Before the Secretary of Commerce

Petition to List the Pacific Bluefin Tuna (*Thunnus orientalis*) as Endangered Under the Endangered Species Act

June 20, 2016

EXECUTIVE SUMMARY

Petitioners formally request that the Secretary of Commerce, through the National Marine Fisheries Service (NMFS), list the Pacific bluefin tuna (*Thunnus orientalis*) as endangered or in the alternative list the species as threatened, under the federal Endangered Species Act (ESA), 16 U.S.C. §§ 1531 – 1544. Pacific bluefin tuna are severely overfished, and overfishing continues, making extinction a very real risk. According to the 2016 stock assessment by the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), decades of overfishing have left the population at just 2.6% of its unfished size. Recent fishing rates (2011-2013) were up to three times higher than commonly used reference points for overfishing. The population's severe decline, in combination with inadequate regulatory mechanisms to end overfishing or reverse the decline, has pushed Pacific bluefin tuna to the edge of extinction.

Pacific bluefin tuna are important apex predators in the marine ecosystem and must be conserved. They are one of three bluefin tuna species. These three species are renowned for their large size, unique physiology and biomechanics, and capacity to swim across ocean basins. They are slow-growing, long-lived, endothermic fish. The Pacific bluefin migrates tens of thousands of miles across the largest ocean to feed and spawn, ranging from waters north of Japan to New Zealand in the western Pacific and off California and Mexico in the eastern Pacific. Both of the two known spawning grounds are located in the western Pacific.

Fishing is the primary threat to the survival of Pacific bluefin tuna. Basin-wide landings of Pacific bluefin have declined substantially since they peaked in 1935 at 47,148 metric tons (mt), ranging from 11,325 mt to 29,174 mt over the last decade. The fact that catch has continued to decline despite increases in fishing effort shows that the bluefin population has crashed. Today, nearly 98% of all Pacific bluefin tuna landed are juveniles caught primarily in nursery grounds near Japan or off the coast of California and Mexico before they have had a chance to spawn. Intensifying the concern surrounding the 97.4% population decline, Pacific bluefin tuna reproduction is currently supported by just a few adult age classes that will soon disappear due to old age. Along with the dwindling number of adults, in 2014, the Pacific bluefin tuna population produced the second lowest number of young fish seen since 1952. Without young fish to mature into the spawning stock to replace the aging adults, the future is grim for Pacific bluefin.

Pacific bluefin are subject to a complicated web of oversight. Two regional fishery management organizations have jurisdiction over Pacific bluefin – the Inter-American Tropical Tuna Commission (IATTC) in the eastern Pacific and the Western and Central Pacific Fisheries Commission (WCPFC) in the western Pacific. A third intergovernmental body, the ISC, conducts stock assessments and oversees other Pacific bluefin science efforts. Domestically in the U.S., the National Marine Fisheries Service (NMFS) is the management authority.

Management of Pacific bluefin tuna fisheries has been a case of too little, too late. Though the stock has been overfished for most of the last 70 years, commercial catch in the eastern Pacific was not restricted until 2012, and catch limits are 20% higher than the ISC scientific advice. Similarly, in the western Pacific, there were no binding catch limits until 2013. The U.S. has done nothing more to regulate commercial Pacific bluefin fishing than implement inadequate international management recommendations, and the recreational fishery is controlled by a bag limit that does not actually constrain overall catch. Existing regulations are insufficient to abate the continued decline of this species or end overfishing, let alone promote recovery to healthy levels. The current WCPFC "rebuilding" plan covers only the western portion of the range and is designed to rebuild the stock to just 6.4% of its unfished level by 2024, with only a 60% required probability of success. However, even with this unambitious target, current management measures do not meet the rebuilding plan requirements. According to the 2016 stock assessment, existing management has just a 0.1% chance of rebuilding Pacific bluefin tuna to healthy levels by 2024.

Pacific bluefin are also compromised by threats to their habitat, including water and plastic pollution, oil and gas development, renewable energy projects, large-scale aquaculture of other species, forage fish depletion, and climate change. Pacific bluefin aquaculture is also growing, both for ranched wild-caught fish and farmed captive-spawned eggs. These practices put additional pressure on the wild Pacific bluefin tuna population and its prey, among other concerns.

This Petition first summarizes the natural history of the Pacific bluefin tuna and the available information on population status. Then the Petition shows that, in the context of the ESA's five statutory listing factors, the severely depleted population status of the species and the ongoing threats to its continued existence, including overutilization, inadequate management, habitat threats, and climate change, leave NMFS with no choice but to list the species as endangered or threatened under the ESA. Lastly, the Petition requests that Pacific bluefin tuna critical habitat be designated concurrently with its listing.

NOTICE OF PETITION

Ms. Penny Pritzker
Secretary of Commerce
U.S. Department of Commerce
1401 Constitution Avenue, NW, Rm. 5516
Washington, D.C. 20230
Email: TheSec@doc.gov

Ms. Eileen Sobeck
Assistant Administrator for Fisheries
National Oceanographic and Atmospheric Administration
1315 East-West Highway
Silver Spring, MD 20910
Email: eileen.sobeck@noaa.gov

Date: this 20th day of June, 2016

PETITIONERS

Catherine Kilduff, Staff Attorney
Center for Biological Diversity
1411 K Street NW, Suite 1300
Washington, DC 20005
(202) 780-8862

Mark J. Spalding, President
The Ocean Foundation
1320 19th St, NW, 5th Floor
Washington, DC 20036
(202) 887-8996

Steve Mashuda, Managing Attorney, Oceans
Earthjustice
705 Second Avenue, Suite 203
Seattle, WA 98104
(206) 343-7340

Adam Keats, Senior Attorney
Center for Food Safety
303 Sacramento Street, 2nd Floor
San Francisco, CA 94111
415-826-2770

Jane Davenport, Senior Staff Attorney
Defenders of Wildlife
1130 17th St. NW
Washington, DC 20036
(202) 772-3274

Phil Kline, Senior Ocean Campaigner
Greenpeace
702 H St NW #300
Washington, DC 20001
(202) 319-2402

Deb Castellana, Director of Communications
Sylvia Earle Alliance/Mission Blue
P.O. Box 6882
Napa, CA 94581
(707) 492-6866

Jim Chambers, Founder and Owner
Prime Seafood
9814 Kensington Parkway
Kensington, MD 20895
(301) 949-7778

Marianne Cufone, Executive Director
Recirculating Farms Coalition
5208 Magazine #191
New Orleans, Louisiana 70115
(844) 732-3276

Carl Safina, PhD, Founding President
The Safina Center
80 North Country Road
Setauket, NY 11733
(631) 838-8368

6/20/2016

Mary M. Hamilton, Executive Director
SandyHook SeaLife Foundation
326 Stokes Rd. #372
Medford, NJ 08055
609.953.2677

Doug Fetterly, Chair, National Marine Action Team
Sierra Club
Honolulu, HI
(808) 627-5722
Fett4Paz@gmail.com

Todd Steiner, Biologist and Executive Director
Turtle Island Restoration Network
9255 Sir Francis Drake Boulevard
Point Reyes Station, CA 94956
(415) 663.8590

Taylor Jones, Endangered Species Advocate
WildEarth Guardians
2590 Walnut St.
Denver, CO 80205
(720) 443-2615

Pursuant to section 4(b) of the Endangered Species Act (ESA), 16 U.S.C. § 1533(b), section 553(e) of the Administrative Procedure Act, 5 U.S.C. § 553(e), and 50 C.F.R. § 424.14(a), sustainable seafood purveyor Jim Chambers, and a number of organizations – the Center for Biological Diversity, The Ocean Foundation, Earthjustice, Center for Food Safety, Defenders of Wildlife, Greenpeace, Mission Blue, Recirculating Farms Coalition, The Safina Center, SandyHook SeaLife Foundation, Sierra Club, Turtle Island Restoration Network and WildEarth Guardians – petition the Secretary of Commerce, through the National Marine Fisheries Service (NMFS), to list the Pacific bluefin tuna (*Thunnus orientalis*) as an endangered species, or in the alternative as a threatened species, under the ESA, 16 U.S.C. §§ 1531 *et seq.*

The Center for Biological Diversity is a national, nonprofit conservation organization with more than 1 million members and online activists dedicated to the protection of endangered species and wild places.

The Ocean Foundation is the only international public foundation dedicated to the ocean and the animal, plant, and human communities that depend on its health. The Ocean Foundation supports ocean conservation solutions on every continent, focusing on all aspects of a healthy ocean, at local, regional, national and global scales.

Earthjustice is the premier nonprofit environmental law organization. We wield the power of law and the strength of partnership to preserve the wild, to fight for healthy communities and to advance clean energy to promote a healthy climate.

Center for Food Safety (CFS) is a national, non-profit public interest organization that works to protect human health and the environment by curbing the use of harmful food production methods and by promoting safe and sustainable alternatives. As part of these efforts, CFS advocates for sustainable fishing practices and seeks to protect species that are at risk of extinction from destructive overfishing.

Defenders of Wildlife is a national nonprofit conservation organization founded in 1947 focused on conserving and restoring native species and the habitats upon which they depend. Defenders has more than 1,200,000 members and supporters nationwide.

Greenpeace is an independent campaigning organization that uses peaceful direct action and creative communication to expose global environmental problems and to promote solutions that are essential to a healthy ocean.

Mission Blue is an initiative of the Sylvia Earle Alliance (S.E.A.) to ignite public support for the protection of Hope Spots—special places that are vital to the health of the ocean, the blue heart of our planet.

Prime Seafood provides 100% sustainable seafood for Washington DC's best restaurants. Prime Seafood is a 12 year old wholesale distributor providing top quality fish and shellfish to chefs of many of the most discriminating restaurants in the nation's capital area and the only one owned by a professional fisheries biologist. www.PrimeSeafood.com.

The Recirculating Farms Coalition is a collaborative group of farmers, educators, non-profit organizations and many others committed to building local sources of healthy, accessible food. Through research, education and advocacy, Recirculating Farms Coalition works together to support the development of eco-efficient farms that use clean recycled water as the basis to grow food. The Coalition believes these recirculating farms can create stable green jobs and supply sustainably-grown food – fruits, vegetables, herbs and humanely-raised seafood – in diverse communities nationwide, and someday, worldwide.

The Safina Center creates an original blend of science, art, and literature to advance the case for life on Earth. www.SafinaCenter.org, www.CarlSafina.org.

SandyHook SeaLife Foundation promotes marine conservation through education, volunteerism, and political action with special focus on creating sustainable fisheries. Dr. Thomas Armbruster, marine biologist, diver, physician and recreational/commercial fisherman launched SandyHook SeaLife Foundation in 2006. SSF has a vision of comprehensive public support for the protection of our endangered marine environment.

The Sierra Club mission: to explore, enjoy and protect the planet; to practice and promote the responsible use of the earth's ecosystems and resources; to educate and enlist humanity to protect and restore the quality of the natural and human environment; and to use all lawful means to carry out those objectives.

Turtle Island Restoration Network works to mobilize people and communities around the world to protect marine wildlife, the oceans and the inland waterways that sustain them. Join us and our over 200,000 online members on Twitter, Facebook and YouTube. SeaTurtles.Org

WildEarth Guardians protects and restores the wildlife, wild places, wild rivers, and health of the American West.

In analyzing whether Pacific bluefin tuna warrants listing under the ESA, NMFS must examine whether the species is endangered or threatened throughout all or a significant portion of its range. In the event NMFS determines that the Petition fails to demonstrate that listing of the Pacific bluefin tuna may be warranted in all of its range, we request that, in the alternative, NMFS consider whether the species is threatened or endangered in "a significant portion of its range."

NMFS has jurisdiction over this Petition. This Petition sets in motion a specific process, placing definite response requirements on NMFS. Specifically, NMFS must issue an initial finding as to whether the Petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). NMFS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." *Id*. Petitioners need not demonstrate that listing of the Pacific bluefin tuna *is* warranted, rather, Petitioners must only present information demonstrating that such listing *may be* warranted. While Petitioners believe that the best available science demonstrates that listing of the Pacific bluefin tuna as endangered is in fact warranted, there can be no reasonable dispute that the available information indicates that listing the species as either endangered or threatened may be warranted. Therefore, NMFS must promptly make a positive initial finding on the petition and commence and complete a status review as required by 16 U.S.C. § 1533(b)(3)(B). Petitioners also request that critical habitat be designated for the Pacific bluefin tuna concurrently with the species being listed as endangered or threatened, pursuant to 16 U.S.C. § 1533(a)(3)(A) and 50 C.F.R. § 424.12.

Contents

I. Introduction

The Pacific bluefin tuna (*Thunnus orientalis*), an iconic pelagic fish, has been overfished to a small percent of its original abundance, leading it to become one of the most imperiled of all marine fish in our oceans. International fishery management organizations have failed to take reasonable steps to implement science-based, mandatory catch limits or an effective rebuilding plan for Pacific bluefin tuna. Domestic regulations in the U.S. have failed as well, allowing catch to increase even as the stock has declined. Habitat threats include water pollution; oil and gas development in both the western and eastern Pacific Ocean; exposure to radioactivity associated with Fukushima leakages into adjacent waters; and climate change that affects bluefin tuna's prey, migration, and interaction with fisheries.

Petitioners formally request that NMFS list the Pacific bluefin tuna as endangered or in the alternative list the species as threatened, under the federal ESA. The ESA provides a means to recover species such as the Pacific bluefin tuna by limiting threats, protecting habitat, planning recovery, providing international assistance, and taking other appropriate steps. Without protections under the ESA, the drastic decline in the Pacific bluefin tuna population is potentially irreversible. By taking a leadership role in protecting bluefin, the U.S. would send a signal to all nations across the Pacific basin, catalyzing efforts to adopt and implement a bona fide, basin-wide rebuilding plan for this imperiled species. It would also serve to raise consumer awareness globally of the Pacific bluefin's plight.

II. Biology and Status of the Pacific Bluefin Tuna

A. Taxonomy

Pacific bluefin tuna (*Thunnus orientalis*) is a member of the order Perciformes, the largest order of fishes, and of the mackerel, bonito and tuna family, Scombridae. Pacific bluefin tuna were originally classified by Temminck and Schlegel in 1844 as *Thunnus thynnus orientalis*, a subspecies of northern bluefin tuna separate from Atlantic bluefin tuna (known at that time as *Thunnus thynnus thynnus*). Pacific bluefin tuna were reclassified as a separate species (*Thunnus orientalis*) by Collette in 1999 based on morphological differences (i.e., the shape of the dorsal wall of the body cavity in large fish and the number of gill rakers) (Collette 1999). This reclassification has been supported by genetic data that shows distinct differences amongst bluefin tunas. The species has a number of common names, including Pacific bluefin tuna, northern bluefin tuna, maguro (Japanese), yokowa (Japanese), atún aleta azul del Pacifico (Spanish), atún cimarrón (Spanish), thon bleu du Pacifique (French), and thon rouge (French).

Pacific bluefin tuna is a distinct species from the Atlantic bluefin tuna (*Thunnus thynnus*) and Southern bluefin tuna (*Thunnus maccoyii*) and is one of a number of tuna species inhabiting the Pacific Ocean, including bigeye (*Thunnus obesus*), yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), albacore (*Thunnus alalunga*), and longtail (*Thunnus tonggol*).

B. Species Description

Pacific bluefin tuna are one of the largest bony fish in the sea, weighing up to 450 kg (900 lbs.) and reaching lengths up to 3 m (nearly 10 ft.). They are pelagic, schooling fish that tend to group together by size and cohort. They have a bullet-like shape with a fusiform body and long, pointed head. Their streamlined body lowers the drag as they swim and is only interrupted by two sickle-shaped dorsal fins, short, wing-like pectoral fins, and an anal fin located far behind the second dorsal fin. They have a caudal peduncle, with two keels, and a robust, lunate caudal fin.

Both sexes exhibit similar coloration and cannot be distinguished externally. The top half of the Pacific bluefin tuna's body is steel blue or black, with a grayish-green or blue iridescence, while the bottom half is silver or chrome, dotted with gray spots or bands. The first dorsal fin is often blue with some regions of yellow; the second dorsal fin is a darker blue with shades of golden brown. The central caudal keel is deep blue to grayish black. The anal fin and finlets are yellow edged with black.

Bluefin tuna are uniquely adapted for long distance migrations and predation upon fast-moving fishes. In addition to their streamlined shape and lunate tail, bluefin tuna have dorsal fins that retract into slots in order to reduce drag during high-speed acceleration and a rigid body and tail to provide greater power. They swim with a unique locomotion pattern, called thunniform swimming, where they keep the entire body stiff but generate vorticity with the thrusts of their tail (Graham and Dickson 2004). Tunas have numerous attributes to reduce skin friction with the seawater, including a reduction in their scales. These physical attributes enable the bluefin tuna to cruise across the oceans efficiently and to occasionally reach burst speeds exceeding 30 miles per hour.

In addition, all bluefin tunas are capable of maintaining their body heat (Carey and Teal 1969). This trait is extremely rare among fish. Their unique circulatory exchange system includes a rete mirabile, a vascular network of arteries and veins. The retia enable the tunas to capture metabolic heat by positioning arteries and veins close together and short-circuiting heat loss at the gills. This enables the fish to raise its body temperature significantly above ambient (Carey and Teal 1969) and to tolerate a wide thermal niche. A thermal excess of 55ºF higher than ambient water has been recorded in Pacific bluefin (Marcinek et al. 2001). Unique cardiac traits, along with the endothermy, enhance this fish's performance, together enabling it to range over thousands of miles and migrate to vastly different parts of the ocean from the equator to high latitudes to feed and spawn.

C. Life History

1. Range and Distribution

Pacific bluefin are a highly migratory species, distributed throughout the Pacific with the largest range of any tuna in the genus *Thunnus* (Whitlock et al. 2012). In the eastern Pacific Ocean (EPO), they are found in the California Current from Washington to Baja California, with historical reports as far south as the Galapagos Islands. In the western Pacific Ocean (WPO), they are found from Sakhalin Island, Russia south to New Zealand and Australia (Bayliff 1994). Despite this large historical range, recent tagging studies have found that Pacific bluefin are primarily distributed over a much more restricted area (Figure 1-2, Boustany et al. 2010).

All Pacific bluefin tuna are born in the western Pacific, and the majority of juveniles remain resident in the western Pacific. However, some migrate to the eastern Pacific in their first or second year to feed for 1 to 4 years before they return to the western Pacific to spawn (Madigan et al. 2014). The percentage of juveniles that make the annual migration to the EPO is hypothesized to be influenced by the sardine abundance off Japan (Polovina 1996). When the abundance of sardines is lower, a greater percentage of juvenile Pacific bluefin tuna are thought to migrate east.

In the EPO, electronic tagging has shown that juvenile bluefin make a seasonal north-south migration in the California Current, seeking coastal upwelling regions and preferred sea surface temperatures (25-30°C) (Kitagawa et al. 2007; Boustany et al. 2010; Block et al. 2011; Whitlock et al. 2015). Therefore, Pacific bluefin tuna range further north off the California coast in El Niño years. In the WPO, tagging has also shown that juveniles migrate north through Japanese and Korean coastal waters in the summer and back south in the winter (Itoh et al. 2003). Movements of adults are not as well documented, but in general they move north from the spawning grounds to foraging areas, although some easterly and southerly migrations have been observed (ISC 2014).

While interannual or decadal environmental variation can greatly affect the distribution of Pacific bluefin tuna, the species has also been subject to range contraction that is correlated with population decline (Worm and Tittensor 2011). A study of a multidecadal database of global Japanese longline fisheries catch data and a United Nations Food and Agriculture Organization (FAO) Tuna and Billfish Atlas that includes spatial catch data from all fleets showed that between 1960 and 1999 the range of Pacific bluefin tuna decreased 25 percent (*Id*.). In the eastern Pacific, they were once found as far north as British Columbia, Canada and as far south as the Galapagos (Crockford 1997). There have been no reports of Pacific bluefin tuna at these distribution extremes in recent years.

