populations and dependent predators, focusing on anchovy as a current, important example of the changes needed to better ensure the sustainability of the CCE.

II. Forage Fish: Ecologically Essential and Environmentally Sensitive

A. Ecological Role Of Forage Fish

Forage fish are essential to the CCE. Pacific sardine, Northern anchovy, Pacific mackerel, jack mackerel, market squid, and krill – are vital to the ecological and economic health of the California Current Ecosystem. These species are known as "forage species" because they form an important part of the diets of other fish, sea birds, and marine mammals. They are also subject to significant fishing pressure by one of the largest commercial fisheries off the U.S. West Coast, the federally managed Coastal Pelagic Species fishery.[2]

The forage species targeted by the Coastal Pelagic Species fishery provide a crucial link in the marine ecosystem. These small fish consume and assimilate nutrients and energy directly from the base of the marine food chain (phytoplankton and zooplankton), which is then transferred to higher trophic level species such as predatory fish, marine mammals, and seabirds when they consume forage species (or to higher level predators,

[2] Under the MSA, a fishery is defined as "one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics" and "any fishing for such stocks." 16 U.S.C. § 1802(13).

such as orcas, that eat direct predators of forage species, such as salmon).[3] Anchovy and sardine in particular are the preferred prey of many predators due to their high fat content and superior nutritional value. Pacific sardine and Northern anchovy, for instance, are preferred food for sea birds like the brown pelican and elegant tern.[4] When the birds' preferred prey is not available they must switch to prey that provides substantially less energy, which can reduce survival and reproductive success.[5]

The forage species managed under the Coastal Pelagic Species Fishery Management Plan (FMP) sustain an estimated 19 species of marine mammals, 33 species of sea birds, and over 40 species of marine fish.[6] Predators supported by sardine, anchovy, squid, and other coastal pelagic species include economically important fish species, such as Chinook salmon, albacore tuna, and California halibut, and depleted fish stocks, such as yellow eye rockfish and canary rockfish.[7] In fact, a recent study showed that under real market conditions, Pacific sardine are actually more economically valuable when left in the ocean as food for wild salmon – which support an important commercial fishery and seafood market – than for the uses supported by the commercial sardine fishery, which include use as aquaculture feed and bait.[8] Sardine and Northern anchovy are such an important food source that fishery managers include them as components of the essential fish habitat for Pacific salmon, groundfish species like flounder and rockfish, and highly migratory species like swordfish and tuna.[9]

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[3] Anthony D.M. Smith, et al., *Impacts of Fishing Low-Tropic Level Species on Marine Ecosystems*, SCIENCE, Aug. 26, 2011, at 1147, 1147–48.

[4] Lindsay Young, et al., CLIMATE CHANGE AND SEABIRDS OF THE CALIFORNIA CURRENT AND PACIFIC ISLANDS ECOSYSTEMS: OBSERVED AND POTENTIAL IMPACTS AND MANAGEMENT IMPLICATIONS, FINAL REPORT TO THE U.S. FISH AND WILDLIFE SERVICE, REGION 1 11-12 (2012); David Ainley, et al., Towards Ecosystem Based-Fishery Management in the California Current System – Predators and the Preyscape: A Workshop (March 2014) (unpublished report to the National Fish and Wildlife Foundation) (on file with Point Blue Conservation Science).

[5] Philippe Cury, et al., *Small pelagics in upwelling systems: patterns of interaction and structural changes in "wasp-waist" ecosystems*, ICES J. OF MARINE SCIENCE, 2000, at 603, 607; Pacific Management Council, Amendment 8 (to the Northern Anchovy Fishery Management Plan) incorporating a name change to: The Coastal Pelagic Species Fishery Management Plan (1998).

[6] PACIFIC FISHERY MANAGEMENT COUNCIL, NA87FC0008, *The Coastal Pelagic Species Fishery Management Plan* amend. 8 app. A at A-2, A-3 (Dec. 1998), http://www.pcouncil.org/wp-content/uploads/cpsa8_apdx_a.pdf.

[7] *Id.* at A-2–A-4, A-21–A-29, A-31 (jack mackerel consumed by tunas and other large predators); A-31(sardines and anchovies consumed by many predators, including commercially important fish); A-31, 32 (Pacific mackerel consumed by a wide variety of predators).

[8] Rögnvaldur Hannesson and Samuel F. Herrick, Jr., *The Value of Pacific Sardine as Forage Fish*, MARINE POLICY, 34: 935–942, at 941–942 (2010).

[9] NMFS, Aug. 25, 2011, Finding of No Significant Impact re Amendment 13 to CPS FMP at 2.

Forage species targeted by this fishery also support marine wildlife such as whales, sea lions, seals, dolphins, and sea birds, and thus are critical to the tourism associated with seeking and watching these animals.[10] In 2015, Northern anchovy were scarce along most of the West Coast. The remnant anchovy population converged in Monterey Bay, creating a food oasis that drew a plethora of wildlife. A BBC live television special captured the phenomenon, treating viewers around the globe to stunning footage of humpback whales breaching, sea lions leaping, and sea birds diving, all of them chasing shiny bait balls of anchovy.[11] Whale watching trips quickly booked weeks in advance. Visitors from all over the state, and the country, flocked to Monterey Bay, filling hotels, restaurants, and local attractions. Owners of Monterey Bay whale watching businesses have estimated that one ton of anchovies is worth about $1,000-$3,000 in whale watching revenue per day (excluding associated hotel, restaurant, and other associated tourism revenue), whereas the same ton of anchovies is worth $100 when caught and sold by the fishery.[12] Careful management of anchovy, sardines, and other forage fish thus offers both ecological and economic benefits.

Just as an abundant forage supply supports an abundance of predators, declines in forage species lead to declines in the predators that rely on them. The availability of anchovies is known to directly affect the breeding success of seabirds such as the Cassin's auklet, pelicans, terns, gulls, and auks.[13] Decreased availability of forage species is thought to be partly responsible for poor marbled murrelet reproduction and may have contributed to the need to list the species under the Endangered Species Act.[14]

Declines in forage species have also resulted in reproductive failures and population declines in seabirds and marine mammal mortality in

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[10] PACIFIC FISHERY MANAGEMENT COUNSEL, COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN, Am. 8 at A-21–A-29. (2011).

[11] *Big Blue Live* (PBS BBC Earth television broadcast Aug. 31-Sept. 2, 2015), http://www.pbs.org/big-blue-live/home/.

[12] *See* Letters to PFMC and NMFS from Diane Glim, American Cetacean Society; Nancy Black, Monterey Bay Whale Watch; Kate Spencer, Fast Raft Ocean Safaris on Monterey Bay; John Calambokidis, Cascadia Research Collective. Nov. 2015 PFMC Meeting Briefing Book, Agenda Item H.3b Public Comment, http://www.pcouncil.org/wp-content/uploads/2015/10/H3b_Public_Comment_FULL_ElectOnly_Nov2015BB.pdf and http://www.pcouncil.org/wp-content/uploads/2015/11/H3b_Sup_Public_Comment_5_Nov2015BB.pdf.

[13] PACIFIC FISHERY MANAGEMENT COUNSEL, COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN, Am. 8 at EIS-15; William J. Sydeman, et al., *Climate-ecosystem change off Southern California: Time-dependent seabird predator-prey numerical responses*, DEEP SEA RES. PART II: TOPICAL STUD. IN OCEANOGRAPHY, Feb. 2015, at 158, 166.

[14] Margot L. Stiles, et al., HUNGRY OCEANS: WHAT HAPPENS WHEN THE PREY IS GONE? 11 (2009).

California waters.[15] Forage fish declines have manifested in significant mortality events and breeding failures among sea birds and sea lions in recent years. These predators require an adequate supply of forage fish within close range of their nesting and pupping sites in order to feed their young. Localized depletions of forage species can have dramatic impacts on imperiled predator populations even if overall abundance of the prey population is high. For example, nesting seabirds and their chicks face starvation and death if prey is not readily available within the brief periods of time that adult birds can leave the nest to forage.[16]

B. Possible Effects of Climate Change on Forage Fish Availability and Distribution

Sardines, anchovy, and other key forage fish species are highly influenced by changing ocean temperature and associated changes in upwelling, currents, and plankton productivity. These changes influence the abundance of forage species, their geographic distribution, reproductive success, and physical condition.[17] Climate change affects forage fish in a number of ways. These species eat plankton associated with highly productive ocean areas, often in areas where significant mixing of deeper ocean waters with surface waters occurs. Plankton productivity depends on favorable ocean temperatures and circulation patterns that increase nutrient availability necessary to drive the growth of plant plankton. Plant plankton is eaten by animal plankton; increased plant plankton leads to increased animal plankton and increased food source for forage fish. In the California Current Ecosystem, the mixing that drives plankton productivity occurs via both upwelling, which brings nutrient-rich water to the surface, where the nutrients spur growth of plant plankton, and horizontal currents (known as advection). As sea surface temperatures rise, ocean waters can become increasingly stratified, hampering mixing and decreasing plankton productivity.

Changes in wind patterns can also affect the timing, intensity, and location of coastal upwelling dynamics and oceanic fronts, both of which are vital for ocean productivity. While some researchers have predicted that that the winds that drive upwelling will intensify, it is unclear whether this would in fact enhance planktonic productivity. Moreover,

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[15] S. T. Lindley, et al., What caused the Sacramento River fall Chinook stock collapse? 26 (2009).

[16] Stiles, *supra* note 14.