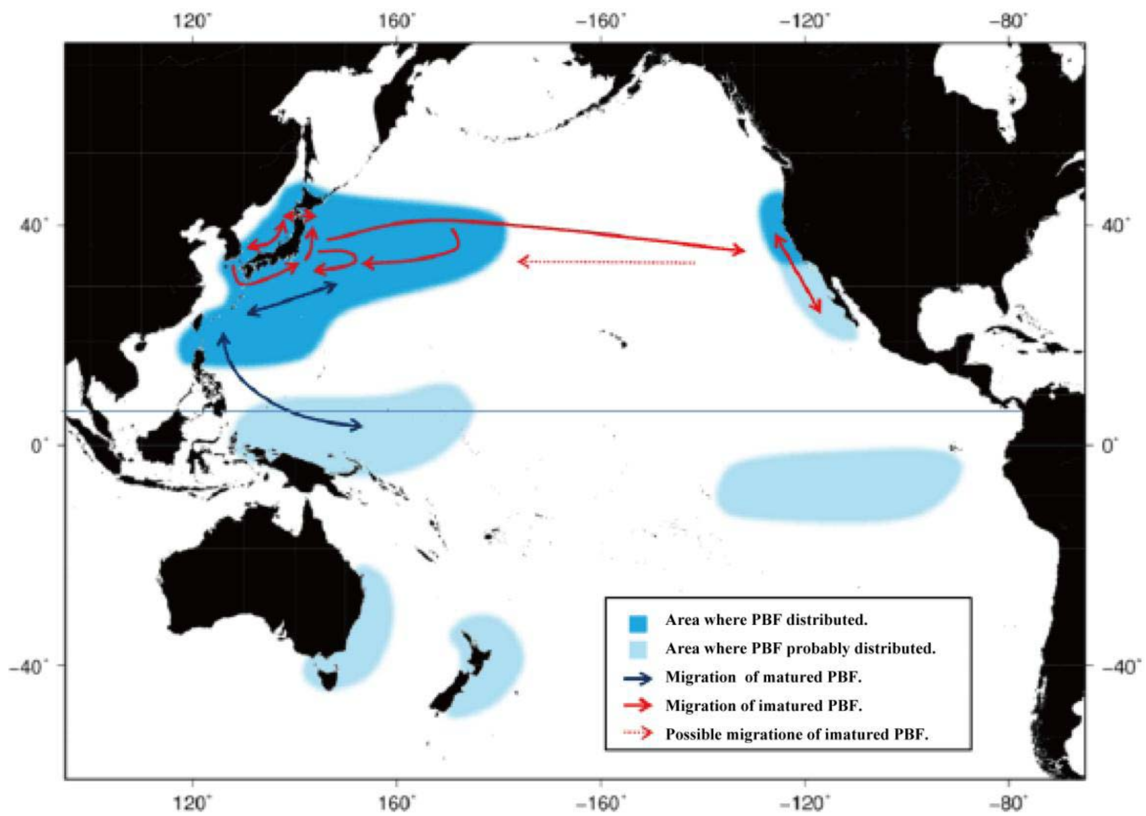

Figure 1. General distribution and migration of Pacific bluefin tuna. Darker areas indicate the main distribution areas. (Source: ISC 2014, Fig. 2-2.)

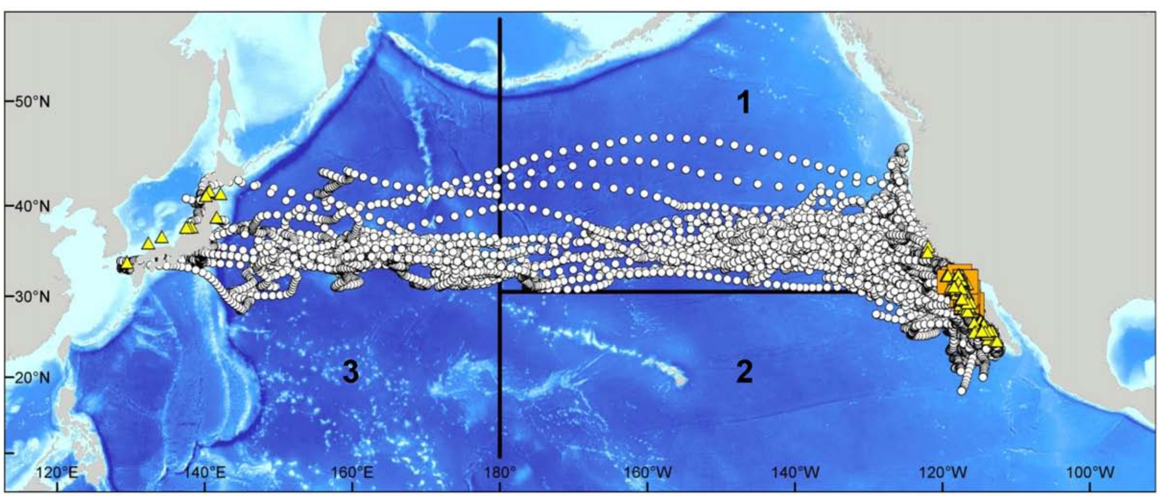

Figure 2. Release (orange squares) and recapture (yellow triangles) locations of electronically tagged juvenile Pacific bluefin tuna, illustrating their relatively confined migratory corridors and feeding hotspots. White circles indicate daily positions of tagged fish. (Source: Whitlock et al. 2012)

2. Habitat

Pacific bluefin prefer temperate waters but travel into subtropical water to reproduce. As Pacific bluefin tuna mature they travel into subpolar waters to feed. Individuals experience a wide range of temperatures, from surface waters that range from 9 to 26ºC (Kitagawa et al. 2009). Their habitat includes a large portion of the water column extending from the surface down to 1000 meters or more. While Pacific bluefin are known to conduct deep dives, they are most often found in the upper 100 m of the water column, in the mixed layer above the thermocline. One study of juveniles in the EPO found that they spent more than 50% of their time in depths shallower than 10 m (Kitagawa et al. 2007). Another study found even higher surface residency (up to 94%) in the WPO (Kitagawa et al. 2004). Bluefin make diel vertical migrations, inhabiting deeper waters during daylight hours. Bluefin diving is also influenced by lunar phase, with fish occupying deeper waters for periods around the full moon.

Bluefin are often associated with fronts, or oceanographic transition zones, a phenomenon known in Japan as Kitahara's Law (Kitagawa et al. 2004). The preference for these habitats has been attributed to finding an optimal temperature range, use of the temperature gradient for thermoregulation, and improved foraging efficiency due to a concentration of prey in the frontal zone (Kitagawa et al. 2004).

3. Feeding

The diet of the bluefin tuna is widely varied, opportunistic, and changes throughout its life. Larvae and juveniles feed on small organisms, such as brine shrimp, other fish larvae, and copepods. When juveniles become large enough, they begin to feed on small fish. Adult bluefin are known to eat a wide range of marine prey, primarily smaller fish, such as sardines, anchovies and small tunas, squid, and crustaceans, but even kelp has been found in bluefin stomachs (Bayliff 1994). A 2015 stomach contents study of bluefin collected in California found that pelagic red crab was by far the dominant prey species (Figure 3), consistent with the strong El Niño and warm "Blob" that year, but other studies have found much different results (Figure 4), indicative of the opportunistic nature of the bluefin diet (DiNardo 2015).

Bluefin are known to aggregate at feeding locations where physical and oceanographic conditions result in a concentration of desirable prey (Boustany et al. 2010). Major foraging aggregations occur in the California Current, Sea of Japan, East China Sea and the Kuroshio-Oyashio transition region. Bluefin in these areas often make foraging dives, with increased diving activity, and hence feeding, during daylight hours (Kitagawa et al. 2004). Another study in the WPO found feeding occurs at dawn and during the day but rarely at dusk or at night (Itoh et al. 2003).

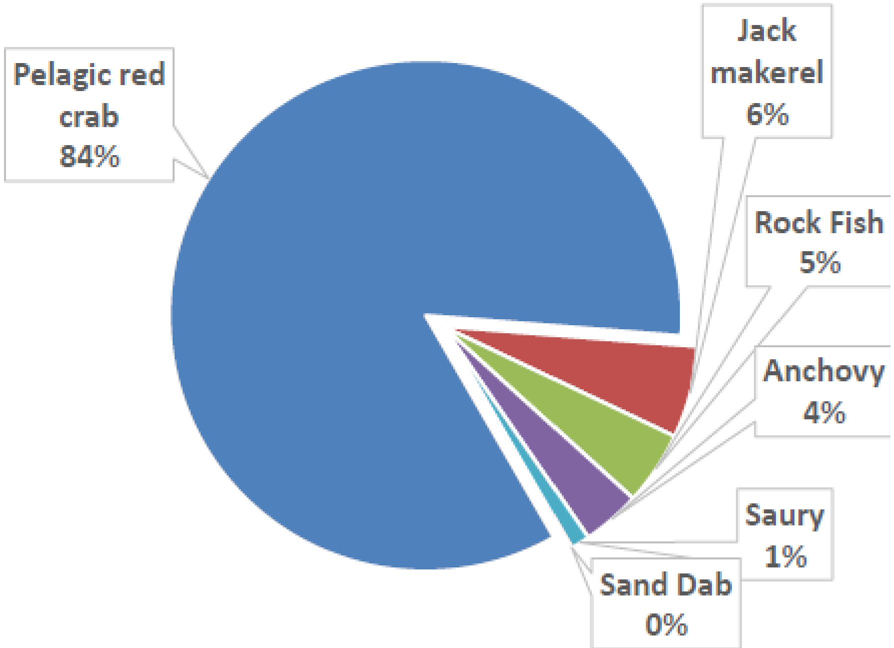

Figure 3. Results of stomach content analysis collected in California in 2015 (n=68) (Source: DiNardo 2015).

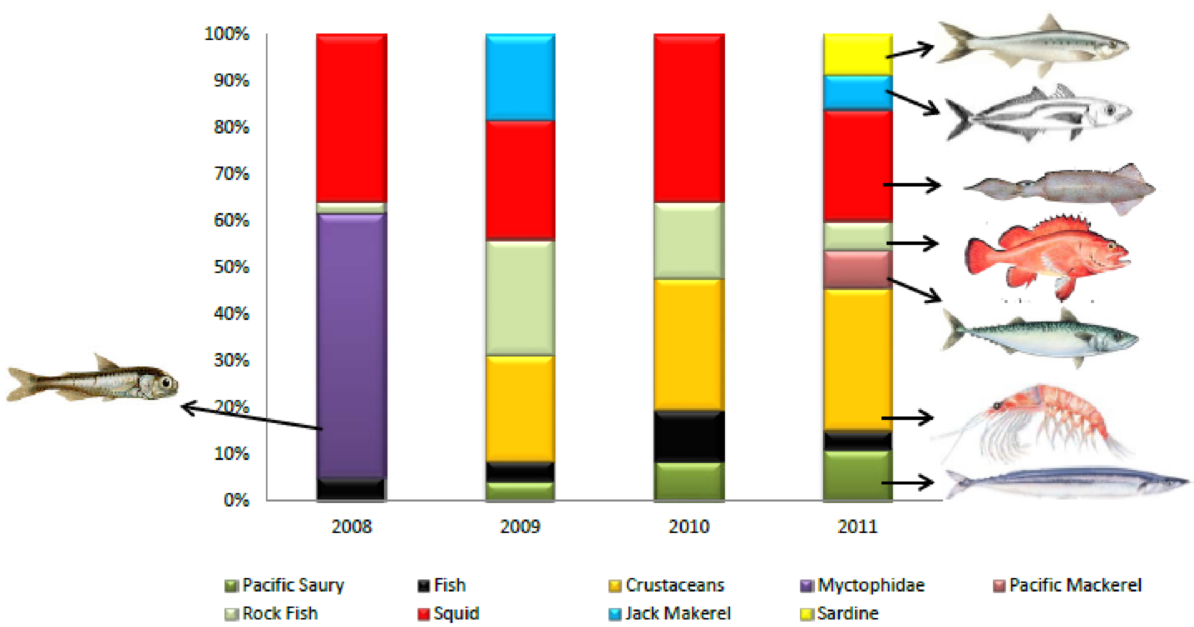

Figure 4. Diet of bluefin tuna collected off California in 2008 (n=75), 2009 (n=78), 2010 (n=54), and 2011 (n=189) (Source: DiNardo 2015).

4. Reproduction

There are two known spawning grounds for Pacific bluefin tuna, both in the WPO – one in the East China Sea between eastern Taiwan and the Ryukyu Islands in April through June, and one further north in the Sea of Japan in June through August (Bayliff 1994; Ashida et al. 2015; Okochi et al. 2016; Shimose et al. 2016). Although there are differences in the size of fish on these spawning grounds, and the spatio-temporal concentration of spawning, there is thought to be only one basin-wide population of Pacific bluefin tuna (Rooker et al. 2001). There are no spawning grounds in the EPO.

Preferred spawning temperature for Pacific bluefin tuna is approximately 26°C, but a much wider range of spawning temperatures (19.3-27.7°C) has been observed in the Sea of Japan (Ashida et al. 2015; Okochi et al. 2016). However, the lower temperatures likely compromise hatching rates as the optimum temperature for hatching is 25°C (Miyashita et al. 2000). In the Sea of Japan, most spawning activity occurs in the evening, from 1700 to 2200 h, with females spawning nearly every day (Okochi et al. 2016).

Currently, there is not scientific consensus on the age of maturity of Pacific bluefin tuna. The ISC stock assessment assumes a maturity ogive where 20% of fish are mature at age 3, 50% at age 4, and 100% at age 5 (ISC 2014). However, this maturity estimate is based on the size of fish on the spawning grounds, which are presumably already reproductively mature. It therefore does not account for fish of these ages that may not be mature and hence would not be found on the spawning grounds (Chen et al. 2006; Tanaka et al. 2006).

Importantly, the scientific literature indicates that fish in the subtropical southern spawning ground are larger and older than bluefin spawning in the temperate waters of the Sea of Japan. The Taiwanese fishery targets fish on the southern spawning ground, and the smallest fish landed between 1999 and 2006 in that fishery was 165 cm, or approximately 6 years old (Chen et al. 2006). In agreement with this, a recent study found that most fish on the southern spawning ground were larger than 200 cm long, or approximately 9 years old, suggesting a later age of first maturity than assumed by the assessment (Ashida et al. 2015). Another study found that fish on the southern spawning ground were 6 to 25 years old (Shimose et al. 2016). Thus, the consensus of the literature on the subtropical spawning ground is that no fish spawns before age 6, and that the majority are spawning at a higher age, with a mean in the 12-14 year-old size class. This is similar to the western Atlantic bluefin tuna, which spawns in the Gulf of Mexico at the same latitude as the Pacific bluefin (Block et al. 2005; Diaz 2011).

In contrast, fish in the temperate waters of the Sea of Japan spawning area are smaller, with 50% and 95% maturity at 114.4 cm and 133.6 cm (3 and 4 years old), respectively (Okochi et al. 2016). The smallest Pacific bluefin tuna ever found in reproductive condition was 107 cm (Shimose et al. 2009). One hypothesis asserts that younger fish spawn in the Sea of Japan and then utilize the southern spawning ground when they are older. However, the possibility that the two spawning grounds reflect two genetically separate populations with different maturation ages has not been ruled out and requires testing.

In sum, the current stock assessment does not account for the fact that older fish are in the EPO during the spawning season, far from either of the spawning grounds, and fish less than 6 years old are absent from the larger, southern spawning ground. By not accounting for these key facts, the stock assessment may be underestimating the mean spawning age of Pacific bluefin tuna and therefore overestimating the number of spawning fish. A later age to first maturity would make Pacific bluefin less resilient to fishing pressure than faster growing tuna species, such as tropical tuna species. This may result in regulators allowing more fishing effort than the stock can withstand based on its later maturity.

5. Fecundity

Bluefin tuna exhibit high fecundity and appear to be batch or multiple spawners (Chen et al. 2006). Fecundity is positively correlated to fork length (Chen et al. 2006; Okochi et al. 2016). Fish of 270 to 300 kg produce about 10 million eggs per spawn (Bayliff 1994). Because fecundity increases with size, a balanced distribution of age classes of bluefin tuna increases resiliency to population declines (Secor et al. 2015). A more recent study on the southern spawning ground found average batch fecundity of 15.4±10.2 million oocytes, with a maximum of 36.6 million eggs (Ashida et al. 2015). Fecundity was slightly lower in the Sea of Japan, consistent with the smaller fish spawning there (116 and 170 cm in one study), with a mean batch fecundity of 6.41 million oocytes, or 122 oocytes per gram body weight (Okochi et al. 2016). Annual fecundity of these females was estimated at 349 million eggs, based on a 2-month spawning period (*Id.*).

6. Recruitment

Recent Pacific bluefin tuna recruitment – the entry of juvenile fish into the fishable population – is near historic lows. Recruitment, measured in Pacific bluefin tuna as the number of age 0 fish as of July 1st, in 2014 was at the second lowest level since 1952 and the average recruitment for the last five years was likely below the historical average level (ISC 2016). While recruitments in recent years in assessments are highly uncertain due to limited information on the cohorts, two of the last three data points from the Japanese troll catch-per-unit-effort-based index of recruitment, which was consistent with other data in the model, were at their lowest since the start of the index in 1980 (ISC 2016). In the Sea of Japan, the number of recruits in 2014 was 77% lower than in 2013 (Japanese Fisheries Research Agency 2014). There was a slight uptick in recruitment in 2015, but it is still near the historic low (Japanese Fisheries Research Agency 2015).

One significant gap in understanding of Pacific bluefin tuna biology is the stock-recruitment relationship, or to what extent the number or biomass of recruits depends on the biomass of the spawning stock. The stock assessment assumes that recruitment is nearly independent of the size of the spawning stock, meaning that even after an 80% decline in the population, recruitment will still be 99.9% of what it was before the decline (ISC 2014). This assumption – that the adult biomass can be depleted to a very low level without any impact on the future of the stock – has been strongly criticized in peer reviews of the assessment yet it has not been changed (Bonhommeau 2013; Carruthers 2013, Powers 2013). It is also contrary to the evidence of stock-recruit relationships for the majority of fish stocks (Myers and Barrowman 1996). It is also inconsistent with the precautionary approach, which is particularly concerning for a decimated stock, such as Pacific bluefin (Mangel et al. 2010).

7. Longevity and Growth

Pacific bluefin tuna are thought to live up to 26 years old, attaining a maximum size of 250 cm, or greater than 400 kg (Shimose et al. 2009). The all-tackle world record Pacific bluefin tuna, caught in New Zealand in 2014, weighed in at 411.6 kg (IGFA 2016). However, maximum growth and age may be higher, as fishing pressure has led to few larger and older fish remaining in the population (Shimose et al. 2009). Earlier estimates of maximum size were as high as 320 cm, more similar to Atlantic bluefin tuna (Bayliff 1994). The largest recent reported U.S. catch of giant bluefin tuna in the eastern Pacific was made in 1988, when the purse seine fishery caught a bluefin tuna that broke California records at 458 kg and 271.2 cm (Crockford 1997 (citing Foreman and Ishizuka 1990)).

Bluefin tuna grow rapidly in their first 5 years, attaining a size of 150 cm. The growth rate declines thereafter, with fish reaching about 200 cm at age 9 and 225 cm at age 13 (corresponding to 90% of maximum length at 50% of maximum age). The declining growth rate after age 10 is attributed to a shifting focus to reproduction rather than feeding (Shimose et al. 2009). Males begin to outgrow females at about age 10 (*Id.*). The growth rate is higher in the summer than the winter (Bayliff 1993).

8. Natural Mortality

Predators of bluefin tuna include sharks, large predatory fishes, and marine mammals, such as orcas (Bayliff 1994). Bluefin tuna avoid predators by schooling and the ability to make a fast escape. Their counter-shaded coloration makes them camouflaged in aquatic environments, with their blue dorsal coloration making them less visible from above and their light ventral coloration making them less visible from below. Natural mortality of larvae is due primarily to starvation and predation and is quite high throughout the larval and early juvenile stage (Tanaka et al. 2006).

Natural mortality is assumed to be relatively high at small sizes, decreasing as the fish age and grow. The Pacific bluefin tuna stock assessment assumes a natural mortality of 1.6 per year for age 0, 0.386 per year for age 1, and 0.25 per year for fish age 2 and older (ISC 2014). Because these values are instantaneous rates, this equates to 79.8% of age 0 fish, 32.0% of age 1 fish, and 22.1% of age 2 and older fish dying of natural causes per year. The assumed level of natural mortality for age 2+ fish has been criticized by peer reviewers as being much too high for a fish like a bluefin tuna (Bonhommeau 2013; Carruthers 2013, Powers 2013). For comparison, the eastern Atlantic bluefin tuna stock assessment assumes a natural mortality of 0.24 for age 2 fish, decreasing to 0.10 by age 10 (ICCAT 2015). The western Atlantic bluefin tuna assessment assumes a natural mortality of 0.14 per year for all ages (ICCAT 2015). Using electronic tagging data, a recent study estimated the natural mortality rate of Pacific bluefin aged 5 and above at 0.15 per year, and as low as 0.12 per year for fish aged 4 and above (Whitlock et al. 2012). This is much lower than assumed by the current stock assessment and more consistent with the assumed Atlantic bluefin tuna natural mortality rates.

An inflated assumption of natural mortality can be very harmful as it influences estimation of maximum sustainable yield and a population's projected response to harvest. Assuming a higher natural mortality rate typically leads to assumptions of a more productive stock and hence higher allowable catches. These assumptions thus can lead to allowable catch levels for Pacific bluefin tuna that are higher than the species can sustain.

D. Population Trends

Due in large part to overfishing, the Pacific bluefin tuna population has diminished to just 2.6% of its unfished biomass (ISC 2016). Spawning stock biomass (SSB) was 16,557 mt in 2014, declined 90% from 160,005 mt in 1961, but slightly up from 13,795 mt in 2012 (Figure 6). The population is less than a third of what it was just 20 years ago. Assuming an average spawning fish size of 150 kg, there are approximately 110,000 adult Pacific bluefin tuna remaining in the *entire* Pacific Ocean. Scientists estimate that Pacific bluefin tuna reproduction is supported by just a few adult age classes that will soon disappear due to old age and immediate reductions in adult mortality may be needed to protect the remaining spawning individuals (Maunder 2016). There is similarly grim news at the other end of the lifecycle: Pacific bluefin tuna produced the second lowest number of young fish in 2014 than at any time since 1952 (ISC 2016).

Not only are Pacific bluefin tuna severely overfished, but overfishing continues on the species (Figure 5). Recent fishing rates ($F_{2011\text{-}2013}$) were up to 300% of commonly used reference points for overfishing.

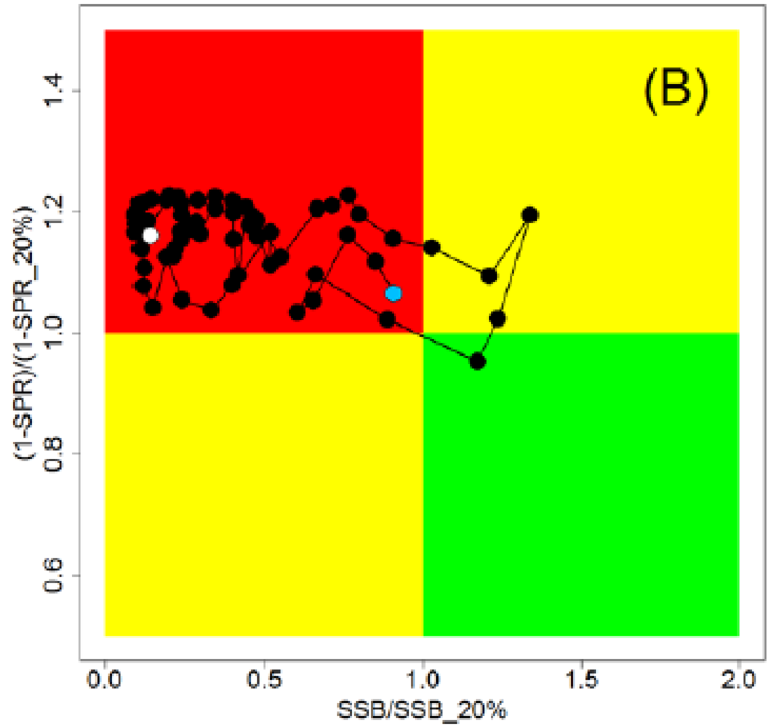

Figure 5. Kobe plot for Pacific bluefin tuna, showing the population status from 1952 (blue circle) to present (white dot). The horizontal axis depicts biomass and the vertical axis depicts the fishing mortality rate. The red quadrant indicates years where the stock was both overfished and subject to overfishing (i.e., in all but 5 years of the 63-year assessment period the stock was overfished, and in all but 1 year the stock was subject to overfishing). (Source: ISC 2016, Fig. 6)

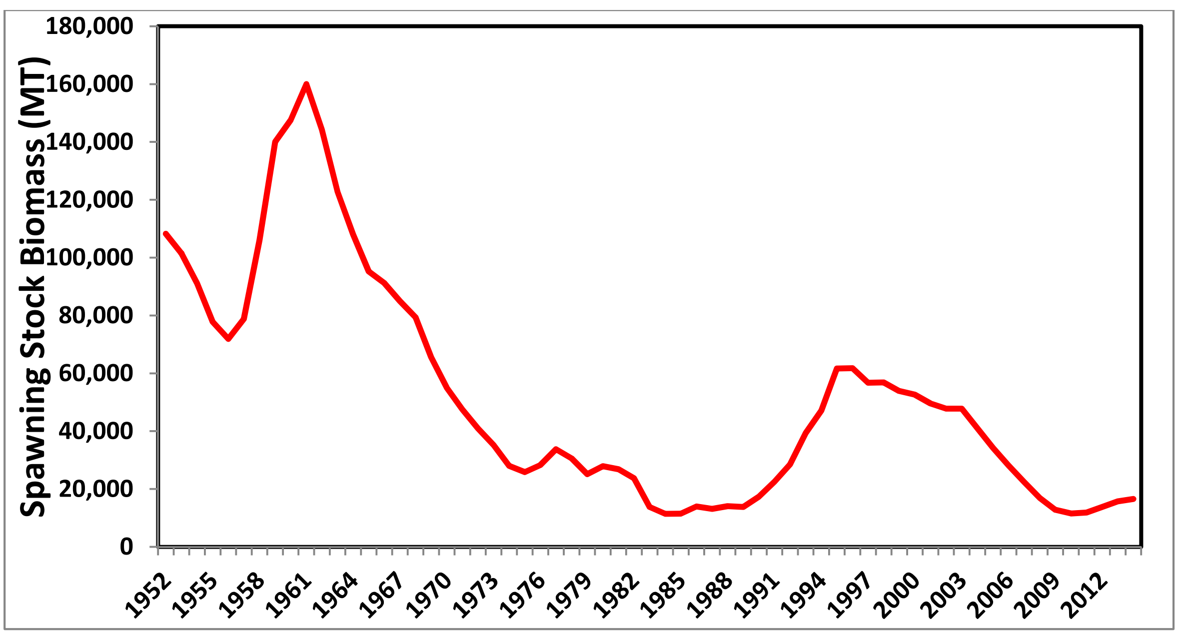

Figure 6. Pacific bluefin tuna spawning stock biomass, 1952-2014. (Source: ISC 2016)

The ISC stock assessment determined that Pacific bluefin have been overfished for all but 5 years of the assessment period starting in 1952, indicative of the heavy exploitation prior to 1952 (Figures 5 and 7). This is based on a reference point of $SSB_{20\%}$ (i.e., the biomass corresponding to the fishing mortality rate that results in 20% of the spawning potential of an unfished stock), chosen by the ISC for "illustrative" purposes since no formal reference point has been agreed for Pacific bluefin tuna (ISC 2016). If a more conservative reference point were used, the stock status reflected in the Kobe plot in Figure 5 would be even less optimistic, with more severe overfishing and an even more overfished stock.

Despite the fact that Pacific bluefin have been overfished for most of the last 70 years, NMFS did not designate them as subject to overfishing until 2010 or overfished until 2013.[1] This is at least in part due to a lack of transparency in the stock assessment process. The first full stock assessment was not conducted by the ISC until 2008, and not until the third full ISC assessment in 2012 was the assessment report publicly released (Whitlock et al. 2012). Management action has been equally slow in coming, with the first catch limit for the EPO adopted in 2012 and the first binding limit (but only for fish <30 kg) in the WPO in place in 2014.

Another worrisome finding of the assessment is the high fishing mortality of young fish: 97.6% of all Pacific bluefin tuna caught are between 0 and 2 years of age (ISC 2014). These fish are all juveniles, as small as 15 cm, which have not yet had the chance to reproduce. This is an egregious case of growth overfishing, a dangerous condition which occurs when fish are harvested at sizes too small to maximize yield per recruit.

In November 2014, the International Union for Conservation of Nature (IUCN) classified the Pacific bluefin tuna as vulnerable, meaning it is considered to be facing a high risk of extinction in the wild (Collette et al. 2014). Pacific bluefin tuna was listed as vulnerable based on an observed, estimated, inferred or suspected population size reduction of ≥ 30% over the last three generations, where the reduction or its causes may not have ceased, or may not be understood, or may not be reversible, based on (b) an index of abundance appropriate to the taxon and actual or potential levels of exploitation (IUCN 2001). While the IUCN listing affords no actual regulatory protection to any species, such a listing is an unequivocal statement from authoritative scientists that the species is imperiled.

Were it not for certain IUCN criteria regarding the timing of species' decline, Pacific bluefin tuna would qualify as a critically endangered species. Importantly, even though Pacific

---

[1] *Fisheries of the Pacific Region; Western Pacific Region, Notification of determination of overfishing or an overfished condition*, 76 Fed. Reg. 28422 (May 17, 2011); McInnis, R. 2013. Letter from Rodney McInnis, Regional Administrator, to Dan Wolford, Chairman, Pacific Fishery Management Council. April 8, 2013; *see also.International Fisheries; Pacific Tuna Fisheries; Fishing Restrictions in the Eastern Pacific Ocean*, 78 Fed. Reg. 33240, 33241 (Apr. 16, 2013) (referencing the 2013 determination that the stock was overfished).
http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2010/2010_status_of_fisheries.pdf
http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/archive/2013/status_of_stocks_2013_web.pdf

bluefin have experienced a decline of greater than 90%, it was not classified as critically endangered because the major decline of the species occurred more than three generations ago. In 2010, the IUCN Red List Workshop for Atlantic Tunas and Billfishes endorsed a statement signed by sixteen scientists highlighting the problem with the 3-generation restriction for fishes with a long history of exploitation. However, to date, the IUCN has not modified its criteria, and Pacific bluefin tuna remain classified as vulnerable.

III. Pacific Bluefin Tuna Meets the Criteria for Listing as Endangered Under the ESA.

The Pacific bluefin tuna meets the criteria for listing as threatened or endangered. Under the ESA, 16 U.S.C. § 1533(a)(1), NMFS is required to list a species for protection if it is in danger of extinction or threatened by possible extinction in all or a significant portion of its range. In making such a determination, NMFS must analyze the species' status in light of five statutory listing factors, relying "solely on the best scientific and commercial data available":

> (A) the present or threatened destruction, modification, or curtailment of its habitat or range;
>
> (B) overutilization for commercial, recreational, scientific, or educational purposes;
>
> (C) disease or predation;
>
> (D) the inadequacy of existing regulatory mechanisms;
>
> (E) other natural or manmade factors affecting its continued existence.

16 U.S.C. § 1533(a)(1)(A)-(E); 50 C.F.R. § 424.11(c)(1) - (5). Many of these factors have brought the Pacific bluefin tuna to its current, imperiled condition.

A species is "endangered" if it is "in danger of extinction throughout all or a significant portion of its range" due to one or more of the five listing factors. 16 U.S.C. § 1531(6). A species is "threatened" if it is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." *Id.* § 1531(20). Under the ESA, a "species" includes any species, subspecies, or a "distinct population segment" of a vertebrate species. *Id.* § 1532(16). As explained in the species description above, the petitioned taxon, Pacific bluefin tuna, is recognized as a distinct species, and therefore qualifies as a "species" under the ESA.

While the ESA does not define the "foreseeable future," NMFS must use a definition that is reasonable, that ensures protection of the petitioned species, and that gives the benefit of the doubt regarding any scientific uncertainty to the species. Slowing and reversing impacts from decades of overfishing will be a long-term process with considerable uncertainty, especially regarding management policy, not unlike the assessment of recovery potential of species vulnerable to climate change. As NMFS has stated in the *Guidance for Treatment of Climate Change in NMFS Endangered Species Act Decisions*, in "cases of significant uncertainty, it is appropriate to assume conditions similar to the *status quo* until new information suggests a change is appropriate."[2] Therefore, NMFS should base its listing decision on current regulatory measures and projections. Threats to Pacific bluefin tuna include: a) overutilization for scientific, commercial, educational, or recreational purposes, b) inadequacy of existing regulatory mechanisms, c) present or threatened destruction, curtailment, or modification of species range, and d) other natural or manmade factors (i.e., climate change).

A. Overutilization for Scientific, Commercial, Educational, or Recreational Purposes;

Fishing is the primary threat driving Pacific bluefin tuna to extinction. Pacific bluefin tuna are severely overfished, and overfishing continues. According to the 2016 stock assessment, decades of overfishing have left the population at just 2.6% of the unfished size (ISC 2016). Recent fishing rates ($F_{2011\text{-}2013}$) were up to three times higher than commonly used reference points for overfishing. This severe decline, in combination with inadequate regulatory mechanisms to reverse the decline, has pushed Pacific bluefin tuna to the edge of extinction.

The development of the Japanese sushi-sashimi market during the 1980s drastically changed the bluefin market, making Pacific bluefin exploitation much more profitable than before. With sashimi prices exorbitantly higher than that of canned tuna, the globalization of this market has encouraged overexploitation. Together, the three bluefin species account for 6% of the global dockside value of tuna fisheries, but only 1% of the volume (Galland et al. 2016). Of all the tunas, Pacific bluefin tuna end-value prices are second only to Atlantic bluefin tuna, at $63,000 per metric ton, and the fishery is valued at nearly $1 billion annually.

1. Life History Vulnerability to Overfishing

The life history of Pacific bluefin tuna makes it vulnerable to overfishing. They are slow-growing, long-lived fish that migrate thousands of miles across the open ocean to feed and spawn. Pacific bluefin tuna are targeted by fisheries at every lifestage, from 15 cm long juveniles to the largest spawning adults. Most Pacific bluefin tuna – a staggering 97.6% – are caught before they have a chance to spawn, primarily on their nursery grounds near Japan and off the coast of California and Mexico. Therefore, most fish in the population never have an opportunity to reproduce (ISC 2014). Industrial fishing fleets target adult Pacific bluefin on their spawning grounds during spawning aggregations – a practice that is widely recognized as unsustainable. In contrast, because of the well-known adverse effects of this practice (van Oversee and Rijnsdorp 2015), directed bluefin fishing on the western Atlantic bluefin tuna's Gulf of Mexico spawning grounds has been prohibited since 1982 (ICCAT 1982), and in 2015, NMFS even implemented a

[2] Memorandum from Sobeck, E., Assistant Administrator for Fisheries, to NMFS Leadership Council, *Guidance for Treatment of Climate Change in NMFS Endangered Species Act Decisions*, dated Jan. 4, 2016.

time-area closure for pelagic longlines in the Gulf to reduce bycatch during the time and area of peak spawn (NMFS 2014a).

Age of maturity has a large impact on the ability of populations to recover from over-exploitation. Species that take several years to reach sexual maturity, like the Pacific bluefin tuna, become particularly vulnerable as many juvenile fish are caught before they can reproduce (Hutchings and Reynolds 2004).

Furthermore, the fish's overall age affects its reproductive output. As with many fish species, the Pacific bluefin's reproductive output is positively correlated with its overall size. For example, a fish measuring 190 cm would likely produce 5 million eggs, but a fish 250 cm in length would produce 25 million eggs (Sawada et al. 2005; Chen et al. 2006). Accordingly, these older, larger fish, which for the most part have been fished out (Maunder 2016), have a proportionately greater contribution to overall species productivity than smaller fish.

2. Historic and Present Overfishing

While Pacific bluefin tuna have been fished for thousands of years, in recent decades fishing has resulted in a collapse of the population. In the EPO, indigenous communities off the coast of British Columbia and Washington fished bluefin as early as 3000 BC, and California anglers targeted Pacific bluefin starting in the late 1800s (Crockford 1997). Purse seine fisheries started hunting bluefin off California and Mexico in 1918, growing to an industrial scale in the late 1950s (Bayliff 1994). EPO landings reached a peak of 15,917 mt in 1966.[3] In the WPO, bluefin tuna fishing has been documented back to 4000 BC (Muto et al. 2009). Small-scale coastal fisheries increased landings off Japan, Korea, Russia and Taiwan in the late 1800s and early 1900s, but the advent of driftnet fisheries and then longlining in the 1920s and 1930s led to dramatic increases in catch (Figure 7). Following the rise of industrial scale fishing, basin-wide Pacific bluefin tuna catch hit a peak in 1935, at an estimated 47,148 mt, nearly two decades before the initial year used in the stock assessment (1952). This explains the fact that the stock was already overfished, depleted to just 17% of its unfished level, and subject to overfishing by the start of the assessment period in 1952 (ISC 2016, Figure 5). Since 1952, the WPO catch hit a peak at 34,029 mt in 1956 (Figure 8).

[3] ISC catch data. http://isc.fra.go.jp/pdf/ISC15/ISC15%20Catch%20Tables%202015071402_17Jul15_v2.xlsx. Downloaded 4/15/16.

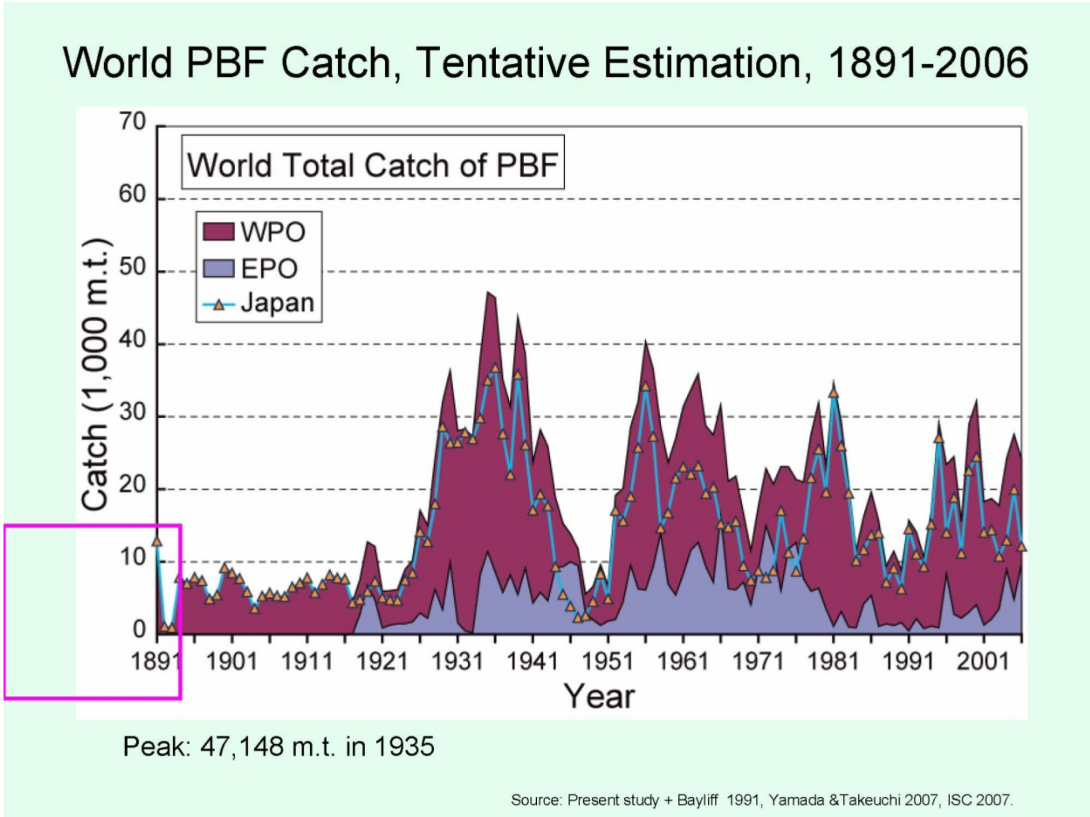

Figure 7. Estimated Pacific bluefin tuna landings, 1891-2006, illustrating the peak in basin-wide catch occurred *prior* to the first year of the stock assessment. (Source: Muto et al. 2009)

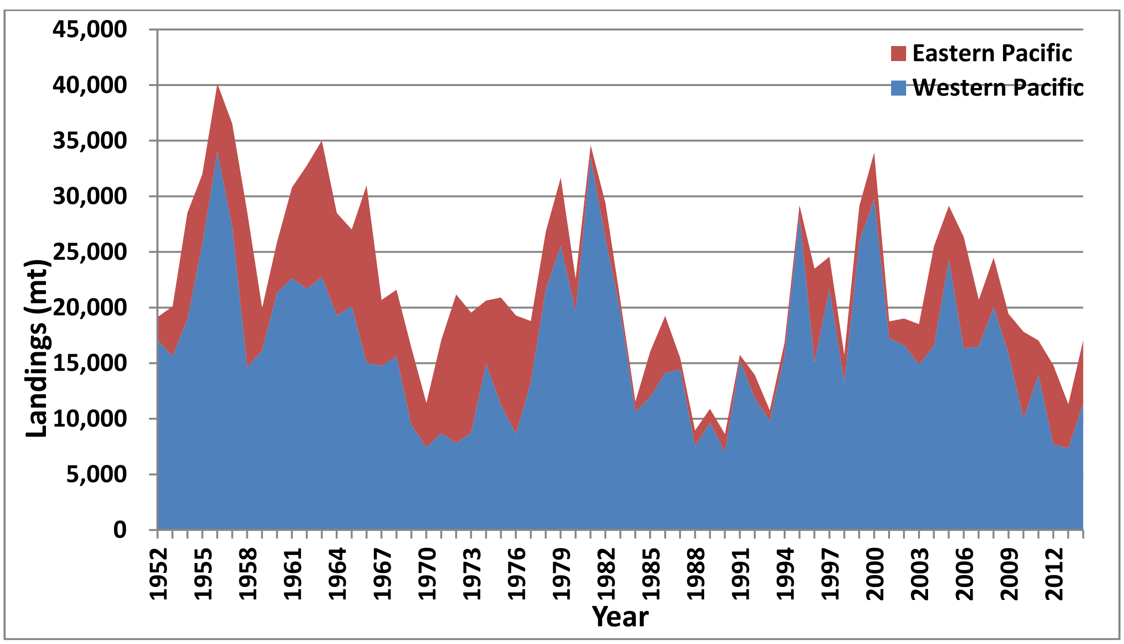

Figure 8. Pacific bluefin tuna landings, 1952-2014 (Source: ISC catch database, downloaded 4/15/16)

Pacific bluefin tuna fishing methods include purse seine, pole and line, set net, gillnet, and pelagic longline. Landings occur year-round, with most of the catch from the WPO taken during May-September and most from the EPO taken during May-October (Bayliff 1994; Tseng and Smith 2012). The recent trend in the global bluefin fisheries has transitioned to purse seine fleets, which supply live fish for ranching operations to meet sashimi market demand.