[17] Martin Lindegren, et al., *Climate, fishing, and fluctuations of sardine and anchovy in the California current*, PNAS, Aug. 13, 2013, at 13672, www.pnas.org/cgi/doi/10.1073/pnas.1305733 110.

researchers have also predicted that thermal stratification will intensify.[18] While it seems likely that changing conditions will produce changes in the ecosystem, predicting how the ecosystem will respond to shifting temperatures, stratification, and upwelling remains a difficult task.[19]

Changes in water temperature, ocean circulation, wind patterns, and upwelling can be expected have a significant effect on the availability of planktonic food sources.[20] Not surprisingly, forage species tend to move according to favorable ocean conditions. In addition to seeking food, anchovy seek out water temperatures of 11.5 to 16.5 degrees Celsius for spawning, while sardines prefer somewhat warmer waters from 15 to 23 degrees Celsius.[21] As ocean temperatures warm, ideal spawning temperatures for anchovy may occur more infrequently and the species may experience less reproductive success. In addition, the geographic locations where these fish find their ideal spawning conditions may change significantly. While some far-ranging predators may be able to follow the forage fish as they move around, predators that cannot travel as far, like nesting pelicans, may be forced to switch to less nutritious prey or starve.

As ocean temperatures and circulation patterns shift, sardines and anchovies tend to shift with them. A geographic shift in sardine and anchovy abundance could lead some predators like larger fish species to follow. Some predators, however, will not necessarily be able to follow so readily.[22] Some species, such as brown pelicans and California sea lions, have limited suitable breeding habitat on land, and limited ability to follow their food source during breeding season. Brown pelicans, for instance, breed in the Channel Islands off Southern California and Mexico. They rely on anchovy for high quality nutrition while they raise their chicks. If anchovy are not available within foraging range of peli-

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[18] Lindsay Young, et al., CLIMATE CHANGE AND SEABIRDS OF THE CALIFORNIA CURRENT AND PACIFIC ISLANDS ECOSYSTEMS: OBSERVED AND POTENTIAL IMPACTS AND MANAGEMENT IMPLICATIONS, FINAL REPORT TO THE U.S. FISH AND WILDLIFE SERVICE, REGION 1 9-10 (2012) (discussing possible effects and scientific uncertainty).

[19] William J. Sydeman, et al., *Climate-ecosystem change off Southern California: Time-dependent seabird predator-prey numerical responses*, DEEP SEA RES. PART II: TOPICAL STUD. IN OCEANOGRAPHY, Feb. 2015 112:158–170.

[20] Martin Lindegren, et al., *Climate, fishing, and fluctuations of sardine and anchovy in the California current*, PNAS, Aug. 13, 2013, Early Edition at 1, www.pnas.org/cgi/doi/10.1073/pnas.1305733110.

[21] Akinori Takasuka, et al., *Contrasting spawning temperature optima: Why are anchovy and sardine regime shifts synchronous across the North Pacific?*, PROGRESS IN OCEANOGRAPHY 77: 225–232, at 230.

[22] Timothy E. Essington, et al., *Fishing amplifies forage fish population collapses*, PNAS, May 26, 2015, 21: 6648–52, www.pnas.org/cgi/doi/10.1073/pnas.1422020112.

can parents, the pelicans often either will not breed or, if they do, their chicks will die of starvation before fledging.[23]

California sea lions face similar challenges. This species also breeds in the Channel Islands. When the forage supply near the pupping grounds is low, mother sea lions are forced to travel farther and longer to find food. In severe cases, when mothers simply can't find enough food to sustain themselves and nurse their pups, they are forced to abandon the pups.[24] Since 2013, the scarcity of calorically dense sardine and anchovy within the foraging range of the California sea lion's Channel Islands rookeries has resulted in the documented stranding of nearly 5,500 emaciated sea lions, most of them pups.[25] National Marine Fisheries Service biologists expect that large numbers of sea lions will die of starvation in 2016 as well, thanks to unusually warm ocean temperatures and a continued dearth of forage.[26]

Another prominent climatic factor in West Coast forage fish abundance is the El Niño Southern Oscillation ("ENSO"). This term refers to the periodic warming and cooling of sea surface temperatures in the central and eastern tropical Pacific Ocean. The shift in ocean temperature causes changes in atmospheric circulation, altering temperature and precipitation patterns across the globe. The phenomenon has three phases: a neutral phase, characterized by average sea surface temperatures; La Nina, characterized by lower than average sea surface temperatures; and El Niño, which is characterized by warmer than average sea surface temperatures. On the U.S. West Coast, El Niño is often accompanied by more rain, reduced upwelling, and decreased ocean productivity.

There is substantial scientific debate about whether and how climate change affects the ENSO.[27] However, researchers increasingly predict that warming ocean temperatures will lead to more frequent, stronger El

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[23] Letter from United States Fish and Wildlife Service to Dorothy Lowman, Pacific Fishery Management Council (May 14, 2015) (on file with author); Harvey, A. L., and Mazurkiewicz, D.M. 2015 California Brown Pelican and Double-Crested Cormorant Breeding Colony Status on Anacapa Island, California in 2014 Determined by a Rapid Assessment Approach (finding an estimated 0.16 to 0.33 young fledged per nest attempt).

[24] Sam McClatchie, et al., Food limitation of sea lion pups and the decline of forage off central and southern California (Oct. 30, 2015) (unpublished manuscript) (on file with the author), https://www.researchgate.net/publication/267899031_Food_limitation_of_sea_lion_pups_and_the_decline_of_forage_off_central_and_southern_California; *2013-2015 California Sea Lion Unusual Mortality Event in California*, NAT'L OCEANIC AND ATMOSPHERIC ADMIN. FISHERIES (Apr. 20, 2015), http://www.nmfs.noaa.gov/pr/health/mmume/californiasealions2013.htm

[25] *Id.*

[26] Peter Fimrite, *Sea lions in trouble, again, off California coast*, S.F. CHRON., Dec. 10, 2015, http://www.sfgate.com/bayarea/article/Sea-lions-in-trouble-again-off-California-coast-6690177.php.

[27] *See e.g.,* Zhangyu Liu, et al., *Evolution and forcing mechanism of El Nino over the past 21,000 years*, NATURE, Nov. 26, 2014, at 550, 550.

Niño events.[28] If climate change does indeed produce more El Niño events like the 2015-16 event currently skewing ocean conditions off the West Coast, some forage species may experience more frequent, significant population declines. For example, El Niño conditions are known to cause increased juvenile mortality, reduced fecundity, and reduced growth in Northern anchovy.[29] The strong El Niño from 1982-1984, for example, was followed by significantly reduced northern anchovy abundance, which was reflected in decreased catch levels by the commercial fishery.[30] Species that depend on anchovy and other fish that experience similar declines during El Niño may suffer during these periods of low food availability. The need for precautionary, ecosystem-based management of forage fisheries is even more critical in El Niño years like 2015 and 2016 in order to mitigate adverse affects on climate-sensitive species like anchovy and their predators.

III. The Competition: The Coastal Pelagic Species Fishery

A. Current Forage Management

Forage fish are relatively easy to target because they travel in schools and are readily scooped up by large nets. They are not so easy to manage. Their populations rise and drop quickly even without fishing pressure. Adding fishing pressure to that dynamic, particularly when a population is declining, can result in the diminution or collapse of both the fish populations being targeted and predators (including humans) that depend on those populations.

The Coastal Pelagic Species fishery removed an estimated 422 million pounds of forage species annually between 2010 and 2013.[31] Vessels in the Coastal Pelagic Species Fishery primarily use purse seines or lampara nets (nets that surround schools of fish swimming close to the surface) to catch Pacific sardine, Pacific mackerel, market squid, Northern anchovy, and jack mackerel.[32] The same stocks also occur in and are

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[28] *See e.g.,* Wenju Cai, et al., *Increasing frequency of extreme El Nino events due to greenhouse warning*, Nature Climate Change, Published Online: 19 January 2014 — DOI: 10.1038/nclimate2100, http://www.nature.com/nclimate/journal/v4/n2/full/nclimate2100.html.

[29] Paul C. Fiedler, et al., *Effects of California El Nino 1982-1984 in the Northern anchovy*, J. of Marine Research 44, Nov. 20, 2014, 317–338.

[30] *Status of the Pacific Coast CPS Fishery and Recommended Acceptable Biological Catches: Stock Assessment and Fishery Evaluation,* Pacific Fishery Management Council, PFMC, 54 (Dec. 2014).

[31] *Id.,* Appdx. A at 56–57 (Dec. 2014).

[32] Pacific Fishery Management Council, NA87FC0008, *The Coastal Pelagic Species Fishery Management Plan* amend. 8 app. A at A-1 (Dec. 1998), http://www.pcouncil.org/wp-content/uploads/cpsa8_apdx_a.pdf.

targeted by fisheries in Mexico and Canada.[33] Forage fish caught in the commercial Coastal Pelagic Species Fishery are primarily used for bait, pet food, and feed for aquaculture operations and livestock.[34] For example, Northern anchovy are often used for agricultural or aquaculture feed, while Pacific sardines are often shipped to Australia to feed penned tuna or used as bait in commercial longline fisheries, and Pacific mackerel are often canned for pet food.[35]

NMFS and the Council manage six groups of fish and invertebrates as "stocks in the fishery" under the Coastal Pelagic Species FMP. These are Pacific sardine, Pacific mackerel, Northern anchovy, jack mackerel, market squid, and krill (also known as euphausiids).[36] The FMP designates three categories of stocks: "actively managed" stocks, which are Pacific sardine and Pacific mackerel; "monitored" stocks, which are Northern anchovy, market squid, and jack mackerel; and "prohibited harvest" for krill.[37] While both managed and monitored categories are subject to management measures, only "actively managed" stocks receive periodic stock assessments (i.e., updated estimates of the population size or biomass of the species) and adjustments to target catch levels.[38] Monitored species, while just as ecologically important and prone to quick changes in population levels, are managed based on generic definitions of overfishing, without regular stock assessments or adjustments to catch levels.[39]

Catch limits and other management measures for "actively managed" Pacific sardine and Pacific mackerel are generally calculated and set each year in what is known as the annual specification process.[40] During this process, fishery managers apply updated information, including the current biomass of the fish species and the portion of the overall stock assumed to be present in U.S. waters, to mathematical formulae set forth in the FMP. Managers use those formulae to calculate measures such as the overfishing limit, acceptable biological catch, and annual catch limit.[41] The formulae used to calculate the annual catch limit incorporate an important parameter called the "cutoff," which is meant to protect the stock's ability to recover from excessive fishing pressure or

[33] *Id*.