In recent years, United States commercial fishermen have primarily used purse seines to catch Pacific bluefin tuna; however, vessels using gillnets, longlines, and the albacore troll and pole-and-line fishery also take some smaller amounts of bluefin tuna (NMFS 2015; *see also* Carruthers 2013 at 26 (giving background on the U.S. Pacific bluefin tuna fishery)). Purse seine landings are much lower than the peak in the 1950s through early 1970s because in 1976 Mexico established its Exclusive Economic Zone (EEZ). By the early 1980s the U.S. fishery had stopped fishing there. Availability of Pacific bluefin in U.S. waters is highly variable, with highest abundance (and therefore highest catches) in years with warmer waters (e.g., due to a strong El Niño or recently the “Blob”) and following low sardine abundance in the WPO, which is hypothesized to lead to an increase in migration of young fish to the EPO. Coastal purse seiners will make targeted bluefin sets if there are bluefin present in the Southern California Bight, but otherwise all commercial bluefin catch is considered bycatch (PFMC 2016). Eleven U.S. purse seiners caught tunas in 2015, up from one in 2012 (*Id.*).

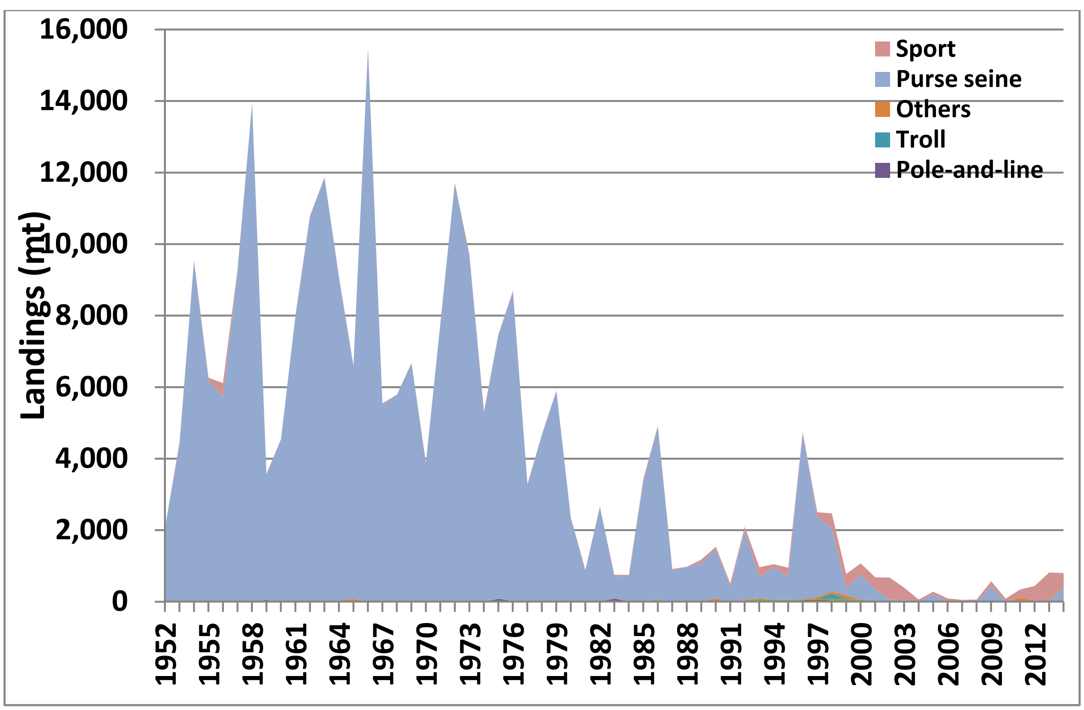

Figure 9. U.S. Pacific bluefin tuna landings, by gear, 1952-2014 (Source: ISC catch database, downloaded 4/15/16)

In the last decade, U.S. recreational catch has become significant, accounting for 64 percent of the U.S. total catch (Table 1). Unlike the commercial fleet, U.S. charter vessels, known as commercial passenger vessels (CPFV), are permitted to fish in Mexican waters. Catch reached a peak in 2013 at 809 mt, accounting for 99% of the U.S. catch and 7% of the basin-wide catch (ISC catch database 2016). This catch was nearly double the U.S. commercial quota and was taken primarily by 127 CPFV vessels (NMFS 2014b). Pacific bluefin landings in the private vessel recreational fishery are minimal, with 558 fish landed in 2013, compared to 63,350 fish in the CPFV fleet (*Id.*). Importantly, almost all Pacific bluefin caught by U.S. fishermen, both commercial and recreational, are juveniles that have not yet reproduced.

3. Aquaculture Impacts

Overharvest for the aquaculture industry is another growing threat to Pacific bluefin tuna. Pacific bluefin aquaculture began in Japan in 1970 and has experienced tremendous growth in recent years. Pacific bluefin tuna aquaculture includes both farming and ranching. Ranching, where small wild fish are caught and fattened in pens, and farming, where fish that were hatched in captivity are raised to market size, both developed to supplement the market demand for wild-caught tuna. All bluefin aquaculture operations in the EPO are ranches, while Japan has a mixture of closed lifecycle farming and ranching of wild-caught fish.

Large-scale ranching began off Japan in 1986. The Japanese industry has increased remarkably, from an output of 521 mt in 2001 to 13,781 mt in 2011 (Sanada 2015). There are now 150 Pacific bluefin tuna ranches operational in Japan (*Id.*). A staggering 400,000 to 500,000 small bluefin tuna are needed per year to stock the pens in Japan, putting tremendous pressure on the wild stock. Over 800,000 age-0 Pacific bluefin were caught for the Japanese ranches in 2011 (Sanada 2015).

The first Mexican Pacific bluefin tuna ranch opened in 1996 (Anonymous 2008). Almost all of Mexico's bluefin catch enters the ranches. At the peak in the late 2000s, there were 12 ranches in operation, but only 2 active ranches remain. Between 2002 and 2008, NMFS regularly published notices and requests for comments on applications for Mexican vessels to receive transfers of live tuna from U.S. purse seiners for the purpose of transporting the tuna to a ranching facility located in Baja California, Mexico, but to our knowledge NMFS did not issue these, and U.S. vessels have not been involved in supplying ranches with tuna.[4]

Besides the threat of overfishing to stock bluefin tuna ranches, keeping bluefin tuna in pens presents concerns about impacts to wild populations. Aquaculture threatens wild fish populations by creating a breeding ground for disease. Because fish are packed densely together, the fish are exposed to pathogens in the marine environment, and can alter the surrounding ecology to such an extent that they actually foster the proliferation of pathogens (Gardner and

---

[4] *See* 73 Fed. Reg. 17326 (Apr. 1, 2008); 72 Fed. Reg. 37731 (July 11, 2007); 70 Fed. Reg. 44326 (Aug. 2, 2005); 69 Fed. Reg. 25882 (May 10, 2004); 67 Fed. Reg. 40277 (June 12, 2002).

Peterson 2003; Cabello 2006; Pulkkinen et al 2009). Sea lice is one of the most notorious pathogens associated with aquaculture facilities and have been found on farmed southern bluefin tuna within 24 hours of the tuna's arrival at the ranching site (Hayward et al. 2011). Sea lice feed on the mucus, skin, and scales of fish, causing skin lesions prone to infection and affecting the host's ability to osmoregulate; chronic infections can cause mucus accumulation and attract myxobacteria and other bacteria, fungi, and ectocommensal organisms, all of which may contribute to further disease (Rae 2002; Barber 2007). While sea lice normally exist outside of aquaculture, the unnaturally high host density created by caged fish farming provides a favorable environment for parasites such as sea lice that rely on spatial proximity between hosts for transmission to proliferate (*Id.*). Blood flukes are also problematic in Pacific bluefin tuna, with one species affecting the heart by clogging blood vessels and blocking circulation and another affecting the gills by compromising gas exchange during respiration (Shirakashi et al. 2012a; Shirakashi et al. 2012b). Since most ranching operations are located in open ocean pens in Pacific bluefin habitat, these parasites, which are particularly pathogenic to juveniles, may be spreading to wild fish.

Unregulated distribution and release of captive-spawned bluefin tuna eggs around the world poses another threat to wild bluefin tuna due to the potential for genetic contamination that theoretically can lead to extinction (Muir and Howard 1999; Benessia and Barbiero 2015). Captive-spawned bluefin tuna eggs are being shipped around the planet with no regulation or monitoring. Farms in the Mediterranean also purposefully release bluefin tuna eggs into the wild without prior environmental analysis. The Domestication of *Thunnus thynnus* (DOTT) program in Europe aims to work with up to six broodstock centers to release one billion captive-spawned eggs annually into the wild (Bridges 2016).

Finally, and arguably most alarmingly, Pacific bluefin tuna aquaculture operations compete directly with wild bluefin tuna for prey. The feed conversion ratio (FCR) for bluefin is as high as 20:1, meaning that twenty pounds of prey fish are required to produce one pound of cultured bluefin (Ottolenghi 2008). An estimated 20,000-30,000 mt of sardines are used to feed the bluefin in the Mexican bluefin ranches during their 6 to 9-month grow-out period (Anonymous 2008). Disturbingly, many of the fresh sardines caught off Ensenada and transferred directly to the ranches are not reported, leading to 37% underreporting of sardine catch (*Id.*). On the U.S. West Coast, there has been a 91 percent decline in sardine abundance since 2007 (Hill et al. 2015). While sardine's decline cannot be attributed solely to overfishing, fishing during declines can exacerbate the natural cycles and delay recovery. The Lenfest Forage Fish Task Force calculated that 90 percent of forage fish are used for agriculture, fish farms, and nutritional supplements (Pikitch et al. 2012). Northern anchovy, another key prey species in the California Current Ecosystem, have also been at very low levels in recent years (MacCall et al. 2016). In a time of sardine scarcity, the additional impact of supporting bluefin tuna ranching from wild sardine populations could impact wild bluefin tuna's feeding success.

B. Inadequacy of Existing Regulatory Mechanisms

Pacific bluefin tuna have endured a long history of exploitation and inadequate regulation. Recent measures to manage the catch of Pacific bluefin tuna have been too little, too late. Existing regulations are insufficient to abate the continued decline of this species, let alone promote a recovery to healthy levels.

1. International Management

The absence of a science-based, mandatory limit on the international catch of Pacific bluefin tuna remains the primary reason that the species risks extinction. While characteristics intrinsic to bluefin tuna, such as life history and exploitation history, contribute to its population decline, implementing and enforcing total allowable catches has had the strongest positive influence on rebuilding overfished tuna and billfish stocks (Pons et al. 2016). Other controls – minimum size regulations or seasonal closures – could benefit Pacific bluefin tuna by reducing fishing pressure, but total allowable catch limits have the greatest relative effectiveness in rebuilding depleted stocks (*Id.*) and remain conspicuously absent in current international management.

Two regional fisheries management organizations, the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC) have adopted management measures for Pacific bluefin tuna, but as NMFS has noted, these measures "are inadequate to end overfishing,"[5] and therefore also inadequate to prevent extinction. The stock is at just 2.6% of its historic level, yet there is no basin-wide rebuilding plan for the species, no agreed upon reference points (which is why the stock assessment produces multiple Kobe plots), and no catch documentation system to monitor trade and ensure timely reporting.

IATTC was formed in 1949 but did not restrict Pacific bluefin tuna fishing until 2012. Even when the IATTC faced evidence in 2014 that the near historically low levels of Pacific bluefin tuna required substantial reductions in fishing mortality, it still failed to establish catch limits that prevent overfishing (IATTC 2014a). The 2014 stock assessment included projections of seven different catch scenarios, and only one scenario predicted measurable growth of the species under current conditions. That scenario called for a reduction in EPO catch to 2750 mt, yet IATTC only reduced the quota to 3300 mt, 20% above the science-based reductions required to rebuild the population (*Id.*). Specifically for the U.S. commercial fisheries, the effective annual IATTC catch limit was reduced by 40%, from 500 mt to 300 mt. The United States was also required to reduce catch by sportfishing vessels "to levels comparable to the levels of reduction applied" to commercial fisheries. However, recreational mortality is not included in the overall IATTC catch limit, nor are dead discards or post-release mortality. Even without

[5] *Fisheries of the Pacific Region; Western Pacific Region, Notification of determination of overfishing or an overfished condition*,76 Fed. Reg. 28422, 28422 (Apr. 7, 2011).

counting these additional sources of mortality, the overall catch limit is still above the level shown to lead to rebuilding of the population. This measure was also inconsistent with the advice of the IATTC staff scientists, which called for a reduction in commercial catch to "below 3,154 mt" and the implementation of a recreational catch limit at "below 221 mt" (IATTC 2014b).

The current resolution (Resolution C-14-06) expires at the end of 2016, but it is likely that the IATTC will just agree to continue the measure for 2017 and 2018. This is incredibly risk-prone considering the new stock assessment shows that the species is at very low abundance, is relying on just a few age classes for reproduction, most juveniles will not survive to reach reproductive maturity, and current management will not lead to a timely recovery of the species. Concerned by the lack of agreement by the IATTC on a long-term plan to rebuild the stock, the European Union has stated that "immediate action should be taken for the recovery of the stock to meet the Convention objectives."[6] Without a plan to control future catches in order to rebuild the stock, including a science-based, hard limit on all Pacific bluefin tuna mortality, there is slim hope for recovery of Pacific bluefin tuna.

WCPFC also delayed needed regulatory measures and did not adopt any restrictions on Pacific bluefin tuna catch until 2009 (WCPFC 2009). Mandatory catch limits were not put into place until 2013 (WCPFC 2013). In 2014, WCPFC adopted a rebuilding plan designed to rebuild the stock to the "historical median" of 42,592 mt within 10 years (WCPFC 2014a). This "historic median" was a median of only the stock assessment time period, a time when the stock was already highly depleted, and had been overfished for all but a few years. In reality, this "historic median" equates to just 6.4% of the historic unfished level, well below the commonly recommended rebuilding target of 20%-40% of unfished levels for species such as bluefin (Restrepo et al. 1998). The U.S. criticized this rebuilding target, stating, "[that it] is not an appropriate application of the precautionary approach for fisheries management, particularly since the latest stock assessment indicates that the Pacific bluefin tuna spawning biomass has been substantially depleted throughout much of the stock assessment period." (WCPFC 2014b) Nevertheless, the historic median was set as the rebuilding target. As part of this rebuilding plan, WCPFC adopted a 50% reduction in the catch limits for juveniles, but because of the baseline years used for the calculation, the new limits actually allow several countries to *increase* their catch. Since many of the fisheries cannot even catch their allocation due to the scarcity of fish, in some ways the "reduced" quota does not limit fishing mortality at all. Furthermore, the measure defines juveniles as fish under 30 kg, despite warnings from scientists that this size boundary does not cover "the whole range of juvenile ages" (ISC 2014). Because the measure only calls for reductions on catch of juveniles, underestimating the top size of a juvenile leaves a large portion of juveniles unprotected from the reduction.

[6] Letter from Angela Martini, Head of EU Delegation to IATTC, to Dr. Guillermo Compean, Director, IATTC, regarding the Scientific Advisory Committee meeting – La Jolla 9-13 May 2016.

Similarly, at its most recent meeting held in December 2015, the WCPFC adopted a measure that, like the previous one, calls for effort and catch limits in fisheries that target Pacific bluefin tuna but does not include forward-looking rules to constrain future fishing in order to rebuild the stock (WCPFC 2015). The only change to the prior measure was to insert a provision that calls for the development in 2016 of an "emergency rule" that would be triggered when "drastic drops of recruitment are detected." While the WCPFC did not define "drastic," the 77% drop between 2013 and 2014 meets any rational definition of the term. Yet the WCPFC took no additional action with this new information in 2015.

In response to the lack of progress at the 2015 meeting, the U.S. stated that "we missed an opportunity to have a meaningful discussion about the long term management of Pacific bluefin tuna. [WCPFC] members have a responsibility to recover [Pacific bluefin tuna], and then manage the stock throughout the Pacific Ocean using the best available science... We cannot delay this work and shirk this responsibility."[7]

As part of the latest 2016 stock assessment, the ISC projected the future impacts of twenty different scenarios, which included several different management measures, as well as different assumptions about the future recruitment levels of the stock (ISC 2016). According to the assessment, existing management measures have just a 0.1% chance of rebuilding Pacific bluefin tuna to healthy levels (i.e., 20% of unfished level) by 2024. Current management measures are not even sufficient to reach the agreed-upon initial WCPFC goal of rebuilding the adult population to 42,592 mt by 2024, with the required 60% probability of success. Under current conditions, even if catch is cut by 20%, there is just a 3% chance of returning to healthy levels by the rebuilding deadline.

Unfortunately, there is no indication that the regional fishery management organizations responsible for Pacific bluefin tuna management will finally adopt adequate, meaningful international measures in the near future. There were no international management measures in place until 2010. Over the last decade, a time during which the catch was supposed to be cut in half, the catch of fish aged 2-10 has increased for all age classes, except for age 6, and mortality has almost doubled for some year classes (ISC 2016). Overall catch increased between 2013 and 2014, even when the dire status of the population was well known. Science has shown that the current measures will not meaningfully decrease the chance of extinction of the Pacific bluefin tuna population. The continued lack of sufficient management measures threatens the Pacific bluefin's existence.

[7] Letter from Michael Tosatto, Regional Administrator, NMFS, to the Chairs of the Western Pacific, North Pacific, and Pacific Fishery Management Councils, dated Jan. 13, 2016, http://www.pcouncil.org/wp-content/uploads/2016/02/F4_Att1_Tosatto_Ltr_MAR2016BB.pdf.

2. U.S. Domestic Management

U.S. regulations for domestic Pacific bluefin tuna fisheries have simply implemented international rules, which themselves are inadequate. The U.S. has not taken any additional steps to prevent overfishing or rebuild Pacific bluefin tuna. The Tunas Conventions Act of 1950, 16 U.S.C. §§ 951-62, requires the Secretary of Commerce to promulgate regulations to carry out recommendations of the IATTC upon approval by both the Secretary of State and the Secretary of Commerce.[8] The United States catches Pacific bluefin only in the EPO, so NMFS does not take any regulatory action to implement WCPFC measures for Pacific bluefin tuna.

U.S. regulations have rarely, if ever, restricted U.S. landings of Pacific bluefin tuna. For commercial fisheries, on June 4, 2013, NMFS implemented IATTC recommendations capping bluefin tuna annual catch for 2012 and 2013 at 500 mt – an amount above any U.S. catches since 2000 (Table 1).[9] Even the annual catch limit for 2015 and 2016, a combined limit of 600 mt for both years, is more than the U.S. commercial fleet has caught in any two-year period since 2002.[10] The fact that NMFS has set Pacific bluefin tuna commercial catch limits so high that they do not actually limit catch in most years demonstrates that those measures are inadequate to conserve the species.

Year	Commercial (mt)	Recreational (mt)	U.S. Total (mt)
1990	1,472	65	1,537
1991	416	92	508
1992	1,989	110	2,099
1993	683	283	966
1994	965	86	1,051
1995	706	245	951
1996	4,709	40	4,749
1997	2,373	131	2,504
1998	2,052	422	2,474
1999	368	408	776
2000	754	319	1,073
2001	340	344	684
2002	62	613	675
2003	40	355	395
2004	11	50	61
2005	208	73	281
2006	2	94	96
2007	44	12	56
2008	1	63	64

[8] 16 U.S.C. § 955(c).
[9] 78 Fed. Reg. 33240 (codified at 50 C.F.R. § 300.24(u) and § 300.25(h)).
[10] *Pacific Tuna Fisheries; 2015 and 2016 Commercial Fishing Restrictions for Pacific Bluefin Tuna in the Eastern Pacific Ocean, Final Rule*, 80 Fed. Reg. 38986 (July 8, 2015).

2009	416	156	572
2010	1	88	89
2011	118	225	343
2012	42	400	442
2013	11	809	820
2014	406	398	804

Table 1. U.S. commercial and recreational annual landings of Pacific bluefin tuna for the past 25 years (1990-2014).[11]

Since NMFS made determinations that overfishing is occurring in 2011 and the stock is overfished in 2013, U.S. regulations have done little to guarantee the reduction of Pacific bluefin tuna catch. In its determination of overfishing, NMFS specifically stated that because international "measures are inadequate to end overfishing" the Councils "must undertake action under [Magnuson-Stevens Act] section 304(i)(2)."[12] Because Pacific bluefin are managed by IATTC and WCPFC, two Councils - the Pacific Fishery Management Council and the Western Pacific Regional Fishery Management Council - have domestic jurisdiction over the stock's management. As recently as January 2016, NMFS has exhorted the two Councils to take action: "[b]ecause Pacific bluefin tuna is overfished, we encourage the Councils to continue to consider any recommendations necessary to address the rebuilding of this stock."[13] Yet the Councils have not recommended action that will guarantee reductions from the current levels of commercial and recreational Pacific bluefin tuna catch.

Since 2010, U.S. recreational catch has been significantly higher than U.S. commercial catch in all but one year and accounts for up to 99% of the U.S. landings (Table 1). Despite the significant take in this fishery, the only management measure is a per-trip bag limit that fails to actually limit overall bluefin tuna catch in the domestic recreational fishery. The bag limit does not provide an absolute limit on recreational catch because (1) the fishery is open access, meaning there is no limit on the number of fishermen who can participate in the fishery, and (2) there is no limit on the number of trips each fisherman can take. Therefore, the bag limits do not provide a reliable mechanism for limiting recreational catch and preventing overfishing.

In 2007, NMFS promulgated a 10-fish bag limit per person for the recreational fishery, more fish per day than any sampled catches for the prior ten years.[14] In 2015, NMFS lowered the

[11] ISC, Fisheries statistics, reported total annual landings, http://isc.fra.go.jp/fisheries_statistics/index.html; Pacific Fishery Management Council, *Final Environmental Assessment: Daily Bag Limits, Possession Limits and At-Sea Processing of Pacific Bluefin Tuna in California Recreational Fisheries*, June 2015.
[12] 76 Fed. Reg. 28422, 28422.
[13] Letter from Michael Tosatto, Regional Administrator, NMFS, to the Chairs of the Western Pacific, North Pacific, and Pacific Fishery Management Councils, dated Jan. 13, 2016, http://www.pcouncil.org/wp-content/uploads/2016/02/F4_Att1_Tosatto_Ltr_MAR2016BB.pdf.
[14] *See, e.g.,* 72 Fed. Reg. 35213 (June 27, 2007) ("The data for bluefin tuna catches shows that 100 percent of the 1997 through 2005 sampled catches that landed bluefin contained less than six fish per day therefore potential expenditure loss under this proposed rule would be zero").

bag limit to two fish per person, with a limit of six fish per person for multi-day trips.[15] This regulation is inadequate because an analysis of historical catches showed that the vast majority of trips caught 2 or fewer bluefin anyway, and the new bag limit would only reduce catch by 19.4% from 2008-13 levels.[16] Indeed, California reported that "the vast majority of CPFV fishing days with tuna catch included no bluefin." (*Id.*) Even so, efforts to reduce the bag limit to 1 fish per angler per day or tune a scaling bag limit to a science-based recreational catch limit failed, and U.S. recreational bag limits remain too high to ensure conservation benefits.

As a result of both international and domestic regulations that failed to prevent overfishing, U.S. catch has increased in the past decade while Pacific bluefin abundance has declined (Table 1). The proportion of Pacific bluefin tuna catch by commercial passenger fishing vessels, compared to other highly migratory species, has increased in recent years, from below 10 percent in 2000 through 2007 to levels between 20 and 55 percent from 2011 through 2013.[17] The 2012 stock assessment of Pacific bluefin tuna showed drastic declines for over a decade and abundance at or near the lowest levels, yet in the two years immediately after (2013 and 2014), U.S. total catch increased to more than triple the average U.S. catch in the previous decade (Table 1). In these years, total U.S. Pacific bluefin catch was higher than in every year since 2000 and were a larger portion of the Pacific-wide landings than in any year since 1998. While there has been a drop in overall recreational catch compared to the exceptionally high catch in 2013, it is more likely that this reduction came from Mexico's closure of important recreational fishing grounds beginning July 14, 2014, than U.S. regulatory mechanisms; from 2004-2013, on average 78 percent of fishing effort (angler days) by West Coast private and commercial passenger fishing vessels occurred in Mexican waters.[18]

To prevent overfishing, U.S. regulations must be adequate to limit catch. Over the last decade, the U.S. has increased catch rather than taking the necessary scientifically recommended actions to sufficiently reduce catch, even as other countries have taken voluntary actions. In addition to the 2014 recreational fishery closure, the Mexican government and fishing industry have indicated that they will take additional actions in the future to protect the stock. The Mexican government has pledged to voluntarily reduce its commercial catch in 2016 by 250 metric tons, from 3,000 mt to 2,750 mt.[19] A portion of the Mexican yellowfin tuna fishing fleet has also preliminarily agreed to stop fishing for Pacific bluefin for five years, beginning in 2015, as part of their bid for Marine Stewardship Council certification.[20] While this unilateral commitment to reducing bluefin catch is encouraging, neither action is binding, and the remaining Mexico fleet will easily be able to catch the full quota in the future. Nevertheless, it is

[15] 80 FR 44887
[16] http://www.pcouncil.org/wp-content/uploads/G4b_HMSMT_Rpt2_PBF_SEPT2014BB.pdf
[17] Pacific Fishery Management Council, September 2014 Agenda Item G.4.b HMSMT Report 2, Figure 7.
[18] Pacific Fishery Management Council, *Final Environmental Assessment: Daily Bag Limits, Possession Limits and At-Sea Processing of Pacific Bluefin Tuna in California Recreational Fisheries*, January 2015.
[19] Appendix 5a http://www.iattc.org/Meetings/Meetings2015/June/PDFs/IATTC-89-Minutes.pdf
[20] https://www.msc.org/track-a-fishery/fisheries-in-the-program/in-assessment/pacific/northeastern-tropical-pacific-purse-seine-yellowfin-and-skipjack-tuna/assessment-downloads-1/20160224_PCR_TUN.pdf

a stronger commitment than the U.S. has shown. In contrast to Mexico, the U.S. has merely implemented a selection of IATTC regulations and has blocked adoption of the IATTC scientists' recommendation to adopt a recreational catch limit at "below 221 mt" (IATTC 2014b).

Not only has the U.S. failed to adopt voluntary restrictions, but it has also failed to fully comply with international regulations mandated in IATTC C-14-06. U.S. transgressions include: 1) the use of bag limits in an open access fishery will not necessarily reduce recreational catch comparable with the commercial quota reduction, 2) neither the commercial nor recreational U.S. regulations implement the objective that only 50 percent of the total catch be comprised of fish less than 30 kilograms[21], and 3) the U.S. monitoring and reporting system is inadequate to abide by the weekly commercial catch reporting mandate, instead delaying reporting by up to 12 weeks and complicating quota management.[22]

Following the overfished designation in 2013, the Councils were required within a year "to develop domestic regulations to address the relative impact of the domestic fishing fleet; and to develop recommendations for the Secretary of State, and to Congress, to address international actions to end overfishing and rebuild Pacific bluefin tuna."[23] In response to the Council's failure to develop regulations within a year, the Center for Biological Diversity filed a petition in April 2014 calling for NMFS to take action.[24] NMFS published a response to this petition on June 16, 2016.[25] Nowhere in the petition does NMFS deny the severity of the decline or continued overfishing on the stock. In the response, NMFS denied the petition nonetheless, asserting that while "NMFS shares CBD's interest in ending overfishing," the "Pacific Council's recommendations and adopted measures [are] sufficient to fulfill international and domestic obligations to conserve the PBF stock and address the relative impact of U.S. vessels." Again, neither a reduction in the current 2-year commercial quota to a level not seen in a 2-year period since 2002, nor a reduced bag limit for an open access recreational fishery, can be credited as

[21] NMFS refused to implement the 30kg requirement, citing additional harvest costs, e.g., search time for schools of larger fish, and the possibility of higher discards, neither of which provide a valid reason for ignoring the international recommendation.

[22] The current commercial reporting system requires fishermen to submit landing receipts to the California Department of Fish and Wildlife twice monthly. It usually takes about six weeks to enter catch data from fish tickets into the system. That means that after landing a bluefin tuna, two weeks could pass before California gets a receipt; six weeks could pass until the bluefin tuna enters the database; and four weeks could pass before it is reported to NMFS or IATTC. It therefore could potentially take 12 weeks to report a commercial landing of bluefin tuna. Indicative of how inadequate this system is, in 2014, the U.S. closed the commercial fishery to avoid exceeding the annual catch limit of 500 mt (79 Fed. Reg. 53631), only to later realize that there were 96.5 mt of quota remaining so the fishery was reopened (79 FR 68133).

[23] Section 304(i) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA)

[24] *Fisheries Off West Coast States; Pacific Bluefin Tuna; Notice of receipt of rulemaking petition to prohibit Pacific bluefin tuna fishing and request for comments*; 79 Fed. Reg. 43017 (July 24, 2014).

[25] *Pacific Bluefin Tuna in the Eastern Pacific Ocean; Response to Petition for Rulemaking; Notice of decision on petition*; 81 Fed. Reg. 39213 (June 16, 2016).

U.S. action to reduce overfishing on this severely depleted stock given that they will not necessarily result in any decrease in catch.[26]

C. Present or Threatened Destruction, Curtailment, or Modification of Species Range

1. Water Pollution

As a relatively long-lived predator, Pacific bluefin tuna are especially susceptible to bioaccumulation of pollutants, including toxic heavy metals like mercury. The number of trophic levels between predators (Pacific bluefin tuna) and prey is critical in causing accumulation of mercury (Morel et al. 1998). Bioaccumulation results from the mercury associating with the very base of the food chain, a diatom. The diatom is eaten by a copepod, which then assimilates the mercury, and so on up the food web. This problem is likely to worsen with ocean acidification, which increases the mobility of mercury in the environment (Morel et al. 1998; Glover et al. 2010; USGS 2000). This results in the potential for increased accumulation of mercury in Pacific bluefin tuna.

Mercury can interfere with cell metabolic processes, including respiration and lipid biosynthesis, and inhibit enzyme activity (Jones et al. 1987; Filimonova et al. 2016). Bluefin tuna generally have mercury levels above regulated thresholds for human health; Lowenstein *et al.* (2010) found that mean mercury levels of bluefin tuna samples collected from restaurants and supermarkets "exceed those permitted by the US Food and Drug Administration (2000), Health Canada (2007) and the European Commission (2008)."[27] Because of the relatively high mercury content compared to other fish, Pacific bluefin tuna are likely susceptible to physiological impacts.

Bluefin tuna are vulnerable not only to mercury, but also bioaccumulation of other pollutants. Several studies have found persistent organic pollutants in Atlantic bluefin tuna (Storelli et al., 2008; Vizzini et al., 2010). One recent study found levels in Atlantic bluefin tuna to be higher than other species, e.g., farmed salmon (Sprague et al. 2012). Scientists have

---

[26] NMFS's response implies that Mexico's enforcement of its regulations has been inadequate to control U.S. recreational catch. In 2013, the U.S. recreational catch alone accounted for about 7 percent of Pacific-wide total catch, but NMFS views "the relatively high 2011 through 2013 recreational catch as an anomaly due to . . . recreational anglers fishing next to the PBF net pens, which serve as fish aggregating devices (FADs), in northern Baja California, Mexico." Further, "NMFS has been informed by Mexico's National Aquaculture and Fishing Commission that they will begin enforcing Mexican law requiring recreational sportfishing to remain 250 m away from commercial fishing activities, such as the PBF pens, beginning in 2015." *The National Marine Fisheries Service's Response to a Petition from the Center for Biological Diversity Requesting Rulemaking to Prohibit Fishing for Pacific Bluefin Tuna*, June 2016, at 5, n.5.

[27] Atlantic Bluefin Tuna (*Thunnus thynnus*), Pacific Bluefin Tuna (*T. orientalis*), and Southern Bluefin Tuna (*T. maccoyii*) are pooled into the sample category "bluefin," but over half the bluefin samples were from *T. thynnus* (Lowenstein *et al.* 2010, data supplement). *Toro* is the Japanese name denoting 'fatty tuna,' and *akami* the Japanese name for 'red tuna.'

sounded a warning of potential reproductive alterations in Atlantic bluefin tuna as a result of the bioaccumulation of endocrine disrupting chemicals (Fossi et al. 2002; Storelli et al. 2008). Storelli et al. (2008) concluded that the exposure of Atlantic bluefin tuna in the Mediterranean to endocrine disrupting chemicals over their long lifetimes might "create the prerequisite for the development of pathological conditions." Similarly, Fossi et al. (2002), based on the data showing high exposure of bluefin tuna to contaminants in the Mediterranean, advised "continuous monitoring to avoid reductions in the population of these species of high commercial and ecological interest."

Unfortunately, Pacific bluefin tuna's habitat in the Southern California Bight is known to be contaminated with pollutants that have had reproductive impacts to fish and marine mammals. A study that collected pelagic forage fish in the Southern California Bight in 2003 and 2004 found an estimated 99% of northern anchovy, 83% of Pacific sardine, and 33% of Pacific chub mackerel landings exceeded wildlife risk screening values for total DDT (Jarvis et al. 2007). DDT, which has been found to impair reproduction in white croaker (Cross and Hose 1988; Hose et al. 1989), gets passed onto predators like Pacific bluefin tuna (Jarvis et al. 2007) and may harm their reproduction as well. As another example of the potential reproductive impacts of contaminants in Southern California, NMFS found that "contaminant levels have been proposed as a causative factor in lower reproductive rates found among humpback whales off Southern California" (Bettridge et al. 2015). The high pollutant loads off southern California and the known uptake and bioaccumulation in bluefin tuna likely impacts Pacific bluefin tuna.

Finally, Pacific bluefin tuna are at risk of radiation pollution from coastal nuclear power plants. Scientists detected Fukushima-derived radionuclides in Pacific bluefin tuna (Madigan et al. 2013). Like other pollutants, there is the potential for biomagnification of radiocesium concentrations (*Id*.).

2. Plastic Pollution

Similar to other large marine species, Pacific bluefin tuna may be susceptible to ingestion and entanglement by marine debris, especially plastics. Plastic pollution harms marine fish particularly through ingestion of small plastic particles, which attract contaminants. Harmful hydrophobic chemicals attach to plastic pellets because of their low polarity, and small pieces can become especially concentrated because of their large surface area relative to their size (Mato et al. 2001; Ashton et al. 2010).

Persistent organic pollutants (POPs) are particularly worrisome because they attach to plastic and can bioaccumulate in predators like Pacific bluefin tuna. Studies of polychlorinated biphenyls (PCB) in nurdles, which are small pieces of plastic, found that the concentration of these chemicals in the resin pellets was 100,000 to 1,000,000 times that of the surrounding waters, suggesting that the nurdles serve as a potential source for toxic chemicals in the marine environment (Mato et al. 2001). Other studies have found that plastic pellets concentrate POPs, including PCBs, up to quantities ranging from 27 to 980 nanograms per gram (Rios et al. 2007). POPs are synthetic organic compounds that are considered among the most persistent anthropogenic organic compounds introduced into the environment. Some of these are highly toxic and have a wide range of chronic effects, including endocrine disruption, mutagenicity and carcinogenicity. Furthermore, POPs are chemically stable, and therefore not easily degraded in the environment or in organisms. They are lipophilic (i.e., they are attracted to nonpolar substances like fats) and accumulate in animals who ingest plastics, and in other animals through the food chain.

Scientists have hypothesized tuna are vulnerable to plastic ingestion because of their feeding habits, in particular the association with drift lines where plastic and debris collect (*see* Hoss and Settle 1990). Plastic ingestion has been documented in the stomach of several tuna species other than bluefin tuna (Laist 1997; Hoss and Settle 1990; Choy and Drazen 2013; Carson 2013). Ingestion of plastic has many detrimental consequences, including gastrointestinal blockages, ulceration, internal perforation and death (Teuten et al. 2009). Even those animals without injury from ingestion may suffer from false sensations of satiation, or experience reduced reproductive output (*Id.*). Finally, tuna are susceptible to plastic ingestion via their prey. For example, common prey species belonging to the Myctophidae have been found to have an average of six plastic pieces in their guts (Boerger et al. 2010).

The amount of plastic in the marine environment has been increasing. Studies show that the Southern California Bight has the highest total number of land-based marine debris items of the Pacific Coast, due to its high human population density (Ribic et al. 2012). Marine debris originates predominantly from land-based sources and is carried primarily by rainfall to oceans (Gordon 2006). In the Los Angeles watershed alone, every three days 2.3 billion plastic fragments, or approximately 30 metric tons, are carried into the Pacific Ocean from land (Moore et al. 2011). In Long Beach, California the weight of the amount of trash collected over different years from storms ranged from over 1,800 tons to about 12,250 tons over a ten year period (California Regional Water Quality Control Board 2007). One study of the stomachs of beached northern fulmars, which feed exclusively at sea, over 40 years found an increase of 34% of individuals with plastic in their stomachs (Avery-Gomm et al. 2012). This shows that the ocean habitat of Pacific bluefin tuna is highly, and increasingly, polluted with marine debris.

3. Oil and Gas Development

Acute and chronic oil spills have a wide array of lethal and sublethal impacts on marine species, including immediate and long-term effects. Direct impacts to wildlife from exposure to oil include behavioral alteration, suppressed growth, induced or inhibited enzyme systems and other molecular effects, physiological responses, reduced immunity to disease and parasites, histopathological lesions and other cellular effects, tainted flesh, and chronic mortality (Holdway 2002). Oil can also exert indirect effects on wildlife through reduction of key prey species, impacting wildlife species and ecosystems for decades (Peterson et al. 2003).

Petroleum oil is a complex mixture of hundreds of different compounds, mostly hydrocarbons, with different levels of toxicity to wildlife. Exposure to crude oil adversely affects fish at all stages (Carls et al. 1999, Bernanke and Kohler 2009). Polycyclic aromatic hydrocarbons (PAHs) are among the most toxic oil components and have been documented to cause significant impacts on wildlife. The early life stages of bluefin tuna, yellowfin tuna, and amberjack, are very sensitive to PAH-induced cardiotoxicity and "exposures of 1–15 ppb total PAH cause specific dose-dependent defects in cardiac function in all three species with circulatory disruption, culminating in pericardial edema and other secondary malformations" (Incardona et al. 2014).

While acute and chronic oil spills represent the greatest concern for Pacific bluefin tuna, routine activities of oil and gas exploration and development can affect bluefin tuna through water quality impairment, industrial noise pollution, and marine debris. There is no question that offshore drilling operations result in significant water pollution during the course of normal operations. Drilling rigs routinely discharge produced water, drilling muds and drill cuttings into the marine environment (MMS 2007). Produced water and drilling muds both contain toxic pollutants such as mercury, lead, chromium, barium, arsenic, cadmium, and polycyclic aromatic hydrocarbons (MMS 2007). Further, about 40% of the chemicals added to fracking fluids have been found to have adverse ecological effects, indicating that they can harm aquatic and other wildlife (Colborn et al. 2011).

Oil and gas exploration and development activities that produce anthropogenic noise underwater can also degrade Pacific bluefin tuna habitat. These activities include seismic surveying, drilling, offshore structure emplacement, offshore structure removal, and production-related activities, including ship and helicopter activity for providing supplies to the drilling rigs and platforms (Ocean Studies Board 2003).

Seismic surveys used to detect oil and gas deposits underneath the ocean floor are particularly harmful. For offshore exploration, the oil and gas industry typically rely on arrays of airguns, which are towed behind ships and release intense impulses of compressed air into the water about once every 10-12 seconds. Although airguns are vertically oriented within the water column, horizontal propagation is so significant as to make them one of the leading contributors to low-frequency ambient noise thousands of miles from any given survey (Nieukirk et al. 2004). A large seismic airgun array can produce effective peak pressures of sound higher than those of virtually any other human-made source save explosives (Ocean Studies Board 2003). Noise from a single seismic survey can affect a region of ~300,000 km^2 and raise noise levels two orders of magnitude higher than normal continuously for days (Weilgart 2007). The highest energy levels produced by seismic airguns fall within the frequency range from 10 to 200 Hz (MMS 2004) and can extend up into the 1-10 kHz band (Ocean Studies Board 2003). Seismic airgun noise is well within the audible range for California highly migratory fish (MMS 2004).

It is well established that the high-intensity pulses produced by seismic surveys can cause a range of impacts on fish including bluefin tuna, such as abandonment of important habitat, masking of important natural sounds, disruption of vital behaviors essential to foraging and spawning, increased stress, temporary or permanent hearing loss, loss of biological diversity, and injuries and mortalities (MMS 2004, Weilgart 2007). Seismic airguns damaged fish ears at distances of 500 meters to several kilometers from seismic surveys, with no recovery apparent 58 days after exposure (Weilgart 2007). Even under moderate levels of noise exposure, some fish experience temporary hearing loss, with fish occasionally requiring weeks to recover their hearing (Weilgart 2007). Noise has been shown to produce a stress response and behavioral reactions in some fish that include loss of coherence, dropping to deeper depths, milling in compact schools, "freezing," or becoming more active (Weilgart 2007). For example, bluefin tuna schools in pens were less coherent in the presence of boat noise (Sara et al. 2007). In addition, fish have also been reported to flee from seismic shooting areas as inferred from decreased catch rates for both longlines and trawl fisheries (Slabbekoorn et al. 2010).

i. California

Pollution from oil and gas activities along the California coast poses a particularly high risk to bluefin tuna because of the pollution from ongoing operations. There are currently 23 platforms in U.S. federal waters off southern California, in Pacific bluefin tuna habitat, from which oil drilling and extraction activities occur. The water pollution discharge permit for these oil and gas platforms allows discharge of 9 billion gallons of produced waters each year. Produced waters can be toxic to marine life. In recent years some of the operations have been using hydraulic fracturing for well stimulation. This process uses chemicals which the platforms are allowed to discharge in unlimited amounts once comingled with produced waters.