[34] *Id.* at A-4, A-11, A-13, A-16.

[35] *Id.* at A-4, A-11, A-13.

[36] Pacific Fishery Management Council, NA87FC0008, *The Coastal Pelagic Species Fishery Management Plan as Amended through Amendment 13* at 7–8 (Sept. 2011), http://www.pcouncil.org/wp-content/uploads/CPS_FMP_as_Amended_thru_A13_current.pdf.

[37] *Id.* at 8–9.

[38] *Id.*

[39] *Id.*

[40] *Id.* at 43–44.

[41] *Id.* at 43–44.

natural decline by maintaining a minimum spawning biomass of fish.[42] Together, these limits and references points are designed prevent overfishing.

In contrast, Northern anchovy and jack mackerel are managed based on static, decades-old estimates of abundance. For example, Northern anchovy management measures in effect now (2015) are based on an abundance estimate published in 1995[43] – this, for a fish that lives for no more than 5-6 years and whose numbers can change by 99 percent within a few years. Given the species' population dynamics, relying on an estimate that is more than 20 years old is unlikely to provide any reliable clue regarding the species' current condition. Fishery managers must gather and analyze current information to come up with an accurate, up-to-date estimate of how many anchovy are actually in the water.

The present situation with respect to Northern anchovy illustrates the profound inadequacy of the current management approach. Under that approach, fishery managers rely upon the 1995 estimate to assume an annual catch limit of 25,000 metric tons for the central subpopulation of Northern anchovy, which occurs from Northern California to Baja California.[44] Until very recently, fishery managers had insisted that there was no need to perform updated stock assessments or revisit management measures unless annual catch exceeded 25,000 metric tons (mt). Managers assumed that the anchovy population was sufficiently large that this level of catch would not significantly affect it. However, an independent study released in fall of 2015 indicates that the entire central subpopulation of northern anchovy may measure less than 20,000 mt, meaning that the annual catch limit could actually exceed the amount of fish available to be caught.[45] This "set it and forget it" management method is fundamentally unsuited for short-lived, highly changeable, ecologically critical forage species.

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[42] *Id.* at 38–39.

[43] Pacific Fishery Management Council, NA87FC0008, *The Coastal Pelagic Species Fishery Management Plan* amend. 8 app. B at B-104 (Dec. 1998), http://www.pcouncil.org/wp-content/uploads/cpsa8_apdx_a.pdf, relying on Conrad, J.M. 1991.A Bioeconomic Analysis of the Northern Anchovy. Working paper in agricultural economics. Department of Agricultural Economics. New York State College, Ithaca New York.

[44] *Fisheries Off West Coast States; Coastal Pelagic Species Fisheries; Multi-Year Specifications for Monitored and Prohibited Harvest Species Stock Categories*, 80 Fed. Reg. 72,676 (proposed Nov. 20, 2015) (to be codified at 50 C.F.R. 660); Pacific Fishery Management Council, NA87FC0008, *The Coastal Pelagic Species Fishery Management Plan as Amended through Amendment 13* at 41 (Sept. 2011), http://www.pcouncil.org/wp-content/uploads/CPS_FMP_as_Amended_thru_A13_current.pdf.

[45] Alec D. MacCall, William J. Sydeman, Peter C. Davison & Julie A. Thayer, *Recent Collapse of Northern Anchovy Biomass Off California*, 175 Fisheries Research: An International Journal on Fisheries Science, Fishing Technology and Fisheries Management 87-94, at 93 (2015), http://www.faralloninstitute.org/Publications/MacCallEtal2015FishRes.pdf.

Moreover, despite its stated intention to meet predator needs, the current FMP manages sardine, anchovy, mackerel, and squid on a species-by-species basis. Under this approach, managers limit catch levels of each species to the extent they believe is necessary to maintain the stock at a level that will support continued fishing. There is no explicit consideration of ecosystem needs or availability of other alternate prey species. This narrow approach increases the risk that the ecosystem will be depleted of key food sources while providing no means to remedy the situation when risk becomes reality.

B. Effects of Fishing on Forage Species and Predators

Fishing pressure exerts significant effects on forage species' population levels.[46] Because these species tend to swim in large schools instead of spreading out through the water column, it is possible to target and catch large numbers of forage fish even when their overall numbers throughout their range are relatively low.[47] In fact, catch levels for the same amount of fishing effort often remain stable or increase even as a forage species' abundance declines, thanks in part to the species' tendency to "ball up" in easy-to-catch schools. The ease with which fishermen can find and catch remnant schools of fish leads to a false impression of overall abundance when in reality the fish is becoming scarce.[48]

In addition to being vulnerable to overfishing, forage fish populations often fluctuate more widely than other species in response to changing ocean conditions such as temperature, currents, and upwelling.[49] These fluctuations make forage species more vulnerable to overfishing during periods of poor oceanographic conditions. Fishing pressure can increase the likelihood and speed of population crashes, par-

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[46] *See* Timothy E. Essington, Pamela E. Moriarty, Halley E. Froehlich, Emma E. Hodgson, Laura E. Koehn, Kiva L. Oken, Margaraet C. Siple & Christine C. Stawitz, *Fishing Amplifies Forage Fish Population Collapses*, 112 PNAS No. 21 6,648-6,652 (May 26, 2015), http://www.pnas.org/content/112/21/6648.

[47] *See* Malin L. Pinsky, Olaf P. Jensen, Daniel Ricard & Stephen R. Palumi, *Unexpected Patterns of Fisheries Collapse in the World's Oceans*, 108 PNAS No.20 8,317-8,322 (May 17, 2011), http://www.pnas.org/content/108/20/8317.abstract; Lenfest Forage Fish Task Force, *Little Fish Big Impact: Managing a Crucial Link in Ocean Food Webs* (Apr. 2012), http://www.oceanconservationscience.org/foragefish/files/Little%20Fish,%20Big%20Impact.pdf.

[48] MacCall, *supra* note 45, at 91.

[49] Malin L. Pinsky, Olaf P. Jensen, Daniel Ricard & Stephen R. Palumi, *Unexpected Patterns of Fisheries Collapse in the World's Oceans*, 108 PNAS No. 20 8,317-8,322, at 8320 (May 17, 2011), http://www.pnas.org/content/108/20/8317.abstract; Pacific Fishery Management Council, NA87FC0008, *The Coastal Pelagic Species Fishery Management Plan* amend. 8 app. A at A-20 - A-21. (Dec. 1998), http://www.pcouncil.org/wp-content/uploads/cpsa8_apdx_a.pdf.

ticularly when fishery management measures are inadequate.[50] Even relatively moderate changes in fishing pressure can result in significant changes in forage species abundance, particularly during times when the species' productivity is already low due to environmental conditions.[51] These effects could also be magnified by long-term changes in ocean conditions caused by climate change.[52]

Fishing can thus magnify a natural decline, rendering the fished species more susceptible to climate change effects in several ways. In addition to decreasing the species' overall abundance, fishing pressure can lead to more frequent population fluctuations, localized depletion and a shortage of reproductive adults (a phenomenon known as truncated age structure, caused by fishing pressure removing most adult fish).[53] Limiting the distribution, age structure, and abundance of forage fish populations limits their ability to recover to vibrant population levels after hitting a trough. Conversely, while it may not halt a natural population decline, reducing fishing pressure can markedly slow the rate of the decline and accelerate the population's recovery.[54]

The U.S. West Coast has witnessed the effects of overfishing a declining forage population before. In the middle of the 20th century, the north Pacific entered a "cold" period – a condition that is generally thought to be good for anchovy productivity but bad for sardine. Heavy fishing pressure on large, fecund adult sardines during these unfavorable ocean conditions resulted in the collapse of both the sardine population and the sardine fishery. By the time fishery managers placed a morato-

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[50] *See* Pinsky, *supra* note 49 generally; Lenfest Forage Fish Task Force, *Little Fish Big Impact: Managing a Crucial Link in Ocean Food Webs* (Apr. 2012), http://www.oceanconservation-science.org/foragefish/files/Little%20Fish,%20Big%20Impact.pdf.

[51] Pinsky, *supra* note 49 generally.

[52] Margot L. Stiles, Laure Katz, Tess Geers, Sarah Winter, Ellycia Harrould-Kolieb, Andrew Collier, Ben Enticknap, E. Kate Barnes, Sarah Hale, Prisca Faure, Jaroslava Waters & Michael F. Hirshfield, *Hungry Oceans: What Happens When the Prey is Gone?* at 20 (Mar. 2009), http://oceana.org/sites/default/files/reports/hungry_oceans_OCEANA_012.pdf.

[53] Pew Environmental Group, *The State of Science: Forage Fish in the California Current* at 20 (Jan, 2013), http://www.pewtrusts.org/~/media/legacy/uploadedfiles/peg/publications/other_resource/the20state20of20the20science2020forage20fish20in20the20california20currentpdf.pdf; Martin Lindegren, David M. Checkley, Jr., Tristan Rouyer, Alec D. MacCall & Nils Chr. Stenseth, *Climate, Fishing, and Fluctuations of Sardine and Anchovy in the California Current*, 110 PNAS No. 33 13,672-13,677, at 6 (Apr. 6, 2015), http://www.pnas.org/content/112/21/6648.full.pdf; *See* Timothy E. Essington, Pamela E. Moriarty, Halley E. Froehlich, Emma E. Hodgson, Laura E. Koehn, Kiva L. Oken, Margaraet C. Siple & Christine C. Stawitz, *Fishing Amplifies Forage Fish Population Collapses*, 112 PNAS No. 21 6,648-6,652 (May 26, 2015), http://www.pnas.org/content/112/21/6648.