Spills related to offshore oil and gas production have polluted the California coast as well. Oil companies installed the platforms between 1967 and 1989, and the first production began in 1969. The platforms range from approximately four to ten miles from shore.[28] Fifteen of these platforms are located in the Santa Barbara Channel, four are located off Long Beach, and four are located in the Santa Maria Basin. In 2013, these wells produced 50,846 barrels of oil per day and 75.2 million cubic feet of gas per day,[29] as well as associated produced water, drilling muds and drill cuttings. In 1969, an oil platform explosion spilled up to 100,000 barrels – or 3 million gallons – of crude oil, creating an oil slick 35 miles long along California's coast and killing thousands of birds, fish and sea mammals.[30]

---

[28] Bureau of Ocean Energy Management, map of Pacific Outer Continental Shelf, http://www.boem.gov/pacific-ocs-map/.
[29] Bureau of Safety and Environmental Enforcement, Website: Offshore Stats and Facts, http://www.bsee.gov/BSEE-Newsroom/Offshore-Stats-and-Facts/Pacific-Region/Pacific-Facts-and-Figures/.
[30] Christine Mai-Duc, *The 1969 Santa Barbara oil spill that changed oil and gas exploration forever*, L.A. Times, May 20, 2015, http://www.latimes.com/local/lanow/la-me-ln-santa-barbara-oil-spill-1969-20150520-htmlstory.html.

Based on historical precedent, pipeline breaks are likely to continue to pollute Pacific bluefin tuna habitat off southern California. An analysis of federal pipeline data showed the vast majority of the 8,000 serious pipeline breaks nationwide since 1986 have involved oil pipelines, spilling more than 2 million barrels – or 84 million gallons -- into waterways and on the ground over the past 30 years.[31] More than 35 percent of these incidents have been caused by corrosion or other spontaneous structural failures.[32] In May 2015, a Plains All American pipeline rupture in Santa Barbara County spilled more than 120,000 gallons of oil onto the California coast, killing hundreds of birds and marine animals.

ii. Russia, Sea of Okhotsk

The threat of oil and gas pollution is even greater around the spawning grounds of Pacific bluefin tuna than in the eastern Pacific Ocean because of the amount of active petroleum development in the Sea of Okhotsk off the northeastern coast of Sakhalin Island. The project *Salkhalin-1* has extraction capability up to 10 billion cubic meters per year, and *Salkhalin-2* is one of the world's largest integrated oil and gas projects, with annual production of liquefied gas at nearly 20 billion cubic meters (Chernenko 2007; Boveng et al. 2013). Initial work and seismic exploration for the projects *Salkahin-3,4,5* and *6* has also begun (Chernenko 2007; Boveng et al. 2013). In 1999, oil and gas development off Sakhalin Island resulted in an oil spill that released about 3.5 tons of oil (Lapko and Radchenko 2000; Boveng et al. 2013).

4. Wind Energy Development

Offshore energy projects threaten to degrade Pacific bluefin tuna habitat by increasing disturbance during construction and operation, which could lead to interference with migration, feeding, and even result in injury or death due to collisions or entanglements. The Pacific Fishery Management Council has written to the U.S. Department of Energy about potential impacts to fish habitat. Specifically the Council was concerned with:

- Fish responses to acoustic stressors including behavioral responses (e.g., attract or repel) and physiological responses (e.g., injury, feeding stress).
- Vertical and horizontal structural components in the water column and on the bottom interacting with fish and their prey (e.g., entanglement, collision, attraction).[33]

The Council noted that in the Pacific, ideal wind conditions for energy generation are located farther and deeper than needed on the East Coast, and therefore installations may have substantial subsurface structure in the water column and on the seafloor (floating devices, more

[31] AMERICA'S DANGEROUS PIPELINES, Analysis by Richard Stover, Ph.D., and the Center for Biological Diversity, at https://www.biologicaldiversity.org/campaigns/americas_dangerous_pipelines/.
[32] *Id.*
[33] Letter from D.O. McIsaac, Executive Director, Pacific Fishery Management Council, to Michael Hahn, U.S. Department of Energy, regarding RFI DE-FOA-0000911: Researching the Environmental Effects of Offshore Wind at the First U.S. Facilities, Oct. 10, 2013, http://www.pcouncil.org/wp-content/uploads/DOE_letter_10_131.pdf.

cabling, extensive mooring) and unforeseen impacts.[34] Because these projects are likely to be located in bluefin tuna pelagic habitat they will add to its cumulative degradation.

As an example of a wind energy project currently proposed off California that could impact bluefin tuna, in January 2016 Trident Winds LLC submitted an unsolicited application for an outer continental shelf renewable energy commercial lease to the U.S. Bureau of Ocean Energy Management.[35] Trident Winds has initiated development of a commercial scale offshore wind farm approximately 33 miles offshore, off the coast of Pt. Estero, consisting of approximately 100 floating offshore wind systems spaced approximately 1,000 meters apart and deployed in 800-1,000 meters of water. Topography in this area includes the Santa Lucia Bank, Santa Lucia Escarpment, the Arguello Canyon, and the Rodriguez Seamount, all of which contribute to creating unique upwelling flows hosting a high density of diverse sea life, including bluefin tuna. Because this project is in deep, productive waters, it has the potential to impact bluefin tuna.

5. Large-Scale Aquaculture Projects

Pacific bluefin tuna habitat is also at risk from pollution from aquaculture projects. For example, off Southern California there is a large-scape project, Rose Canyon Aquaculture Project, being developed. Rose Canyon Fisheries – a partnership between Hubbs-SeaWorld Research Institute and the private equity firm Cuna Del Mar – seeks to construct and operate an open ocean aquaculture facility approximately 4.5 miles off the coast of San Diego, California. At full capacity, the proposed project would be the largest commercial fish farm in the United States, producing 5,000 metric tons – or 11 million pounds – of yellowtail each year in ecologically rich and important areas. The operation will generate a significant amount of waste, including excess fish feed, dead fish and fish feces that will pollute the marine environment. One study found that a 200,000-fish salmon farm releases enough nitrogen to equal the untreated sewage of 19,800 people, phosphorus for 26,667 people, and fecal matter for 62,505 people (Goldburg et al. 2001). Given that the proposed project will produce 11 million pounds of fish per year, the amount of waste it would generate could be magnitudes higher. This amount of nutrients can cause oxygen depletion and harmful algal blooms in nearby waters. In addition, fish farms often use a large amount of antibiotics, pesticides and other drugs or chemicals to curb disease and parasites, which are especially prevalent in crowded conditions. Little is known about how these substances affect marine ecosystems and other organisms, but these additional pollutants will further degrade Pacific bluefin tuna habitat.

---

[34] *Id.*

[35] Trident Winds LLC, UNSOLICITED APPLICATION FOR AN OUTER CONTINENTAL SHELF RENEWABLE ENERGY COMMERCIAL LEASE, Jan. 14, 2016, http://www.boem.gov/MBO-Unsolicited-OCS-Lease-Request/

6. Prey Depletion

Pacific bluefin tuna must compete with large-scale commercial fisheries for forage fish and squid. In combination with a changing climate that is altering patterns of prey and marine productivity generally, competition with fishermen presents a cumulative challenge that may be too much for Pacific bluefin tuna.

Despite being omnivores, the declining populations of multiple Pacific bluefin tuna prey species have diminished the quality of their habitat in the California Current Large Marine Ecosystem (LME). For example, market squid is considered an "exceptional" forage species in part because of how many species it feeds (Monterey Bay Aquarium 2012). The fishery for market squid has rapidly expanded in the last 25 years, with the California fishery rarely landing more than 20,000 metric tons (mt) prior to 1987. Since then landings have increased fivefold, with a current quota of 107,000 mt (Vojkovich 1998; CDFW 2014). Despite recognizing the importance of market squid in the California Current LME, managers have not assessed impacts of the fishery to the ecosystem, including impacts on predators such as Pacific bluefin tuna (Monterey Bay Aquarium, 2012 citing Porzio, pers. comm., 2012; PFMC 2011). Another example of a drastic change is the depletion of bottomfish (Moore and Barlow 2013). Demersal fishing has contributed to a 60% decline in bottomfish abundance between 2003 and 2010 (Levin et al. 2006; Keller et al. 2012). Sardines, another important prey species for Pacific bluefin in the EPO, have declined 91% since 2007, to the point that the directed fishery has been closed since 2015 (Hill et al. 2015). Another vital prey species, northern anchovy, has also been significantly depleted in recent years. These depletions of prey species are so drastic as to change the food web in the California Current Large Marine Ecosystem (Morejohn et al. 1978; Jackson and Domeier 2003).

D. Other Natural or Manmade Factors That Threaten the Species' Continued Existence: Climate Change

The habitat of the Pacific bluefin tuna is changing profoundly because of human activity. Increasing greenhouse gas emissions contribute to ongoing climate change and its associated ocean impacts, such as warming, ocean acidification and decreases in dissolved oxygen. The cumulative impact of changes due to climate have the potential to decrease fish biomass, particularly in already-depleted stocks (Ainsworth et al. 2011). Current atmospheric concentrations of greenhouse gases are already resulting in significant climate change impacts that are projected to worsen as emissions rise (Melillo et al. 2014). Key changes include ocean warming, an increasing frequency of extreme weather events, an increase in surface ocean acidity, and changes in dissolved oxygen (IPCC 2013; Melillo et al. 2014). In the EPO in particular, for the past three years there have been record warm waters, unusual species distributional shifts and harmful algal blooms that have impacted fish, seabirds and marine mammals (Figure 10). The 100+ year time series of sea surface temperature in the EPO shows recent years have been the warmest on record.

Anthropogenic climate change poses a significant threat to biodiversity. Climate change is already causing changes in distribution, phenology, physiology, genetics, species interactions, ecosystem services, demographic rates, and population viability: many animals and plants are moving poleward and upward in elevation, shifting their timing of breeding and migration, and experiencing population declines and extirpations (Parmesan and Yohe 2003, Root et al. 2003, Parmesan 2006, Chen et al. 2011, Maclean and Wilson 2011, Warren et al. 2011, Cahill et al. 2012). Because climate change is occurring at an unprecedented pace with multiple synergistic impacts, climate change is predicted to result in catastrophic species losses during this century. The IPCC concluded that 20% to 30% of plant and animal species will face an increased risk of extinction if global average temperature rise exceeds 1.5°C to 2.5°C relative to 1980-1999, with an increased risk of extinction for up to 70% of species worldwide if global average temperature exceeds 3.5°C relative to 1980-1999 (IPCC 2007). Other studies have predicted similarly severe losses: 15%-37% of the world's plants and animals committed to extinction by 2050 under a mid-level emissions scenario (Thomas et al. 2004); the potential extinction of 10% to 14% of species by 2100 if climate change continues unabated (Maclean and Wilson 2011); and the loss of more than half of the present climatic range for 58% of plants and 35% of animals by the 2080s under the current emissions pathway, in a sample of 48,786 species (Warren et al. 2013).

Scientists have warned that the Earth is fast approaching a global "state-shift" that could result in unanticipated and rapid changes to Earth's biological systems (Barnosky et al. 2012). As summarized by the 2014 National Climate Assessment, "landscapes and seascapes are changing rapidly, and species, including many iconic species, may disappear from regions where they have been prevalent or become extinct, altering some regions so much that their mix of plant and animal life will become almost unrecognizable" (Melillo et al. 2014:196).

Climate change will disrupt Pacific bluefin tuna migrations and, most importantly, spawning patterns due to temperature changes (Kimura et al. 2010). The success of bluefin spawning and hatching, as well as larval survival, are closely linked to water temperature. Because of this, Pacific bluefin tuna prefer areas with low variability in inter-annual temperatures. Even small variations in egg and larval survival and growth rates could cause significant impacts to populations (Kimura et al. 2010). This is a serious concern for the future viability of Pacific bluefin tuna. Simulations under a climate warming scenario predicts a 3^{o}C increase in temperature by 2100 and, when considering a spawning season between April and June, results in a predicted 36% decline in larval survival due to exposure to lethally warm temperatures (*Id.*). For Atlantic bluefin tuna, in light of increasing sea temperatures, Muhling et al. (2011) predicted drastic reductions in the areas of the Gulf of Mexico with a high probability of bluefin tuna larval occurrence in the late spring: a 39–61% reduction in area by 2050 and a

93–96% reduction by the end of the 21st century. This indicates that the changes to Pacific bluefin tuna habitat will also likely be drastic.

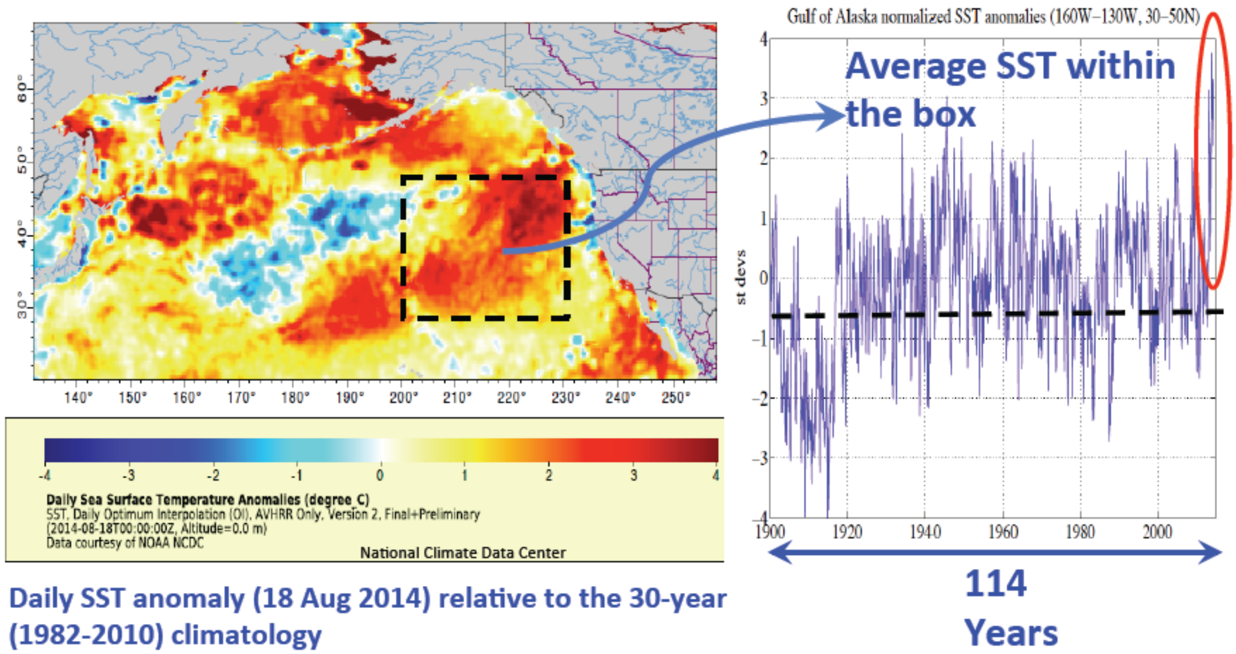

Figure 10. Eastern Pacific Ocean temperature anomalies (left) and normalized anomalies (right). (Source: Werner and Stein 2015)

Climate-associated ecosystem changes have reduced productivity in the last half-century in the California Current Large Marine Ecosystem (Black et al. 2014). Scientists have recently identified an increased frequency of negative (downwelling-favorable) anomalies associated with reduced productivity after 1950 as compared to before 1950 (*Id.*). The negative anomalies occurred three to five times more frequently in the past 60 years, with observed effects across taxa (*Id.*). Positive anomalies, associated with abundant cold-water, lipid-rich copepod species and high marine productivity, correlated with vigorous fish growth, early seabird egg laying, and high seabird breeding success (*Id.*). The conclusion that marine productivity is linked strongly to environmental factors and the increased frequency of negative anomalies has reduced marine productivity means that Pacific bluefin tuna likely has reduced prey availability. One effect on Pacific bluefin tuna diet is evident from recent years' stomach analyses of bluefin tuna caught in California showing an increasing proportion of pelagic red crab as a result of warmer water temperatures due to El Niño and the "Blob" (Figures 2, 3).

Because environmental variability affects Pacific bluefin tuna's feeding and migration, it also affects vulnerability to fishing effort. Pinsky et al. (2013) have predicted that the large and rapid changes in species' range due to climate change will fundamentally reorganize marine communities, spark cross-border fisheries conflicts, and confound fisheries management, all of which are a problem for Pacific bluefin tuna. For an example of Pacific bluefin tuna's recently increased interactions with U.S. fisheries, in the 2015-16 fishing season the California drift gillnet fleet caught 375 bluefin tuna per 100 sets, the highest number in observed history (since 1990) and more than twice as many on a per set basis as any year prior.[36] The observed increase in fishery interactions in spite of the bluefin's declining abundance and the fleet's declining effort is most likely driven by environmental factors causing bluefin distribution to shift further north into U.S. waters. This variability is especially concerning while Pacific bluefin tuna's population and recruitment are at historical lows.

1. Ocean Acidification

As the global oceans take up excess carbon dioxide (CO_2), seawater chemistry profoundly changes, and the oceans become more acidic (Orr et al. 2005, Fabry et al. 2008, Doney et al. 2009, Gattuso and Hansson 2011, Feely et al. 2013). The average pH of the global surface ocean has already decreased by 0.1 units (from 8.2 to 8.1 pH units), which represents a 30% increase in acidity and a 10% decrease in carbonate ion concentration compared to pre-industrial levels (Feely et al. 2004, Caldeira and Wickett 2005, Orr et al. 2005, Cao and Caldeira 2008, Doney et al. 2009, Byrne et al. 2010).

Once anthropogenic CO_2 enters the oceans, it is impossible to remove. The global oceans may require thousands of years to naturally return to a higher pH state (Solomon et al. 2009). Long-term monitoring and modeling studies of waters across the Pacific West Coast of the United States show a clear pH decline over the past decades (Beman et al. 2011, Friedrich et al. 2012). In fact, anthropogenic ocean acidification already exceeds the natural variability on regional scales and is detectable in several Pacific regions (Friedrich et al. 2012, McLaughlin et al. 2015, Takeshita et al. 2015). Current CO_2 emission trajectories are tracking some of the most extreme emission scenarios (IPCC 2013), rates of atmospheric CO_2 are forecast to reduce surface ocean pH by 0.3 to 0.5 units on average by 2100, and regional changes may be even more severe (Caldeira and Wickett 2005, Orr et al. 2005, McNeil and Matear 2006, Steinacher et al. 2009, Doney et al. 2009).

Ocean acidification will unavoidably alter marine ecosystems, but questions remain as to exactly how biota will change. Although research on ocean acidification's direct effects on tuna is in its infancy, preliminary experiments hatching yellowfin tuna eggs in ocean water of varying pH, including current and predicted near future ocean pH (6.9, 7.3, 7.7, and 8.1), showed that decreasing pH (i.e., acidification) significantly increased hours until complete hatching (Bromhead et al. 2013, Frommel et al. 2016). Extrapolating from reef fish experiments, ocean acidification could possibly cause loss of senses of sight, smell and touch in other fish species (Branch et al. 2013, Ferrari et al. 2012a, Simpson et al. 2011, Nowicki et al. 2012, Domenici et al. 2012, Ferrari et al. 2012b).

---

[36] NMFS, West Coast Region Observer Program, Data Summaries & Reports, http://www.westcoast.fisheries.noaa.gov/fisheries/wc_observer_programs/sw_observer_program_info/data_summ_report_sw_observer_fish.html.

Changes in the ocean's CO_2 concentration result in accumulation of CO_2 in the tissues and fluids of fish and other marine animals, called hypercapnia, and increased acidity in the body fluids, called acidosis. These impacts can cause a variety of problems for marine animals, including difficulties with acid-base regulation, calcification, growth, respiration, energy turnover, predation response, and mode of metabolism (Pörtner et al. 2004; Pörtner et al. 2005). Studies have shown adverse impacts in squid and fish, among other animals (Rosa and Seibel 2008; Ishimatsu et al. 2004; Pörtner et al. 2004). For example, when exposed to acidification, orange clownfish suffer a type of brain malfunction that interferes with their homing abilities and makes them 5-9 times more likely to swim toward a predator (Munday et al. 2009; Simpson et al. 2011; Ferrari et al. 2011).

An animal's ability to transport oxygen is reduced by pH changes (Pörtner et al. 2005). Water breathing animals have a limited capacity to compensate for changes in the acidity (Haugan et al. 2006). For example, fish that take up oxygen and respire CO_2 through their gills are vulnerable because decreased pH can affect the respiratory gas exchange (Raven et al. 2005). Changes in metabolic rate are caused by the changes in pH, carbonates, and CO_2 in marine animals (Haugan et al. 2006).

In fish, pH also affects circulation. Fish exposed to high concentrations of CO_2 in seawater experience cardiac failure and increased mortality (Ishimatsu et al. 2004). At lower concentrations, sublethal effects can be expected that can seriously compromise the fitness of fish. Juvenile and larval stages of fish were found to be even more vulnerable (Ishimatsu et al. 2004).

2. Dissolved Oxygen

Dissolved oxygen (DO), in particular, is known as a constraint to vertical habitat range for pelagic fishes (Prince et al. 2010). Climate model predictions in conjunction with observations show that declines in oceanic DO are likely influenced by global warming (Stramma et al. 2012). Indeed, climate models predict a 20 to 40% decline in global deepwater oxygen concentrations over the coming century (Matear and Hirst 2003). Already reduced oxygen levels have been observed in Pacific bluefin tuna habitat – in waters off Japan, and the California Current (Bograd et al. 2008, Emerson et al. 2004, McClatchie et al 2010). Some fish in the Southern California bight have declined >60% in abundance since the 1980s due to increasing deep-water hypoxia (Koslow et al. 2011).

Recent science regarding the increasing deoxygenation of the upper oceans under climate change scenarios has heightened awareness of the importance of DO for pelagic fishes (Stramma et al. 2012). There are several mechanisms by which changing temperature and DO off the U.S. West Coast will impact Pacific bluefin tuna. First, predators of mesopelagic animals, like Pacific bluefin tuna, may be more successful at hunting during periods of low oxygen, when a shoaling of the hypoxic boundary layer renders prey more vulnerable to visually orienting predators

(Koslow et al. 2011). The net result on Pacific bluefin tuna, however, may be negative if the low oxygen drives a decline of fish populations due to the constraints of the boundary layer and resulting increase in natural mortality (*Id*.). Second, scientists have hypothesized that a combination of thermal constraints and oxygen limitations drive Pacific bluefin tuna's northward migration along Baja California and into the United States (Whitlock et al. 2015). Large meals as a result of feeding off the West Coast increases metabolic – and oxygen – demand (*Id*.). Thus changes in temperature and DO directly impact Pacific bluefin tuna's migration.

IV. Conclusion

In sum, the Pacific bluefin tuna is in danger of extinction throughout all or part of its range due to overutilization, an inadequacy of existing regulatory mechanisms, habitat threats and climate change. Therefore, Petitioners ask the Secretary to take immediate action to halt the precipitous decline in the Pacific bluefin tuna by listing the species as endangered or in the alternative list the species as threatened, under the federal Endangered Species Act (ESA), 16 U.S.C. §§ 1531 – 1544. Petitioners further request that the Secretary designate critical habitat in areas essential to the conservation of Pacific bluefin tuna.

V. References

Ainsworth, C. H., Samhouri, J. F., Busch, D. S., Cheung, W. W. L., Dunne, J., and Okey, T. A. 2011. Potential impacts of climate change on Northeast Pacific marine foodwebs and fisheries. – ICES Journal of Marine Science, 68: 1217–1229.

Anonymous. 2008. Marine science assessment of capture-based tuna (*Thunnus orientalis*) aquaculture in the Ensenada region of northern Baja California, Mexico. Final Report of the Binational Scientific Team to the Packard Foundation. 95 pp.

Ashida H, N Suzuki, T Tanabe, N Suzuki, Y Aonuma. 2015. Reproductive condition, batch fecundity, and spawning fraction of large Pacific bluefin tuna *Thunnus orientalis* landed at Ishigaki Island, Okinawa, Japan. Environmental Biology of Fishes 98:1173-1183.

Ashton, K., Holmes, L. & Turner, A. 2010. Association of metals with plastic production pellets in the marine environment, Marine Pollution Bulletin, 60(11), 2050, 2050, http://www.ncbi.nlm.nih.gov/pubmed/20696443.

Avery-Gomm, S., O'Hara, P. D., Kleine, L., Bowes, V., Wilson, L. K., & Barry, K. L. 2012. Northern fulmars as biological monitors of trends of plastic pollution in the eastern North Pacific. Marine Pollution Bulletin, 64(9), 1776-1781.

Barber, I. 2007. Parasites, behaviour and welfare in fish. Applied Animal Behaviour Science 104(3–4), 251–264.

Barnosky, AD, EA Hadly, J Bascompte, EL Berlow, JH Brown, M Fortelius, WM Getz, J Harte, A Hastings, PA Marquet, ND Martinez, A Mooers, P Roopnarine, G Vermeij, JW Williams, R Gillespie, J Kitzes, C Marshall, N Matzke, DP Mindell, E Revilla, and AB Smith. 2012. Approaching a state shift in Earth's biosphere. Nature 486:52.

Bayliff, W.H. 1993. Growth and age composition of northern bluefin tuna, *Thunnus thynnus*, caught in the eastern Pacific Ocean, as estimated from length-frequency data, with comments on trans-Pacific migrations. Bull. IATTC, 20:501-540.

Bayliff, W. H. 1994. A review of the biology and fisheries for northern bluefin tuna, *Thunnus thynnus*, in the Pacific Ocean. In 'Interactions of Pacific Tuna Fisheries'. (Eds R. S. Shomura, J. Majkowski, and S. Langi.) pp. 244–295, FAO Fisheries Technical Paper 336/2, http://www.fao.org/docrep/005/t1817e/T1817E13.htm#ch10.

Beman, J. M., C.-E. Chow, A. L. King, Y. Feng, J. A. Fuhrman, A. Andersson, N. R. Bates, B. N. Popp, and D. A. Hutchins. 2011. Global declines in oceanic nitrification rates as a consequence of ocean acidification. Proceedings of the National Academy of Sciences 108:208–213.

Benessia, A., & Barbiero, G. 2015. The impact of genetically modified salmon: from risk assessment to quality evaluation. Visions for Sustainability 3:35-61.

Bernanke, J., and H.-R. Kohler. 2009. The impact of environmental chemicals on wildlife vertebrates. Reviews of Environmental Contamination and Toxicology 198:1-47.

Bettridge, S., C.S. Baker, J. Barlow, P.J. Clapham, M. Ford, D. Gouveia, D.K. Mattila, R.M. Pace, P.E. Rosel, G.K. Silber, P. Wade. 2015. Status review of the Humpback Whale (*Megaptera novaeangliae*) under the Endangered Species Act, NOAA-TM-NMFS-SWFSC-540.

Black, B. A., Sydeman, W. J., Frank, D. C., Griffin, D., Stahle, D. W., García-Reyes, M., Rykaczewski RR, Bograd SJ & Peterson, W. T. 2014. Six centuries of variability and extremes in a coupled marine-terrestrial ecosystem. Science 345(6203):1498-1502.

Block BA, SLH Teo, A Walli, A Boustany, MJW Stokesbury, CJ Farwell, KC Weng, H Dewar and TD Williams. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature 434: 1121-1127.

Block BA, ID Jonsen, SJ Jorgensen, AJ Winship, SA Shaffer, SJ Bograd, EL Hazen, DG Foley, GA Brees, A-L Harrison, JE Ganong, A Swithenbank, M Castleton, H Dewar, BR Mate, GL Shillinger, KM Schaefer, SR Benson, MJ Weise, RW Henry, DP Costa. 2011. Tracking apex marine predator movements in a dynamic ocean. Nature 475:86–90.

Boerger, C. M., Lattin, G. L., Moore, S. L., & Moore, C. J. 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin, 60(12), 2275-2278.

Bograd, S. J., Castro, C. G., Di Lorenzo, E., Palacios, D. M., Bailey, H., Gilly, W., & Chavez, F. P. 2008. Oxygen declines and the shoaling of the hypoxic boundary in the California Current. Geophysical Research Letters, 35(12):L12607.

Bonhommeau, S. 2013. CIE Independent Peer Review on the Stock Assessment of Pacific Bluefin Tuna. http://swfsc.noaa.gov/uploadedFiles/Divisions/DO/2013_06_28%20Bonhommeau%20PBFT%20review%20report.pdf.

Boustany, A.M., R. Matteson, M.Castleton, C. Farwell, and B.A. Block. 2010. Movements of Pacific bluefin tuna (*Thunnus orientalis*) in the eastern North Pacific revealed with archival tags. Progress in Oceanography 86: 94–104.

Boveng, P. L., J. L. Bengtson, M. F. Cameron, S. P. Dahle, E. A. Logerwell, J. M. London, J. E. Overland, J. T. Sterling, D. E. Stevenson, B. L. Taylor, and H. L. Ziel. 2013. Status review of the ribbon seal. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC-255, 174 p.

Branch, T. A., DeJoseph, B. M., Ray, L. J., & Wagner, C. A. 2013. Impacts of ocean acidification on marine seafood. Trends in ecology & evolution 28(3):178-186.

Bridges C. 2016. Progress in the domestication of Thunnus thynnus (DOTT) – Perspectives for Atlantic bluefin tuna aquaculture in the Mediterranean. Presentation at Bluefin Futures Symposium, Monterey, California, 20 January 2016.

Bromhead, D., V. Scholey, D. Margulies, S. Nicol, J. Wexler, M. Santiago, S. Hoyle, C. Lennert-Cody, J. Havenhand, J. Williamson, T. Ilyina, and P. Lehodey. 2013. Assessing the impacts of ocean acidification upon tropical tuna. Secretariat of the Pacific Community Fisheries Newsletter #142, September–December 2013.

Byrne, R. H., Mecking, S., Feely, R. A., & Liu, X. 2010. Direct observations of basin-wide acidification of the North Pacific Ocean. *Geophysical Research Letters*, 37(2).

Cabello, F.C. 2006. Heavy use of prophylactic antibiotics in aquaculture: a growing problem for human and animal health and for the environment. Environmental Microbiology 8(7): 1138.

Cahill, A. E., Aiello-Lammens, M. E., Fisher-Reid, M. C., Hua, X., Karanewsky, C. J., Ryu, H. Y., Sbeglia GC, Spagnolo F, Waldron JB, Warsi O & Wiens, J. J. 2012. How does climate change cause extinction? Proceedings of the Royal Society of London B: Biological Sciences, rspb20121890.

Caldeira, K., and M. E. Wickett. 2005. Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. Journal of Geophysical Research: Oceans 110:C09S04.

California Department of Fish and Wildlife (CDFW). 2014. 2014 California Legislative Fisheries Forum: Department of Wildlife Annual Marine Fisheries Report. 31 pp., https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=81206&inline=1.

California Regional Water Quality Control Board, Los Angeles Region, Trash Total Maximum Daily Loads for the Los Angeles River Watershed, 1, 18 (2007).

Cao, L., and K. Caldeira. 2008. Atmospheric CO 2 stabilization and ocean acidification. Geophysical Research Letters 35.

Carey, F. G. and Teal, J. M. 1969. Regulation of body temperature by the bluefin tuna. Comparative Biochemistry and Physiology 28:205-213.

Carls, M. G., S. D. Rice, and J. E. Hose. 1999. Sensitivity of fish embryos to weathered crude oil: part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval pacific herring (*Clupea pallasi*). Environmental Toxicology and Chemistry 18:481-493.

Carruthers, T. 2013. CIE Independent Peer Review on the Stock Assessment of Pacific Bluefin Tuna. http://swfsc.noaa.gov/uploadedFiles/Divisions/DO/2013_06_28%20Carruthers%20PBFT%20review%20report.pdf

Carson, H. S. 2013. The incidence of plastic ingestion by fishes: From the prey's perspective. *Marine pollution bulletin*, 74(1), 170-174.

Chen, K.S., P. Crone, and C.C. Hsu. 2006. Reproductive biology of female Pacific bluefin tuna *Thunnus orientalis* from south-western North Pacific Ocean. Fisheries Science 72: 985–994.

Chen, I. C., Hill, J. K., Ohlemüller, R., Roy, D. B., & Thomas, C. D. 2011. Rapid range shifts of species associated with high levels of climate warming. Science, 333(6045), 1024-1026.

Chernenko, T. 2007. Appendix 1. The status of the yellow-billed loon in Russia: a summary of Russian language information. Comments submitted by Center for Biological Diversity, Pacific Environment, and Natural Resources Defense Council on August 6, 2007, to the U.S. Fish and Wildlife Service on the 90-day Finding and Status Review of the Yellow-billed Loon. 16 p.

Choy, C. A., & Drazen, J. C. 2013. Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific. Marine Ecology Progress Series, 485, 155-163.

Colborn, T., Kwiatkowski, C., Schultz, K., & Bachran, M. 2011. Natural gas operations from a public health perspective. Human and ecological risk assessment: An International Journal, 17(5), 1039-1056.

Collette, BB. 1999. Mackerels, molecules, and morphology. In Séret, B.; Sire, J.Y. Proceedings. 5th Indo-Pacific Fish Conference: Nouméa, New Caledonia, 3–8 November 1997. Paris: Société Française.

Collette, B., Fox, W., Juan Jorda, M., Nelson, R., Pollard, D., Suzuki, N. & Teo, S. 2014. *Thunnus orientalis*. The IUCN Red List of Threatened Species 2014: e.T170341A65166749. http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T170341A65166749.en. Downloaded on 05 May 2016.

Crockford, S. 1997. Archeological evidence of large northern bluefin tuna, *Thunnus thynnus*, in coastal waters of British Columbia and northern Washington. Fishery Bulletin 95:11-24.

Cross JN, Hose JE. 1988. Evidence for impaired reproduction in white croaker (*Genyonemus lineatus*) from contaminated areas off southern California. Mar Environ Res 24:185–188.

Diaz GA. 2011. A revision of western Atlantic bluefin tuna age of maturity derived from size samples collected by the Japanese longline fleet in the Gulf of Mexico (1975-1980). ICCAT Collective Volume of Scientific Papers 66:1216-1226.

DiNardo, G. 2015. Pacific Bluefin Tuna Research Activities, Domestic & International, Report to Pacific Fishery Management Council, November 2015, http://www.pcouncil.org/wp-content/uploads/2015/11/G1a_Sup_NMFS_PPT_E-Only_Gerard_Nov2015BB.pdf.

Domenici, P, B Allan, MI McCormick, PL Munday. 2012. Elevated carbon dioxide affects behavioural lateralization in a coral reef fish. Biology Letters 8:78–81.

Doney, S. C., V. J. Fabry, R. A. Feely, and J. A. Kleypas. 2009. Ocean Acidification: The Other CO 2 Problem. Annual Review of Marine Science 1:169–192.

Emerson S, Watanabe YW, Ono T, Mecking S. 2004. Temporal trends in apparent oxygen utilization in the upper pycnocline of the North Pacific: 1980–2000. Journal of Oceanography 60: 139–147.

1. **Fabry, V. J., B. A. Seibel, R. A. Feely, and J. C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science: Journal du Conseil 65:414–432.**

2. **Feely, R. A., C. L. Sabine, K. Lee, W. Berelson, J. Kleypas, V. J. Fabry, and F. J. Millero. 2004. Impact of anthropogenic CO2 on the CaCO3 system in the oceans. Science 305:362–366.**

3. **Feely, R., R. Wanninkhof, C. Sabine, J. Mathis, T. Takahashi, S. Khatiwala, and G. Park. 2013. Global ocean carbon cycle, in “State of the Climate in 2012, Global Oceans.” Bull. Am. Meteorol. Soc 94:S72–S75.**

4. Ferrari, MCO, MI McCormick, PL Munday, MG Meekan, DL Dixson, O Lönnstedt, DP Chivers. 2012a. Effects of ocean acidification on visual risk assessment in coral reef fishes. Functional Ecology 26:553–558.

Ferrari, MCO, RP Manassa, DL Dixson, P. Munday, MI McCormick, MG Meekan, A Sih, DP Chivers. 2012b. Effects of ocean acidification on learning in coral reef fishes. PLoS ONE 7, e31478.

Filimonova, V., Gonçalves, F., Marques, J. C., De Troch, M., & Gonçalves, A. M. 2016. Fatty acid profiling as bioindicator of chemical stress in marine organisms: A review. Ecological Indicators 67:657-672.

Foreman, T.J. and Y. Ishizuka. 1990. Giant bluefin off Southern California, with a new California size record. California Fish and Game 76: 181–186.

Fossi, M.C., S. Casini, L. Marsili, G. Neri, G. Mori, S. Ancora, A. Moscatelli, A. Ausili, G. Notarbartolo-di-Sciara. 2002. Biomarkers for endocrine disruptors in three species of Mediterranean large pelagic fish. Marine Environmental Research 54:667-671.

Friedrich, T., A. Timmermann, A. Abe-Ouchi, N. R. Bates, M. O. Chikamoto, M. J. Church, J. E. Dore, D. K. Gledhill, M. González-Dávila, M. Heinemann, T. Ilyina, J. H. Jungclaus, E. McLeod, A. Mouchet, and J. M. Santana-Casiano. 2012. Detecting regional anthropogenic trends in ocean acidification against natural variability. Nature Climate Change 2:1–5.

Frommel, A.Y., D. Margulies, J. B. Wexler, M.S. Stein, V.P. Scholey, J.E. Williamson, D. Bromhead, S. Nicol, and J. Havenhand. 2016. Ocean acidification has lethal and sub-lethal effects on larval development of yellowfin tuna, *Thunnus albacores*. Journal of Experimental Marine Biology and Ecology 482:18-24.

Galland, G, A Rogers, A Nickson. 2016. Netting billions: a global valuation of tuna. The Pew Charitable Trusts. http://www.pewtrusts.org/~/media/assets/2016/05/netting_billions.pdf.

Gardner, J. & D.L. Peterson. 2003. "Making Sense of the Salmon Aquaculture Debate: Analysis of issues related to netcage salmon farming and wild salmon in British Columbia." Pacific Fisheries Resource Conservation Council, January: 4.

Gattuso, J.-P., and L. Hansson. 2011. Ocean Acidification. Oxford University Press, Oxford, UK.

Glover, J.B., J.W. Dillman, J.P. Eidson. 2010. Mercury in South Carolina Fishes, USA. Ecotoxicology 19:781–795.

Goldburg, R., Elliott, M. S., & Naylor, R. 2001. Marine aquaculture in the United States: environmental impacts and policy options (p. 33). Arlington, Virginia: Pew Oceans Commission. (citing Hardy, R. (2000). Fish, Feed and Nutrition in the New Millenium. Aquaculture Magazine-Arkansas, 26(1), 85-89.).

Gordon, M. 2006. Eliminating land-based discharges of marine debris in California: A plan of action from the Plastic Debris Project. California State Water Resources Control Board, Sacramento, CA.

Graham JB and KA Dickson. 2004. Tuna comparative physiology. The Journal of Experimental Biology 207:4015-4024.

Haugan, P. M., Turley, C., & Pörtner, H. O. 2006. Effects on the marine environment of ocean acidification resulting from elevated levels of CO2 in the atmosphere. OSPAR intersessional correspondence group. DN-utredning 2006-1. www. dirnat. no.

Hayward, C. J., Svane, I., Lachimpadi, S. K., Itoh, N., Bott, N. J., & Nowak, B. F. 2011. Sea lice infections of wild fishes near ranched southern bluefin tuna (*Thunnus maccoyii*) in South Australia. Aquaculture, 320(3), 178-182.

Hill, K.T., P.R. Crone, D.A. Demer, J. Zwolinski, E. Dorval, and B.J. Macewicz. 2015. Assessment of the Pacific Sardine Resource in 2015 for U.S.A. Management in 2015-16, http://www.pcouncil.org/wp-content/uploads/2015/03/G1a_ExecSumSardine_Assessment_Print_APR2015BB.pdf.

Holdway, D. A. 2002. The acute and chronic effects of wastes associated with offshore oil and gas production on temperate and tropical marine ecological processes. Marine Pollution Bulletin, 44(3), 185-203.

Hose J, Cross J, Smith S, Diehl D. 1989. Reproductive impairment in a fish inhabiting a contaminated coastal environment off southern California. Environ Pollut 57:139–148

Hoss, D.E. and L.R. Settle, 1990. In R. S. Shomura and H. L. Codfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989. Honolulu, Hawaii. Memo. NMFS, NOAA-TH-NMFS-SUFSC-15L. https://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-154_P693.PDF.

Hutchings, J.A. and J.D. Reynolds. 2004. Marine fish population collapses: Consequences for recovery and extinction risk. BioScience 54: 297–309.

IATTC. 2014a. IATTC Resolution C-14-06, Measures for the Conservation and Management of Pacific Bluefin Tuna in the Eastern Pacific Ocean, 2015-2016, http://www.iattc.org/PDFFiles2/Resolutions/C-14-06-Conservation-of-bluefin-2015-2016.pdf.

IATTC. 2014b. Recommendations by the staff for conservation measures in the eastern Pacific Ocean, 2014. Inter-American Tropical Tuna Commission, Document IATTC-87-03d, 87th Meeting of the IATTC, July 14-18, 2014. http://www.iattc.org/Meetings/Meetings2014/July/PDFs/IATTC-87-03d-Conservation-recommendations.pdf.

ICCAT. 1982. Recommendation 82-1: New regulations for the Atlantic bluefin tuna catch [1983]. http://iccat.int/Documents/Recs/compendiopdf-e/1982-01-e.pdf.

ICCAT. 2015. Report of the 2014 Atlantic Bluefin Tuna Stock Assessment Session (Madrid, Spain - September 22 to 27, 2014). ICCAT Collective Volume of Scientific Papers 71:692-945.