[54] Martin Lindegren, David M. Checkley, Jr., Tristan Rouyer, Alec D. MacCall & Nils Chr. Stenseth, *Climate, Fishing, and Fluctuations of Sardine and Anchovy in the California Current*, 110 PNAS No. 33 13,672-13,677, at 3, 6 (Apr. 6, 2015), http://www.pnas.org/content/112/21/6648.full.pdf

rium on targeting sardines in 1967, sardine had virtually disappeared. It would take several decades for the sardine to rebound; when it did, it reached only a third of the levels seen in the 1930s.[55]

In 2012, NMFS scientists published a study warning that this pattern of unsustainable fishing on a declining population was repeating itself. While additional management measures had been established to limit fishing effort on sardine, authorized catch levels were too high relative to the number of large, fecund adults and their declining numbers. Scientists predicted that the sardine population would once again collapse if fishing effort was not significantly decreased.[56] Unwilling to believe that their management framework wasn't working and under pressure to keep catch limits on the higher end of the spectrum, fishery managers ignored the scientists' warnings and declined to lower catch limits. In April 2015, a revised stock assessment for Pacific sardine revealed that the stock had indeed dropped to very low levels – well below the minimum biomass available for fishing under the Coastal Pelagic Species Fishery Management Plan. As a result, the fishery was closed for the remainder of the 2014-2015 fishing season (through June 30, 2015), as well as for the 2015-2016 season (July 1, 2015 through June 30, 2016).[57]

Northern anchovy have also declined dramatically in recent years. The best available science shows that the biomass of the central subpopulation of Northern anchovy, which ranges from Baja California to Northern California, reached record low levels in 2011 and shows no signs of recovery through 2015.[58] The most recent, available abundance estimate for this subpopulation indicates that its biomass is below 20,000 metric tons (mt) – 5,000 mt lower than the annual catch limit NMFS proposed in November 2015.[59]

This situation is all the more worrisome because other forage species that might otherwise fill the ecological gap left by sardine are also scarce now. Recent scientific information indicates that multiple impor-

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[55] Juan P. Zwolinski, David A Demer, *A Cold Oceanographic Regime with High Exploitation Rates in the Northeast Pacific Forecasts a Collapse of the Sardine Stock*, 109 PNAS No. 11 4,175-4,180 (Mar. 13, 2012), http://www.pnas.org/content/109/11/4175.full.pdf.

[56] *Id*.

[57] *Fisheries Off West Coast States; Coastal Pelagic Species Fisheries; Closure*, 80 Fed. Reg. 22,926 (published Apr. 24, 2015) (to be codified at 50 C.F.R. pt. 660) (indicating immediate closure until June 30, 2015); *Fisheries Off West Coast States; Coastal Pelagic Species Fisheries; Annual Specifications,* 80 Fed. Reg. 36,933 (proposed May 21, 2015) (to be codified at 50 C.F.R. pt. 660) (indicating the date of limited fishing from July 1, 2015 through June 30, 2016).

[58] *Supra*, note 45, at 93.

[59] *Id.*; *Fisheries Off West Coast States; Coastal Pelagic Species Fisheries; Multi-Year Specifications for Monitored and Prohibited Harvest Species Stock Categories*, 80 Fed. Reg. 72,676, at 72,678 (proposed Nov. 20, 2015) (to be codified at 50 C.F.R. pt. 660).

tant forage species in the U.S. West Coast forage assemblage have declined to low levels. One recent study reported a 72 percent decline in the abundance of larval fish between 1972 to 1981 and 2002 to 2011, concluding that "much of this decline can be attributed to the decline of northern anchovy and Pacific hake . . .."[60]

Another study further analyzed this information and concluded that "fish declines off southern California are largely driven by commercially exploited forage fishes," specifically "anchovy, hake, sardine, & jack mackerel."[61] Abundance data show that four important forage fish species that are targeted by commercial fisheries (Pacific sardines, northern anchovy [central subpopulation], Pacific herring, and Pacific mackerel) are currently well below their average levels since 1980 (see Fig. 1). In addition, the ongoing El Niño event is predicted to reduce the availability of market squid. In short, marine predators face an unusual paucity of forage species in the CCE, as potential substitute prey items are not available for species that rely on sardines and anchovies.

The consequences of diminished forage supplies have been all too apparent along the California coast. The brown pelican, once considered a great Endangered Species Act success story, has experienced adult mortality events, anomalous feeding behavior such as the predation of common murre chicks, and poor reproductive success in the United States and Mexico since 2009. Recently published analyses of seabird and forage fish distribution and abundance in the CCE show that a substantial decline in seabird abundance in the northern portion of the southern CCE (from around Point Conception, California, northward) – a rate of decline of 2.2 percent per year from 1987-2011 – is attributable to declines in anchovy abundance and availability. California sea lion pups have died of starvation by the thousands in 2013, 2014, and 2015.[62] Their deaths are linked to low anchovy and sardine abundance, especially in waters surrounding sea lion and pelican breeding grounds in the Channel Islands.

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[60] J. Anthony Koslow, Eric F. Miller & John A. McGowan, *Dramatic Declines in Coastal and Oceanic Fish Communities in California*, 538 MARINE ECOLOGY PROGRESS SERIES 221-227 (2015).

[61] Sam McClatchie, Andrew Thompson, Steven Bograd, Samantha Siedlecki, Simone Alin & William Watson, *Fish Diversity and Corrosive Water in the Southern California Current System*, Presentation at CalCOFI Conference at Moss Landing, CA (Dec. 15, 2015).

[62] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, 2013-2015 California Sea Lion Unusual Mortality Event in California (updated Apr. 21, 2015), http://www.nmfs.noaa.gov/pr/health/mmume/californiasealions2013.htm; NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, 2015 Elevated California Sea Lion Strandings in California: FAQs (updated June 1, 2015), http://www.westcoast.fisheries.noaa.gov/mediacenter/faq_2015_ca_sea_lion_strandings.pdf.; Peter Fimrite, *Sea Lions in Trouble, Again, Off California Coast*, SFGATE, Dec. 10, 2015, http://www.sfgate.com/bayarea/article/Sea-lions-in-trouble-again-off-California-coast-6690177.php.

Unprecedented California sea lion pup strandings and starvation and sustained brown pelican nesting failures highlight the effects of the depleted anchovy stock on dependent predators. These effects are magnified when coupled with low levels of other similar forage species such as Pacific sardines, Pacific herring, Pacific mackerel, and krill. "The severe decline in anchovies is a likely factor in recent reports of reproductive failure, mortality, and declines of California's marine mammals and seabirds."[63]

As this grim situation illustrates, the combination of natural prey fluctuations, changing ocean conditions, and unsustainable fishing pressure can produce significant harm to the ecosystem. These circumstances are likely to be more frequent and perhaps more extreme as climate change effects continue to manifest themselves in the CCE. If we are to restore the health of the ecosystem and build its resilience to changing ocean conditions, we must rapidly reform the one aspect of the problem over which we have immediate control: fishery management.

[63] MacCall, *supra* note 45, at 92-93.

ABUNDANCE INDICES FOR 4 WEST COAST FORAGE FISH

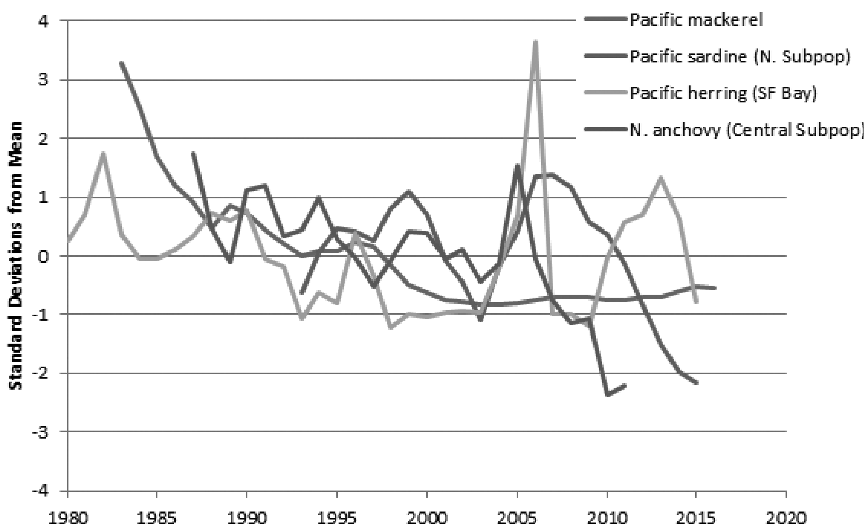

Figure 1: Standardized abundance of Pacific mackerel, Pacific sardine (NSP), Pacific herring (San Francisco Bay), and Northern anchovy (central subpopulation) relative to their mean values since 1980.[64]
Data sources: 2015 Pacific mackerel stock assessment (1984–2015),[65] 2015 Pacific sardine stock assessment (1992–2015),[66] 2015 San Francisco Bay Herring Population Estimate (1980–2015),[67] Sydeman et al. 2015 anchovy larval spring surveys (1987-2011).[68]

IV. MAGNUSON-STEVENS ACT: OVERVIEW AND TOOLS FOR CLIMATE RESILIENT MANAGEMENT

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) establishes the regulatory system for conserving and managing

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64 Figure courtesy of Oceana, Inc.

65 P. R. Crone, K. T. Hill, *Pacific Mackererl (Scomber japonicas) Stock Assessment for USA Management in the 2015-16 Fishing Year*, Pacific Fisheries Management Council Agenda Item G.2.a (June 2015), http://www.pcouncil.org/wp-content/uploads/2015/05/G2a_PMackerel_Assmt_ExecSum_JUN2015BB.pdf.

66 Kevin T. Hill, Paul R. Crone, Emmanis Dorval & Beverly J. Macewicz, *Assessment of the Pacific Sardine Resource in 2015 for U.S.A. Management in 2015-16*, Pacific Fisheries Management Council Agenda Item G.1.a (Apr. 2015), http://www.pcouncil.org/wp-content/uploads/2015/03/G1a_ExecSumSardine_Assessment_Print_APR2015BB.pdf.

67 STATE OF CALIFORNIA, THE NATURAL RESOURCES AGENCY, DEPARTMENT OF FISH AND WILDLIFE, Sch No. 98052052, Draft Supplemental Environmental Document: Pacific Herring Commercial Fishing Regulations (2015), https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=99472&inline.

68 Sydeman, W.J., Thompson, S.A., Santora, J.A., Koslow, J.A., Goericke, R., and Ohman, M.D., *Climate-ecosystem change off Southern California: Time-dependent seabird predator-prey numerical responses*. DEEP SEA RESEARCH II: TOPICAL STUDIES IN OCEANOGRAPHY, 112:158-170 (2015).

fish populations targeted by U.S. fishing vessels. The MSA aims, among other things, "to take immediate action to conserve and manage the fishery resources found off the coasts of the United States" and "to establish Regional Fishery Management Councils to exercise sound judgment in the stewardship of fishery resources."[69] The MSA thus creates eight regional fishery management councils and charges them with preparing fishery management plans (FMPs) for each fishery requiring conservation and management.[70] Councils must include in their FMPs and plan amendments the measures necessary to conserve and manage the fishery.[71] The Pacific Fishery Management Council ("Council") has jurisdiction over the Coastal Pelagic Species Fishery off the coasts of California, Oregon, and Washington.[72]

The Secretary of Commerce, acting through NMFS, must review FMPs and plan amendments to ensure that they comply with the "National Standards" set forth by 16 U.S.C. § 1851(a), the other provisions of the MSA, and other applicable laws.[73] The MSA assigns NMFS the ultimate "responsibility to carry out any FMP or amendment approved or prepared by NMFS," as well as the authority to "promulgate such regulations . . . as are necessary to discharge that responsibility or carry out any other provision of [the MSA]."[74] Courts have clarified that the twin goals of National Standard 1 – preventing overfishing while achieving optimum yield on a continuing basis – have primacy over other considerations such as short-term economic impacts on the fishing industry.[75]

While the MSA generally has not been used to protect ecosystems and anticipate approaching climate change effects, its requirements provide a sound basis for doing so.[76] This section presents a brief overview of basic MSA requirements relevant to forage management; Section V

[69] 16 U.S.C. § 1801(c)(1), (5) (2012).

[70] 16 U.S.C. §§ 1852(a)(1); 1852(h)(1) (2012).

[71] 16 U.S.C. § 1853(a)(1)(A) (2012).

[72] 16 U.S.C. § 1852(a)(1)(F) (2012).

[73] 16 U.S.C. § 1854(a)(1)(A) (2012).

[74] 16 U.S.C. § 1855(d) (2012).

[75] 16 U.S.C. § 1851(a)(1) (2012); 50 C.F.R. § 600.310(l)(2016); *see also Natural Resources Defense Council v. Daley*, 209 F.3d 747, 753 (D.C. Cir. 2000) ("we reject the District Court's suggestion that there is a conflict between [the Magnuson Act's] expressed commitments to conservation and to mitigating adverse economic impacts. . . . [U]nder the [Magnuson Act], the Service must give priority to conservation measures."); *NRDC v. NMFS*, 421 F.3d 872, 879 (9th Cir. 2005) ("The purpose of the Act is clearly to give conservation of fisheries priority over short-term economic interests.").

[76] *See* 16 U.S.C. §§ 1852(h)(1), 1853(a)(1) (2012); 50 C.F.R. § 600.310(d),(h) (2016). "Conservation and management" refers to legal measures "required to rebuild, restore, or maintain, and which are useful in rebuilding, restoring, or maintaining, any fishery resource *and* the marine environment; and . . . which are designed to assure that . . . irreversible or long-term adverse effects on fishery resources *and* the marine environment are avoided." *Id.* § 1802(5) (emphasis added).

describes how fishery management should be adapted to meet those requirements and foster ecosystem resilience in the age of climate change.

A. Preventing Overfishing and Protecting the Marine Environment

The foremost of the national standards set out in the MSA is National Standard 1 (National Standard 1), which requires that "[c]onservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery. . .."[77] The MSA defines the term "overfishing" to mean "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis."[78] NMFS regulatory guidelines state that overfishing consists of fishing at a rate that jeopardizes the stock's capacity to produce "maximum sustainable yield" (MSY).[79]

The concepts of maximum sustainable yield and optimum yield form the basis of fishery management measures under the MSA.[80] MSA regulations define maximum sustainable yield as the "largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological, environmental conditions and fishery technological characteristics . . . and the distribution of catch among fleets."[81] The statute itself defines "optimum yield" as the "amount of fish which will provide the greatest overall benefit to the Nation . . . taking into account the protection of marine ecosystems," and states that optimum yield is to be based on maximum sustainable yield "as reduced by any relevant economic, social, or ecological factor."[82]

These two measures can be conceptualized by thinking of a fish population as a bank account with multiple account holders, where the population at any given time represents the amount of money in the account. *Maximum sustainable yield* is equivalent to the maximum amount of money a single account holder, in this case the commercial fishery that directly targets the fish species in the account, could spend without

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[77] 16 U.S.C. § 1851(a)(1)(2012).

[78] 16 U.S.C. § 1802(34) (2012).

[79] *See* 50 C.F.R. § 600.310(e)(2)(i)(B)(2016). While these regulatory guidelines do not have the force of law, they "are routinely cited by courts as persuasive authority on the meaning of the MSA." *Oceana, Inc. v. Locke*, 831 F.Supp.2d 95, 117 (D.D.C. 2011), *citing Oceana, Inc. v. Evans,* No. 04-811, 2005 WL 555416, at *10–14; *Natural Resources Def. Council v. Daley*, 209 F.3d 747, 753 (D.C. Cir. 2000).

[80] *See* 50 C.F.R. § 600.310(b)(2)(i)-(ii)(2016).

[81] 50 CFR § 600.310(e)(1)(i)(A)(2016).

[82] 16 U.S.C. § 1802(33)(A)-(B) (2012).

consistently depleting the account. However, whales, sea lions, terns, and tuna also hold part of the account to meet their basic food needs (an example of an ecological factor), and other fishermen hold part of it to feed the larger predatory fish that they target with their own lines and nets (an example of another ecological factor as well as an economic and social factor). *Optimum yield* then is the amount of fish that the directed fishery account holder could "spend" without impacting the ability of the other account holders to pay their necessary expenses. Optimum yield, in effect, drives fishery managers to budget their fish wisely in order to accommodate the needs of all account holders, be they fishermen, whale watch operators, or sea birds.

The MSA requires that each FMP "assess and specify the present and probable future condition of, and the maximum sustainable yield and optimum yield from, the fishery, and include a summary of the information utilized in making such specification."[83] The National Standard 1 guidelines state that as part of this process a fishery management plan must identify ecological, social, and economic factors relevant to managing each particular stock, and evaluate them to determine optimum yield.[84]

NMFS's National Standard 1 guidelines specify that "maintaining adequate forage for all components of the ecosystem" is a key consideration relevant to optimum yield.[85] The guidelines also direct fishery managers to consider a number of ecological factors in determining the appropriate level for optimum yield, including the fishery's "impacts on . . . forage fish stocks, other fisheries, predator-prey or competitive interaction, marine mammals, threatened or endangered species, and birds. . . . In addition, consideration should be given to managing forage stocks for higher biomass than B_{msy} [stock size, measured as biomass, that would be achieved by fishing at a rate that would result in maximum sustainable yield] to enhance and protect the marine ecosystem."[86] Accounting for ecosystem needs is thus an essential part of achieving optimum yield.

In order for this accounting to have any effect in the water, optimum yield must be reflected in annual catch limits (ACLs) that are set at a level that ensures a sufficient amount of forage fish is left in the ocean to feed marine predators. This involves explicitly reducing MSY to ac-

[83] 16 U.S.C. § 1853(a)(3)(2012).

[84] 50 C.F.R. § 600.310(e)(3)(ii)(2016).

[85] 50 C.F.R. § 600.310(e)(3)(iii)(C)(2016).

[86] 50 C.F.R. § 600.310(e)(3)(iv)(C)(2016).

count for each relevant ecological factor[87] and setting ACLs at a level such that catch will not exceed optimum yield. Unfortunately, NMFS's regulatory guidelines as currently written largely ignore optimum yield in setting management measures. Those regulatory guidelines direct fishery managers to establish ACLs with reference to two other measures: the overfishing limit and acceptable biological catch.[88] The *overfishing limit* is defined as an estimate of the catch level above which overfishing is occurring.[89] *Acceptable biological catch* is a measure meant to account for scientific uncertainty in estimating the overfishing limit, as well as other sources of scientific uncertainty.[90] The National Standard 1 guidelines state that the annual catch limit may not exceed the acceptable biological catch level, which in turn may not exceed the overfishing limit (i.e., ACL = acceptable biological catch = overfishing limit).[91] This step-wise system of limits is meant to prevent overfishing by ensuring that fishing efforts stays well below the level that would deplete the stock, taking into account that avoiding overfishing for a data-poor stock requires an extra buffer of precaution.

In essence, the National Standard 1 guidelines establish a system where management measures focus on preventing overfishing but lack an explicit mechanism for achieving optimum yield. The MSA itself does not provide a great deal of help on that front, since the ACL provision simply requires that ACLs be set "at a level such that overfishing does not occur in the fishery."[92] However, ACLs remain subject to the MSA's broader requirement that all conservation and management measures achieve optimum yield on a continuing basis.[93]

Fishery managers have a number of tools beyond catch limits to ensure sustainable management of forage fisheries. For instance, the MSA authorizes fishery managers to close important areas to fishing on a permanent or seasonal basis. These "time-area closures" can be espe-

[87] 16 U.S.C. § 1802(33) (2012) (OY "is prescribed as such on the basis of the maximum sustainable yield from the fishery, *as reduced by* any relevant economic, social, or ecological factor." (emphasis added)); *see also* Sustainable Fisheries Act Report of the Committee on Commerce, Science, and Transportation, Sen. Rep. 104-276 (May 23, 1996) at 32–33 (Sustainable Fisheries Act of 1996 changed the definition of "optimum" to clarify that ecological, economic, and social factors could only be used to set catch levels *lower* than MSY, but not higher (emphasis added)).

[88] 50 C.F.R. § 600.310(b)(2)(ii) (2016).

[89] 50 C.F.R. § 600.310(e)(2)(i)(D)(2016).

[90] 50 C.F.R. § 600.310(f)(2)(ii)(2016).

[91] 50 C.F.R. § 600.310(f)(2)(ii), (iv) (2016).

[92] 16 U.S.C. § 1853(a)(15). Interestingly, the legislative history of the Magnuson-Stevens Reauthorization Act demonstrates a desire on Congress' part to establish ACLs with reference to OY rather than MSY and ensure that ACLs did not exceed OY. *See* Sen. Rep. 109-229 on S. 2012 at 6–7, 20–21 (Apr. 4, 2006).

[93] 16 U.S.C. § 1851(a)(1) (2016).

cially valuable for protecting spawning fish aggregations, important feedings areas, and special habitat areas.[94] Even more broadly, the MSA allows fishery managers to establish management measures "to conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations."[95]

B. Gathering and Using the Best Available Science as the Basis for Management

Crucially, National Standard 2 of the MSA requires that "[c]onservation and management measures [are] based on the best scientific information available."[96] Courts have emphasized that NMFS "must utilize the best scientific data *available,* not the best scientific data *possible.*"[97] In other words, NMFS may not decline to take actions to conserve and manage the fishery on the basis that the available information is uncertain or could be improved by more research or analysis. "It is well settled . . . that the Secretary can act when the available science is incomplete or imperfect, even where concerns have been raised about the accuracy of the methods or models employed."[98] In a recent case concerning emergency action, a federal court confirmed: "Because the imperative imposed on the agency by Congress is one of urgent action, and not the achievement of fishery science perfection, the agency may—indeed must—act in times of perceived emergency on 'incomplete or imperfect' data."[99]

When taking management action, NMFS must make "a thorough review of all the relevant information available at the time. NMFS may not disregard superior data in reaching its conclusion."[100] There is no requirement that scientific information be peer reviewed or published in order to be considered the "best available." In fact, NMFS frequently bases management decisions on data that have not been peer reviewed or published. Continued reliance on information that the agency knows is

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[94] 16 U.S.C. §§ 1853(b)(2)(A), 1855(d) (2012).

[95] 16 U.S.C. § 1853(b)(12) (2012).

[96] 16 U.S.C. § 1851(a)(2) (2012).

[97] *Blue Water Fishermen's Assn. v. Nat'l Marine Fisheries Serv.*, 226 F.Supp.2d 330, 338 (D. Mass. 2002) (*quoting Building Indus, Ass'n of Superior California v. Norton*, 247 F.3d 1241, 1246–47 (D.C. Cir. 2001) (emphasis in original)).

[98] *General Category Scallop Fishermen v. Secretary, U.S. Dept. of Commerce*, 635 F.3d 106, 115 (3rd Cir. 2011) (*citing North Carolina Fisheries Ass'n, Inc. v. Gutierrez*, 518 F.Supp.2d 62, 85 (D.D.C. 2007).

[99] *Massachusetts v. Pritzker*, 10 F. Supp. 3d 208, 220 (D. Mass. 2014).

[100] *Guindon v. Pritzker*, 31 F. Supp. 3d 169, 195-96 (D.D.C. 2014) (*citing Ctr. for Biological Diversity*, 933 F.Supp.2d at 148) (*quoting N.C. Fisheries Ass'n*, 518 F.Supp.2d at 85).

outdated and inaccurate is arbitrary and capricious.[101] In evaluating best available science, NMFS essentially must determine whether the new information presented is better than the information on which it currently relies.

Notably, courts have held that the MSA's "best available science" requirement does not require fishery managers to gather new data or develop new models.[102] To some degree, this is a pragmatic nod to the realities of fishery management. Collecting data on fish abundance, distribution, interactions with other species, and environmental conditions can be difficult and expensive. Moreover, the law does not require any particular level of scientific knowledge or certainty regarding the biology of a fish stock or the effects of fishing it in order to allow fishing to proceed.[103] Thus management decisions often must be made in compressed time periods with a paucity of reliable data.

The darker side of this so-called pragmatism is that fishery managers have little motivation to update the science underpinning management decisions, especially when newer science indicates a need to restrict fishing effort. The lack of an explicit requirement to update stock assessments, revisit catch-setting formulae, and monitor the effects of a fishery on other species in the ecosystem, in some cases, has been used as excuse to rely on outdated, shoddy science and preserve the status quo. As discussed below, NMFS has used this provision as an excuse not to monitor abundance levels and revise abundance estimates for several important forage species in the Coastal Pelagic Species fishery. Instead, the agency relies on decades-old data to manage species that fluctuate in abundance from year-to-year and whose declines have serious consequences for CCE. NMFS's interpretation of the MSA's best available science requirement does not meet the broader definition of basing management on best available science, which includes concepts beyond mere

[101] *Natural Resources Defense Council v. Evans*, 168 F. Supp. 2d 1149, 1153-54 (N.D. Cal. 2001), *aff'd in part and vacated in part by Natural Resources Defense Council v. Evans*, 316 F.3d 904 (9th Cir. 2003) (holding that NMFS acted unreasonably in relying on 15-year old data that it knew with "virtual certainty" were inaccurate); *Ctr. for Biological Diversity v. Lohn*, 296 F. Supp. 2d 1223, 1240 (W.D. Wash. 2003) (finding that NMFS must take action in accord with the Endangered Species Act best available science requirement "without reliance upon science that its own scientists unanimously agreed is inaccurate").

[102] *See, e.g., Massachusetts v. Pritzker*, 10 F. Supp. 3d 208, 220 (D. Mass. 2014) (National Standard 2 " 'does not mandate any affirmative obligation on [NMFS'] part' to collect new data." (*quoting Commonwealth of Mass. by Div. of Marine Fisheries v. Daley*, 10 F. Supp. 2d 74, 77 (D. Mass. 1998))).

[103] *See, e.g.*, *General Category Scallop Fishermen v. Secretary, U.S. Dept. of Commerce*, 635 F.3d 106, 115 (3rd Cir. 2011) ("It is well settled . . . that the Secretary can act when the available science is incomplete or imperfect, even where concerns have been raised about the accuracy of the methods or models employed.") (*citing North Carolina Fisheries Ass'n, Inc. v. Gutierrez*, 518 F.Supp.2d 62, 85 (D.D.C. 2007).

data, such as a basic understanding of a forage species' ecological role, the dynamic nature of forage populations, and the risk of depleting them.

It's also worth pausing for a moment to consider whether the traditional MSA management approach – allowing fishing to proceed in absence of reliable data unless and until it's proven to cause serious harm – makes sense. Is it really pragmatic to allow a species to be targeted by a fishery when we don't know how many fish are available to catch? If we don't know enough to manage a fishery in an ecologically intelligent way, then perhaps we shouldn't permit that fishery to operate. This is a particularly salient question for forage species, which have high value to the ecosystem (including communities and businesses that rely on that ecosystem's health), relatively low market value, high vulnerability to fishing, and high uncertainty in management.

V. What might West Coast forage management look like if MSA tools were applied with climate resilience in mind?

Fostering robust, resilient forage fish populations in the face of climate change will require a fundamental shift in how we approach fishery management. That shift could be reflected in a few concrete reforms: (1) regularly updating abundance estimates for forage fish and using updated estimates to set more accurate catch limits; (2) establishing a minimum biomass of a given forage species (e.g. anchovy) that must be left in the ocean to protect the stock and feed the ecosystem; (3) prohibiting fishing for key forage species around key breeding areas for predators to protect predators' ability to feed their young; (4) accounting for uncertainty in how fish species will respond to climate change effects when setting catch limits and other management measures; and (5) moving to a multispecies approach that explicitly considers predator needs and the availability of alternative preferred prey species when setting catch limits for forage species. These changes will require the development of more complex modeling approaches and a concomitant willingness to try new methods and lower catch levels in order to protect against ecosystem overfishing. They will not, however, require changes to the law. The MSA already provides the tools necessary to adapt forage fish management to the challenges posed by climate change.

Clearly, climate-resilient forage management will require us to move beyond simply plugging new data into status quo catch-setting formulae. Rather, we need to update the overall management framework to make sure that it reflects the best available science on forage species' population dynamics and likely responses to changing ocean conditions.

For example, the current management framework for Northern anchovy is fundamentally ill-suited to the biology and ecological role of this crucial species. Northern anchovy live only for about four years (and not more than five to six); they take about a year to reach reproductive maturity. Their population can rise and fall quickly and dramatically. Between 2005 and 2009, Northern anchovy abundance fell by 99 percent.[104] They rank among the most important prey species in the CCE.[105] They are also highly sensitive to changes in ocean conditions. Anchovy are known to experience increased juvenile anchovy mortality, reduced fecundity, and reduced growth during El Niño conditions.[106]

To put it mildly, NMFS's "set it and forget it" approach to managing anchovy is a poor match for this species. Under the Coastal Pelagic Species FMP, key management measures like the overfishing limit and annual catch limit for Northern anchovy are based on an abundance number derived from data through 1991. The FMP assumes that the central subpopulation of northern anchovy is comprised of some 733,000 mt of fish, allowing a maximum sustainable yield and overfishing limit of 123,000 mt and a supposedly precautionary catch limit of 25,000 mt.[107] NMFS has not reexamined that number in two decades. Indeed, the Coastal Pelagic Species FMP does not call for ever revisiting that number unless catch levels exceed 25,000 mt.[108] The FMP calls this approach "precautionary" because it leaves a 75 percent buffer between the overfishing limit and the catch limit. The FMP further suggests this approach is reasonable because anchovy are not heavily targeted (or rather, weren't at the time the FMP was written) and the fishery is not suffi-

[104] MacCall, A.D., W.J. Sydeman, P.C. Davison, J.A. Thayer, *Recent collapse of northern anchovy biomass off California*, 175 FISHERIES RESEARCH 87, 93 (2016).

[105] DAVID AINLEY, PETER ADAMS & JAIME JAHNCKE, TOWARDS ECOSYSTEM BASED-FISHERY MANAGEMENT IN THE CALIFORNIA CURRENT SYSTEM – PREDATORS AND THE PREYSCAPE: A WORKSHOP at 14 (2014); William J. Sydeman, Sarah Ann Thompson, Jarrod A. Santora, J. Anthony Koslow, Ralf Goericke & Mark D. Ohman, *Climate-ecosystem change off Southern California: Time-dependent seabird predator-prey numerical responses*, 112 DEEP-SEA RESEARCH II 158, 166-67 (2015).

[106] Paul C. Fielder, Richard D. Methot & Roger P. Hewitt, *Effects of California El Nino 1982-1984 in the northern anchovy*, 44 JOURNAL OF MARINE RESEARCH at 317 (1986).

[107] *Fisheries off West Coast States*; *Coastal Pelagic Species Fisheries*; *Multi-Year Specifications for Monitored and Prohibited Harvest Species Stock Categories*, 80 Fed. Reg. 72,676, 72,678 (Nov. 20, 2015) (to be codified at 50 C.F.R. pt. 600); PACIFIC FISHERY MANAGEMENT COUNSEL, COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN at 41 (2011); CPS Am. 8 at B-104 (relying Jon M. Conrad, *A Bioeconomic Analysis of the Northern Anchovy* (Cornell University, Department of Applied Economics and Management, Working Paper No. 7266, 1991)).

[108] PACIFIC FISHERY MANAGEMENT COUNSEL, COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN at 41 (2011) (stating that the default ABC control rule would remain in place until the SSC recommends an alternate value based on the best available science, and that ACLs for monitored stocks are "specified for multiple years until such time as the species becomes Actively managed or new scientific information becomes available").

ciently large or economically valuable to justify more intensive management.[109]

The problem with this approach is that anchovy can and do fluctuate by as much as 99 percent in just a few years. A recent study found that the central subpopulation of Northern anchovy is likely at historically low levels, with the entire stock weighing in at around 20,000 mt – well below the supposedly precautionary annual catch limit. And while anchovy's market value may be low, its ecological and economic value when left in the water to support dependent predators is considerable.

Climate change brings another wrinkle: the potential for stronger, more frequent El Niño events and warming ocean temperatures. The current Coastal Pelagic Species FMP recognizes that sardine are generally more productive when ocean temperatures are warmer, and allows for higher catch of sardine when average sea surface temperatures are relatively warm.[110] However, the FMP does not yet address the response of other species to changing ocean conditions or to El Niño events. Building in a management response to such changes is essential to maintaining a resilient forage base. The Pacific is currently experiencing the second consecutive year of El Niño conditions, characterized by unusually warm water temperatures, reduced upwelling and changes in plankton composition and abundance. The conditions predicted for 2016 are thought to be among the strongest El Niño events in recorded history. In the past, El Niño conditions such as those we are seeing now have resulted in increased juvenile anchovy mortality, reduced fecundity and reduced growth.[111] The strong El Niño from 1982-1984, for example, was followed by significantly reduced Northern anchovy catch levels.[112] These unfavorable conditions make it less likely that the increase in larvae reported offshore in summer 2015 will yield an increase in the spawning biomass of anchovy. The most likely response consistent with previous history will be a decrease in Northern anchovy abundance. This situation underscores the need to build in management measures to promote the resilience of this environmentally-driven population.

[109] Pacific Fishery Management Counsel, Coastal Pelagic Species Fishery Management Plan at 8-9 (2011); *Fisheries off West Coast States; Coastal Pelagic Species Fisheries; Multi-Year Specifications for Monitored and Prohibited Harvest Species Stock Categories*, 80 Fed. Reg. 72,676, 72,677 (Nov. 20, 2015) (to be codified at 50 C.F.R. pt. 600).

[110] Pacific Fishery Management Counsel, Coastal Pelagic Species Fishery Management Plan at 39 (2011) (analysis is done on a yearly basis; no temperature range specified in FMP).

[111] Paul C. Fielder, Richard D. Methot & Roger P. Hewitt, *Effects of California El Nino 1982-1984 in the northern anchovy*, 44 Journal of Marine Research at 317 (1986).

[112] Pacific Fishery Management Counsel, Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches, Stock Assessment and Fishery Evaluation at 54 (Dec 2014).

What would anchovy fishery management look like if the management framework were aligned with the species' biology and ecology? First of all, the stock would be assessed and annual catch limits specified at frequent, regular intervals – preferably on a yearly basis. Amending the FMP to require frequent stock assessments and catch limit specifications would be consistent with multiple MSA requirements. As discussed, it reflects the best available science on anchovy population dynamics. While the MSA does not explicitly require fishery management to proactively collect best available data, NMFS must base the management framework on an accurate, current understanding of the species' biology. In this case, the species' tendency to experience rapid, large changes in abundance renders it impossible to manage based on a static number that becomes stale within a couple of years.[113] This leads us to the more fundamental point: having an accurate, current estimate of anchovy abundance is essential to meeting the MSA's primary goals of preventing overfishing and accounting for ecosystem needs by achieving optimum yield. Quite simply, a basic prerequisite for preventing overfishing and accounting for ecosystem needs is knowing how many fish are in the ocean and roughly how many need to be left there. Because frequent stock assessments and catch limit specifications are necessary and appropriate for the conservation and management of the anchovy fishery, the FMP should require them.[114]

Second, the FMP would ensure that a minimum amount of anchovy is protected from fishing in order to maintain a healthy breeding population of anchovy and an adequate forage base for marine predators.[115] The "cutoff" parameter in the catch-setting formula for Pacific sardine provides a useful concept for accomplishing these two goals. The "cutoff" parameter is meant to protect the stock's ability to recover from excessive fishing pressure or natural decline by maintaining a minimum

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[113] *See* David Ainley, Peter Adams & Jaime Jahncke, Towards Ecosystem Based-Fishery Management in the California Current System – Predators and the Preyscape: A Workshop at 30-31 (2014) (recognizing that no true "sustainable" static catch limits can be set for forage species due to their variability and ecological importance).

[114] Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, 16 U.S.C. § 1853(a)(1)(A) (2007) (FMP must contain "[c]onservation and management measures necessary and appropriate to prevent overfishing and rebuild overfished stocks, and to protect, restore, and promote the long-term health and stability of the fishery.").

[115] *See, e.g.,* Timothy E. Essington, Pamela E. Moriarty, Halley E. Froehlich, Emma E. Hodgson, Laura E. Koehn, Kiva L. Oken, Margaret C. Siple & Christine C. Stawitz, *Fishing amplifies forage fish population collapses*, 112 Proceedings of the National Academy of Sciences 6648-52 (2015), http://www.pnas.org/cgi/doi/10.1073/pnas.1422020112; David Ainley, Peter Adams & Jaime Jahncke, *Towards Ecosystem Based-Fishery Management in the California Current System – Predators and the Preyscape: A Workshop* at 9 (2014), http://www.pointblue.org/uploads/assets/calcurrent/REPORT_Forage_Fish_Workshop_FINAL.pdf.

spawning biomass of Pacific sardine.[116] If the sardine stock (which is assessed annually) falls below the "cutoff" value, fishing effort is reduced to zero.[117] When properly implemented, the "cutoff" mechanism provides a means to prevent overfishing of sardines, in accordance with the first half of National Standard 1.[118] Applied more broadly, the "cutoff" mechanism could provide a way to lower or eliminate fishing pressure when forage fish are susceptible to collapse.[119]

As currently implemented, the "cutoff" mechanism does not ensure that a sufficient amount of sardine is left in the water as forage for predators. However, it could be adapted to accomplish both parts of National Standard 1 – preventing overfishing and achieving optimum yield in order to account for relevant ecological, economic, and social factors. Doing so would require fishery managers to determine how large a spawning stock biomass (how many breeding adults) is necessary to ensure that the anchovy population can bounce back to healthy numbers in a short period of time and, separately, how much anchovy is required to support healthy predator populations. That exercise would, in turn, require an explicit accounting of both the minimum stock size needed (1) to prevent overfishing and (2) to meet the needs of marine predators and economic uses that depend on those predators.[120],[121] For instance, fishery managers could determine that a minimum biomass of 100,000 mt of Northern anchovy must be maintained in order to prevent the stock from becoming overfished, and that an additional 250,000 mt must be left in the water to feed dependent predators and account for economic impacts to other fisheries. Therefore, a total biomass of 350,000 mt anchovy

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[116] Pacific Fishery Management Counsel, Coastal Pelagic Species Fishery Management Plan at 38-39 (2011).

[117] *Id.* at 38.

[118] Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, 16 U.S.C. § 1851(a)(1) (2007).

[119] *See* Timothy E. Essington, Pamela E. Moriarty, Halley E. Froehlich, Emma E. Hodgson, Laura E. Koehn, Kiva L. Oken, Margaret C. Siple & Christine C. Stawitz, *Fishing amplifies forage fish population collapses*, 112 Proceedings of the National Academy of Sciences at 6648-52 (2015), http://www.pnas.org/cgi/doi/10.1073/pnas.1422020112.

[120] Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, 16 U.S.C. § 1853(a)(3) (2007) (FMP must "assess and specify the present and probable future condition of, and the maximum sustainable yield and optimum yield from, the fishery, and include a summary of the information utilized in making such specification"); National Standard 1 – Optimum Yield, 50 C.F.R. § 600.310(e)(3)(iii) (2009) (clarifying the preventing overfishing and achieving OY are separate requirements and both must be met); National Standard 1- Optimum Yield, 50 C.F.R. § 600.310(e)(3)(iv)(factors to consider in specifying OY).

[121] National Standard 1- Optimum Yield, 50 C.F.R. § 600.310(e)(3)(iii) (2009) (NS1 guidelines explaining that the value of "maintaining adequate forage for all components of the ecosystem" should be weighed "when considering the economic, social, and ecological factors used in reducing [maximum sustainable yield] to obtain [optimum yield].").

would need to remain unfished.[122] Fishery managers could use this information in conjunction with a current estimate of the total biomass of anchovy to set an annual catch limit that would leave 350,000mt of anchovy in the ocean.

Another approach fishery managers could use in situations where they have only a moderate amount of information about the fish species they are managing would be to cap fishing effort at half the fish species' natural mortality rate and leave at least 40 percent of the species' unfished biomass as forage. For species that are poorly understood, experts recommend leaving at least 80 percent of the unfished biomass.[123]

Explicitly describing and accounting for relevant ecological, economic, and social factors when setting catch levels would also foster a more transparent, informed decision-making process. A full accounting of the environmental and economic costs of fishing for forage species relative to the economic value of catching and selling them for low-dollar value uses such as bait, aquaculture feed, and pet food would likely foster more ecosystem-minded, risk-averse fishery management. It would shift the focus from direct consumptive uses to the broader role of forage species in supporting a multitude of other valued resources, like whale- and bird-watching, supporting other commercial and recreational fisheries, and sustaining protected marine species. It would also allow the general public, who own the fishery resource and have a real stake in its management, to understand true tradeoffs and longer term consequences of targeting these forage species.

Third, climate-resilient forage fish management requires fishery managers to think beyond mere numbers of fish. We must also consider where and when those fish are being caught relative to where and when dependent predators need them.[124] As described above, forage fish tend to concentrate in areas where ocean conditions and planktonic food sources foster great productivity. These areas naturally become hotspots for predators as well, both human and non-human. Fishery managers might consider limiting fishing effort in these hotspots to prevent overfishing of the stock as a whole as well as to prevent localized depletion of the prey base. In addition, it may be necessary to prohibit fishing during breeding seasons around critical breeding areas for predators, such as the Channel Islands for pelicans and California sea lions. Such

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122 Note that these are purely hypothetical numbers used for illustrative purposes only.

123 LENFEST FORAGE FISH TASK FORCE, LITTLE FISH BIG IMPACT: MANAGING A CRUCIAL LINK IN OCEAN FOOD WEBS at 87–91 (Apr. 2012).

124 *Id.* at 26-29, 87; David Ainley, Peter Adams & Jaime Jahncke, *Towards Ecosystem Based-Fishery Management in the California Current System – Predators and the Preyscape: A Workshop* at 9 (2014), http://www.pointblue.org/uploads/assets/calcurrent/REPORT_Forage_Fish_Workshop_FINAL.pdf. .

measures provide an additional way to ensure that fishery management accounts for ecosystem needs and thus is consistent with optimum yield. In addition, NMFS has explicit authority to "designate zones where, and periods when, fishing shall be limited, or shall not be permitted . . . ."[125] NMFS may also prescribe management measures that "conserve target and non-target species and habitats, considering the variety of ecological factors affecting fishery populations."[126] While time-area closures cannot make up for prey moving out of a predator's range, they can act as a backstop against local depletion of food that remains within range. Closures can also be used to protect spawning fish, foster greater reproductive success, and allow the fish population to rebound to higher numbers more quickly.

Fourth, management measures must account for the considerable uncertainty involved in managing these quick-changing, environmentally sensitive forage populations in the face of changing ocean conditions. Managing anchovy and other forage species is already an exercise in uncertainty. Climate resilient management will have to do a better job at detecting and responding to downturns in the population. It will also need to consider the risks that come with fishing for a species when managers do not know its status or whether its population is trending up or down. One direct way to address this risk would be to adopt a substantially lower "acceptable biological catch" level in order to account for scientific uncertainty involved in setting the overfishing limit, which establishes the upper limit for the annual catch limit.

In statistical terms, "uncertainty" is generally represented as a range of possible values for the thing being measured. For a well-known value, the range will be small. For a value that is poorly known or tends to fluctuate a great deal, like the biomass of most forage species, the range will be large. The more sources of uncertainty there are in estimating a value like biomass, the less certainty managers can have that the particular value they are using as an annual catch limit, for example, is the correct one. Examples of scientific uncertainty that should be accounted for by acceptable biological catch include uncertainty in estimating the biomass of a stock, uncertainty in setting overfishing limits, as well as uncertainty in stock assessment results and stock projections, and time lags in updating stock assessments.[127] Moreover, fishery management

[125] Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, 16 U.S.C. § 1853(b)(2)(A) (2007).

[126] *Id.* at § 1853(b)(12).

[127] National Standard 1 – Optimum Yield, 50 C.F.R. § 600.310(f)(1), (4) (2009).

measures are expected to become more conservative as uncertainty increases.[128]

A proper estimate for acceptable biological catch thus provides a margin of safety between the overfishing level and the annual catch limit such that even if fishery managers choose the wrong value for the overfishing limit, the annual catch limit will still prevent overfishing.[129] Properly accounting for sources of uncertainty is crucial for ensuring that the margin of safety is large enough to catch any likely errors, especially for data-limited, ecologically important species like those managed under the Coastal Pelagic Species FMP. Indeed, NMFS has identified the failure to consider scientific uncertainty as a primary cause of overfishing.[130]

Forage fish management measures in the age of climate change must fully reflect the fact that we do not know how these species will respond to changing ocean conditions, as well as the considerable risk associated with making incorrect or overly optimistic assumptions to the fish species themselves and the myriad animal and human predators that depend on them. Like the optimum yield accounting, a thorough accounting of the uncertainties and risks involved in targeting anchovy and other key forage species should lead to more conservative catch levels.

Finally, at a broader level, ecosystem resilience requires managing forage fish stocks with reference to one another, meaning that fishery managers should consider the relative abundance of alternative prey species when setting catch limits for a particular species like anchovy or sardine. Forage species' populations are bound to experience highs and lows. Predators must be able to switch to other quality prey in order to get adequate nutrition and breed successfully. Thus, when other prey species are at low numbers, catch limits for anchovy (for example) should be decreased to ensure that predators have some prey available to them. This approach would ensure that the entire multi-species fishery is managed in a way that accounts for the ecological, economic, and social factors required for optimum yield.

Managing anchovy, sardine, and other forage species in close coordination would also fulfill fishery managers' responsibility under MSA National Standard 3, which requires that, "[t]o the extent practicable, an individual stock of fish shall be managed as a unit throughout its range,

[128] *Id.* § 600.310(f)(1).

[129] *Greenpeace v. Nat'l Marine Fisheries Serv.*, 106 F. Supp. 2d 1066, 1084 (W.D. Wash. 2000) ("Because the science is not certain, the acceptable biological catch . . . [is] intended to be a conservative estimate of the amount of fishing that can be done without overfishing the stock.")

[130] Magnuson-Stevens Act Provisions; Annual Catch Limits; National Standard Guidelines, 74 Fed. Reg. 3178, 3181 (Jan. 16, 2009) (to be codified at 50 C.F.R. pt. 600).

and *interrelated stocks of fish shall be managed as a unit or in close coordination*."[131] NMFS's regulatory guidelines clarify that management units "may be organized around biological, geographic, economic, technical, social, or ecological perspectives."[132] The ecological perspective offered in the regulations, which "could be based on species that are associated in the ecosystem," would easily encompass management of a predator species' prey base.[133] Given that "[t]he purpose of this standard is to induce a comprehensive approach to fishery management,"[134] and a comprehensive approach to fishery management would consider predator-prey interactions that affect multiple fisheries, National Standard 3 supports stronger management of forage species.

VI. Conclusion

Reforming the management of fisheries targeting anchovy, sardine, and other forage fish is essential to building resilience in the CCE, as well as the coastal communities and economies that depend on it. Since the late 2000s, the interplay of unusual ocean conditions and fishing pressure has brought about declines in anchovy and sardine populations, which have reverberated throughout the CCE food web. The starvation and breeding failures experienced by California sea lions, brown pelicans, and other marine predators provide a very visible illustration of the consequences of gambling the health of forage species based on outdated, overly optimistic management assumptions. Fishery management decisions must reflect the crucial role that anchovy, sardine, and other forage fish play in the CCE. They must also recognize that changing ocean conditions may make forage fish populations more vulnerable to adverse effects from fishing pressure.

Fishery managers can achieve significant, beneficial reforms by bringing forage fishery management in line with MSA requirements to prevent overfishing, account for ecosystem needs, and base management decisions on the best available science regarding forage fish biology and ecology. Regular, frequent assessments of the health of anchovy and other forage stocks are essential to keep up with both the species' rapid changes in abundance and responses to changing ocean conditions. Setting catch limits at a level that maintains a robust spawning population and provides an adequate food supply for predators will serve to support

[131] Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, 16 U.S.C. § 1851(a)(3) (2007) (emphasis added).

[132] National Standard 3 – Management Units, 50 C.F.R. § 600.320(d)(1) (2009).

[133] 50 C.F.R. § 600.320(d)(1)(vi) (2009).

[134] 50 C.F.R. § 600.320(b) (2009).

a healthy, resilient ecosystem. It will also bolster the forage species' ability to rebound from unfavorable conditions, meaning that species will be available sooner to both natural predators and the fishery. Spatial and temporal management measures to protect food sources around rookeries will provide an additional safeguard for predator health. Finally, managers will have to account for both the uncertainty inherent in setting catch limits at a level that actually protects the stock and predators, and the risk inherent in getting those limits wrong – a risk that is likely to grow as what we've known as normal ocean conditions are disrupted by climate change.

Changing fishery management practices will not prevent all of the ecosystem disruptions that climate change effects will likely bring. Fishery management is, however, one factor that we can readily control. More importantly, the reforms recommended here are necessary to protect ecosystem health even in absence of climate change effects. They are also entirely consistent with existing MSA requirements. Fishery managers have the legal tools they need to start building resilience to climate change now. Applying those tools will be neither simple nor easy, but it is possible and necessary. Indeed, implementing a science-based, transparent management framework for these key "energy broker" species should lead to decisions that produce the greatest long-term benefit to the ecosystem and society as a whole, thus achieving a central goal of the MSA.