Incardona, JP, LD Gardner, TL Linbo, TL Brown, AJ Esbaugh, EM Mager, JD Stieglitz, BL French, JS Labenia, CA Laetz, M Tagal, CA Sloan, A Elizur, DD Benetti, M Grosell, BA Block, NL Scholz. 2014. Deepwater Horizon crude oil impacts the developing hearts of large predatory pelagic fish. Proceedings of the National Academy of Sciences 111:E1510-E1518.

International Game Fish Association. 2016. IGFA Online World Record Search. Web accessed 17 May 2016. http://wrec.igfa.org/WRecordsList.aspx?lc=AllTackle&cn=Tuna,%20Pacific%20bluefin.

IPCC. 2007. Intergovernmental panel on climate change. Climate change 2007: Synthesis report.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

ISC PBFWG. 2014. Stock assessment of bluefin tuna in the Pacific Ocean in 2014. http://isc.fra.go.jp/pdf/2014_Intercessional/Annex4_Pacific%20Bluefin%20Assmt%20Report%202014-%20June1-Final-Posting.pdf.

ISC PBFWG. 2016. 2016 Pacific bluefin tuna stock assessment, Draft Executive Summary. http://www.iattc.org/Meetings/Meetings2016/SAC7/PDFfiles/INF/SAC-07-INF-C(a)-ISC-Letter-IATTC-Executive-Summary.pdf.

Ishimatsu, A., Kikkawa, T., Hayashi, M., Lee, K. S., & Kita, J. 2004. Effects of CO2 on marine fish: larvae and adults. Journal of Oceanography, 60(4), 731–741. doi:10.1007/s10872-004-5765-y.

Itoh T, S Tsuji, A Nitta. 2003. Migration patterns of young Pacific bluefin tuna (*Thunnus orientalis*) determined with archival tags. Fishery Bulletin 101:514-534.

IUCN. 2001. Red List Categories and Criteria Version 3.1, Source: http://www.iucnredlist.org/static/categories_criteria_3_1

Jackson, G. D., & Domeier, M. L. 2003. The effects of an extraordinary El Niño/La Niña event on the size and growth of the squid *Loligo opalescens* off Southern California. *Marine Biology*, 142(5), 925-935, http://www.marinecsi.org/wp-content/uploads/2010/05/jackson_domeier_squid_031.pdf.

Japanese Fisheries Research Agency. December 2014. Flash report on Pacific bluefin tuna 2014 recruitment monitoring.

Japanese Fisheries Research Agency. December 2015. Flash report on Pacific bluefin tuna 2015 recruitment monitoring.

Jarvis, E., Schiff, K., Sabin, L., & Allen, M. J. 2007. Chlorinated hydrocarbons in pelagic forage fishes and squid of the Southern California Bight. Environmental Toxicology and Chemistry, 26(11), 2290-2298.

Jones, G. J., Nichols, P. D., Johns, R. B., & Smith, J. D. 1987. The effect of mercury and cadmium on the fatty acid and sterol composition of the marine diatom Asterionella glacialis. Phytochemistry 26(5):1343-1348.

Keller, A.A., Wallace, J.R., Horness, B.H., Hamel, O.S., Stewart, I.J. 2012. Variations in eastern North Pacific demersal fish biomass based on the U.S. west coast groundfish bottom trawl survey (2003–2010). Fishery Bulletin 110:205–222.

Kimura, S., Kato, Y., Kitagawa, T., & Yamaoka, N. 2010. Impacts of environmental variability and global warming scenario on Pacific bluefin tuna (*Thunnus orientalis*) spawning grounds and recruitment habitat. Progress in Oceanography 86(1): 39-44.

Kitagawa T, S Kimura, H Nakata, H Yamada. 2004. Diving behavior of immature, feeding Pacific bluefin tuna (*Thunnus thynnus orientalis*) in relation to season and area: the East China Sea and the Kuroshio–Oyashio transition Region. Fisheries Oceanography 13:161-180.

Kitagawa, T., A.M. Boustany, C. Farwell, T.D. Williams, M. Castleton, and B.A. Block. 2007. Horizontal and vertical movements of juvenile Pacific bluefin tuna (*Thunnus orientalis*) in relation to seasons and oceanographic conditions. Fisheries Oceanography 16: 409–421.

Kitagawa T, S Kimura, H Nakata, H Yamada, A Nitta, Y Sasai, H Sasaki. 2009. Immature Pacific bluefin tuna, Thunnus orientalis, utilizes cold waters in the Subarctic Frontal Zone for trans-Pacific migration. Environmental Biology of Fishes 84:193-196.

Koslow, J., Goericke, R., Lara-Lopez, A., & Watson, W. 2011. Impact of declining intermediate-water oxygen on deepwater fishes in the California Current. Marine Ecology Progress Series 436:207-218.

Laist, D. W. 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In Marine Debris (pp. 99-139). Springer New York.

Lapko, V. V., and V. I. Radchenko. 2000. Sea of Okhotsk. Marine Pollution Bulletin 41:179-187.

Levin, P.S., Holmes, E.E., Piner, K.R., Harvey, C.J. 2006. Shifts in a Pacific Ocean fish assemblage: the potential influence of exploitation. Conservation Biology 20:1181–1190.

Lowenstein, J. H., Burger, J., Jeitner, C. W., Amato, G., Kolokotronis, S. O., & Gochfeld, M. 2010. DNA barcodes reveal species-specific mercury levels in tuna sushi that pose a health risk to consumers. Biology Letters 6(5):692-695.

MacCall, A.D., W.J. Sydeman, P.C. Davison, J.A. Thayer. 2016. Recent collapse of northern anchovy biomass off California. Fisheries Research 175, 97-94.

Maclean, I. M. D., and R. J. Wilson. 2011. Recent ecological responses to climate change support predictions of high extinction risk. Proceedings of the National Academy of Sciences of the United States of America 108: 12337-12342.

Madigan, D. J., Baumann, Z., Snodgrass, O. E., Ergül, H. A., Dewar, H., & Fisher, N. S. 2013. Radiocesium in Pacific Bluefin Tuna *Thunnus orientalis* in 2012 validates new tracer technique. Environmental Science & Technology 47(5):2287-2294.

Madigan, D.J., Z. Baumann, A.B. Carlisle, D.K. Hoen, B.N. Popp, H. Dewar, O.E. Snodgrass, B.A. Block, and N.S. Fisher. 2014. Reconstructing trans-oceanic migration patterns of Pacific bluefin tuna using a chemical tracer toolbox. Ecology 95: 1674–1683.

Mangel, M, J Brodziak, G DiNardo. 2010. Reproductive ecology and scientific inference of steepness: a fundamental metric of population dynamics and strategic fisheries management. Fish and Fisheries 11:89-104.

Marcinek, D.J., Blackwell, S.B., Dewar, H., Freund, E.V., Farwell, C., Dau, D., Seitz, A.C., Block, B.A. 2001. Depth and muscle temperature of Pacific bluefin tuna examined with acoustic and pop-up satellite tags. Marine Biology 138:869–885.

Matear, R. J., & Hirst, A. C. 2003. Long-term changes in dissolved oxygen concentrations in the ocean caused by protracted global warming. Global Biogeochemical Cycles 17(4).

Mato Y, T Isobe, H Takada, H Kanehiro, C Ohtake, T Kaminuma. 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment, Environmental Sci. Technology, 35(2), 318-324.

Maunder, MN. 2016. Updated assessment and management of Pacific Bluefin Tuna. Inter-American Tropical Tuna Commission, Document SAC-07-0-5d, Seventh Meeting of the Scientific Advisory Committee Meeting, May 9-13, 2016 http://www.iattc.org/Meetings/Meetings2016/SAC7/PDFfiles/SAC-07-05d-PBF-Status-of-Pacific-bluefin.pdf.

McClatchie, S., Goericke, R., Cosgrove, R., Auad, G., & Vetter, R. 2010. Oxygen in the Southern California Bight: multidecadal trends and implications for demersal fisheries. Geophysical Research Letters 37(19).

McLaughlin, K., S. Weisberg, A. Dickson, G. Hofmann, J. Newton, D. Aseltine-Neilson, A. Barton, S. Cudd, R. Feely, I. Jefferds, E. Jewett, T. King, C. Langdon, S. McAfee, D. Pleschner-Steele, and B. Steele. 2015. Core Principles of the California Current Acidification Network: Linking Chemistry, Physics, and Ecological Effects. Oceanography 25:160–169.

McNeil, B. I., and R. J. Matear. 2006. Projected climate change impact on oceanic acidification. Carbon Balance and Management 1:1–6.

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Miyashita, S., Murata, O., Sawada, Y., Okada, T., Kubo, Y., Ishitani, Y., Seoka, M.,Kumai, H., 2000. Maturation and spawning of cultured bluefin tuna, *Thunnus* thynnus. Suisanzoshoku 48:475–488.

Monterey Bay Aquarium. 2012. Seafood Watch. Market Squid Doryteuthis (Loligo) opalescens.

Moore, J., & Barlow, J. 2013. Declining abundance of beaked whales (Family Ziphiidae) in the California current large marine ecosystem. PLoS ONE , 8 (1), 1-12.

Moore, C. J., Lattin, G. L., & Zellers, A. F. 2011. Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California. Journal of Integrated Coastal Zone Management, 11(1), 65-73.

Morejohn, G.V., J.T. Harvey, L.T. Krasnow. 1978. The importance of *Loligo opalescens* in the food web of marine vertebrates in Monterey Bay, California. Fish Bulletin 169:66-98.

Morel F. M. M., Kraepiel A. M. L., Amyot M. 1998. The chemical cycle and bioaccumulation of mercury. Annu. Rev. Ecol. Syst. 29, 543–566.

MMS. 2004. Geological and Geophysical Exploration for Mineral Resources on the Gulf of Mexico Outer Continental Shelf. U.S. Department of the Interior, Minerals Management Service, MMS 2004-054.

MMS 2007. Minerals Management Service MMS 2007-003, Outer Continental Shelf Oil & Gas Leasing Program: 2007-2012 Final Environmental Impact Statement at IV-279 (2007).

Muhling, B. A., Lee, S. K., Lamkin, J. T., & Liu, Y. 2011. Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico. ICES Journal of Marine Science: Journal du Conseil, 68(6), 1051-1062.

Muir, W. M., & Howard, R. D. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success: Sexual selection and the Trojan gene hypothesis. *Proceedings of the National Academy of Sciences*, 96(24), 13853-13856.

Munday, P. L., Dixson, D. L., Donelson, J. M., Jones, G. P., Pratchett, M. S., Devitsina, G. V., & Døving, K. B. 2009. Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. Proceedings of the National Academy of Sciences 106(6), 1848-1852.

Muto F, Y Takeuchi, K Yokawa, S Ochi, M Tabuchi. 2009. Pacific bluefin tuna fisheries in Japan and adjacent areas before the mid-20th century. ICCAT Collective Volume of Scientific Papers 63:238-240.

Myers, RA and NJ Barrowman. 1996. Is fish recruitment related to spawner abundance? Fishery Bulletin 94: 707-724.

Nieukirk, S. L., K. M. Stafford, D. K. Mellinger, R. P. Dziak, and C. G. Fox. 2004. Low-frequency whale and seismic airgun sounds recorded in mid-Atlantic Ocean. Journal of Acoustical Society of America 115:1832-1843.

NMFS. 2014a. Final Amendment 7 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan. 757 pp. http://www.nmfs.noaa.gov/sfa/hms/documents/fmp/am7/final_amendment_7_to_the_2006_consolidated_atlantic_highly_migratory_species_fishery_management_plan_8_28_2014_for_web.pdf.

NMFS. 2014b. Highly migratory species management team report on management measures for 2015-2016 fisheries: recreational bluefin tuna fishery. http://www.pcouncil.org/wp-content/uploads/G4b_HMSMT_Rpt2_PBF_SEPT2014BB.pdf.

NMFS. 2015. Regulatory Impact Review (RIR) Rule to Establish Commercial Pacific Bluefin Tuna Annual and Trip Catch Limits in the Eastern Pacific Ocean for 2015 and 2016, February 11, 2015, at https://www.regulations.gov/#!docketDetail;D=NOAA-NMFS-2014-0151.

Nowicki, JP, GM Miller and PL Munday. 2012. Interactive effects of elevated temperature and CO_2 on foraging behavior of juvenile coral reef fish. Journal of Experimental Marine Biology and Ecology 412:46–51.

Ocean Studies Board. 2003. Ocean Noise and Marine Mammals. Committee on Potential Impacts of Ambient Noise in the Ocean on Marine Mammals. The National Academies Press, Washington, D.C., available at http://www.nap.edu/openbook.php?isbn=0309085365.

Okochi Y, O Abe, S Tanaka, Y Ishihara, A Shimizu. 2016. Reproductive biology of female Pacific bluefin tuna, *Thunnus orientalis*, in the Sea of Japan. Fisheries Research 174:30-39.

Orr, J. C., V. J. Fabry, O. Aumont, L. Bopp, S. C. Doney, R. A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R. M. Key, K. Lindsay, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R. G. Najjar, G.-K. Plattner, K. B. Rodgers, C. L. Sabine, J. L. Sarmiento, R. Schlitzer, R. D. Slater, I. J. Totterdell, M.-F. Weirig, Y. Yamanaka, and A. Yool. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681–686.

Ottolenghi, F. 2008. Capture-based aquaculture of bluefin tuna. In A. Lovatelli and P.F. Holthus (eds). Capture-based aquaculture. Global overview. FAO Fisheries Technical Paper. No. 508. Rome, FAO. pp. 169–182.

PFMC (Pacific Fishery Management Council). 2011. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches: Stock Assessment and Fishery Evaluation (SAFE). Pacific Fishery Management Council 12: 1-93. http://www.pcouncil.org/coastal-pelagic-species/stock-assessment-and-fishery-evaluation-safe-documents/

PFMC (Pacific Fishery Management Council). 2016. Stock Assessment and Fishery Evaluation (SAFE) Documents: Current HMS SAFE Report, http://www.pcouncil.org/highly-migratory-species/stock-assessment-and-fishery-evaluation-safe-documents/current-hms-safe-document/, last accessed May 31, 2016.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology Evolution and Systematics 37:637–669.

Parmesan, C., and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37–42.

Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E., & Irons, D. B. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. Science, 302(5653), 2082-2086.

Pikitch, E., Boersma, P.D., Boyd, I.L., Conover, D.O., Cury, P., Essington, T., Heppell, S.S., Houde, E.D., Mangel, M., Pauly, D., Plagányi, É., Sainsbury, K., and Steneck, R.S. 2012. Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp.

Pinsky, M. L., Worm, B., Fogarty, M. J., Sarmiento, J. L., & Levin, S. A. 2013. Marine taxa track local climate velocities. Science, 341(6151), 1239-1242.

Polovina, J. J. 1996. Decadal variation in the trans-Pacific migration of northern bluefin tuna (*Thunnus thynnus*) coherent with climate-induced change in prey abundance. Fisheries Oceanography 5(2):114-119.

Pons M, TA Branch, MC Melnychuk, OP Jensen, J Brodziak, JM Fromentin, SJ Harley, AC Haynie, LT Kell, MN Maunder, AM Parma, VR Restrepo, R Sharma, R Ahrens & R Hilborn. 2016. Effects of biological, economic and management factors on tuna and billfish stock status. Fish and Fisheries DOI: 10.1111/faf.12163.

Pörtner, H., Langenbuch, M., & Reipschlager, A. 2004. Biological impact of elevated ocean CO 2 concentrations: lessons from animal physiology and earth history. Journal of Oceanography 60(4):705–718.

Pörtner, H., Langenbuch, M., & Michaelidis, B. 2005. Synergistic effects of temperature extremes, hypoxia, and increases in CO2 on marine animals: From Earth history to global change. Journal of Geophysical Research, 110(C9), C09S10. doi:10.1029/2004JC002561.

Powers, J. 2013. CIE Independent Peer Review on the Stock Assessment of Pacific Bluefin Tuna. http://swfsc.noaa.gov/uploadedFiles/Divisions/DO/2013_06_28%20Powers%20PBFT%20review%20report.pdf

Prince, ED, J Luo, CP Goodyear, JP Hoolihan, D Snodgrass, ES Orbesen, JE Serafy, M Ortiz and MJ Schirripa. 2010. Ocean scale hypoxia-based habitat compression of Atlantic istiophorid billfishes. Fisheries Oceanography 19: 448–462.

Pulkkinen, K. L.-R. Suomalainen, A. F. Read, D. Ebert, P. Rintamäki, E. T. Valtonen. 2009. Intensive fish farming and the evolution of pathogen virulence: the case of culumnaris disease in Finland. Proceedings of the Royal Society of London B: Biological Sciences 277.1681 (2010): 593-600.

Rae, G. H. 2002. Sea louse control in Scotland, past and present. Pest Management Science, 58(6), 515–520.

Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., Shepherd J, Turley C & Watson, A. 2005. Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society. Policy document 12/05. 60 pp.

Restrepo, V. R., Thompson, G. G., Mace, P.M., Gabriel, W. L., Low, L. L., MacCall, A. D., Methot, R. D., Powers, J. E., Taylor, B. L., Wade, P. R., and Witzig, J. F. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson– Stevens Fishery Conservation and Management Act. National Oceanic and Atmospheric Administration (US) Technical Memorandum NMFS-F/SPO-31. 54 pp.

Ribic, C. A., Sheavly, S. B., Rugg, D. J., & Erdmann, E. S. 2012. Trends in marine debris along the US Pacific Coast and Hawai'i 1998–2007. Marine Pollution Bulletin 64(5):994-1004.

Rios, L.M., Moore, C. & Jones, P.R., 2007. Persistent organic pollutants carried by synthetic polymers in the ocean environment, Marine Pollution Bulletin, 54(8), 1230, 30. http://www.ncbi.nlm.nih.gov/pubmed/17532349.

Rooker, J.R., D.H. Secor, V.S. Zdanowicz, and T. Itoh. 2001. Discrimination of northern bluefin tuna from nursery areas in the Pacific Ocean using otolith chemistry. Marine Ecology Progress Series 218: 275–282.

Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57–60.

Rosa, R., & Seibel, B. A. 2008. Synergistic effects of climate-related variables suggest future physiological impairment in a top oceanic predator. Proceedings of the National Academy of Sciences 105(52):20776-20780.

Sanada Y. 2015. A repeated story of the tragedy of the commons: a short survey on the Pacific bluefin tuna fisheries and farming in Japan. 160 pp.

Sara G, JM Dean, D D'Amato, G Buscaino, A Oliveri, S Genovese, S Ferro, G Buffa, M Lo Martire, S Mazzola. 2007. Effect of boat noise on the behaviour of bluefin tuna *Thunnus thynnus* in the Mediterranean Sea. Marine Ecology Progress Series 331:243-253.

Sawada Y., T. Okada, S. Miyashita, O. Murata, and H. Kumai. 2005. Completion of the Pacific bluefin tuna, *Thunnus orientalis*, life cycle under aquaculture conditions. Aquaculture Research 36: 413–421.

Secor, D. H., Rooker, J. R., Gahagan, B. I., Siskey, M. R., & Wingate, R. W. 2015. Depressed resilience of bluefin tuna in the Western Atlantic and age truncation. Conservation Biology 29(2):400-408.

Shimose T, T Tanabe, K Chen, C Hsu. 2009. Age determination and growth of Pacific bluefin tuna, Thunnus orientalis, off Japan and Taiwan. Fisheries Research 100:134-139.

Shimose T, Y Aonuma, N Suzuki, T Tanabe. 2016. Sexual differences in the occurrence of Pacific bluefin tuna *Thunnus orientalis* in the spawning ground, Yaeyama Islands. Environmental Biology of Fishes 99:351-360.

VI. **Shirakashi S, M Andrews, Y Kishimoto, K Ishimaru, T Okada, Y Sawada, K Ogawa. 2012a. Oral treatment of praziquantel as an effective control measure against blood fluke infection in Pacific bluefin tuna (***Thunnus orientalis***). Aquaculture** 326–329**:15–19.**

Shirakashi S, Y Kishimoto, R Kinami, H Katano, K Ishimaru, O Murata, N Itoh, K Ogawa. 2012b. Morphology and distribution of blood fluke eggs and associated pathology in the gills of cultured Pacific bluefin tuna, *Thunnus orientalis.* Parasitology International 61:242–249.

Simpson, SD, PL Munday, ML Wittenrich, R Manassa, DL Dixson, M Gagliano, HY Yan. 2011. Ocean acidification erodes crucial auditory behaviour in a marine fish. Biology Letters 7:917–920.

Slabbekoorn, H., N. Bouton, I. van Opzeeland, A. Coers, C. ten Cate, and A. N. Popper. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution doi:10.1016/j.tree.2010.04.005.

Solomon, S., G.-K. Plattner, R. Knutti, and P. Friedlingstein. 2009. Irreversible climate change due to carbon dioxide emissions. Proceedings of the national academy of sciences 106:1704–1709.

Sprague, M., Dick, J. R., Medina, A., Tocher, D. R., Bell, J. G., & Mourente, G. 2012. Lipid and fatty acid composition, and persistent organic pollutant levels in tissues of migrating Atlantic bluefin tuna (*Thunnus thynnus,* L.) broodstock. Environmental pollution, 171, 61-71.

Steinacher, M., F. Joos, T. L. Frölicher, G.-K. Plattner, and S. C. Doney. 2009. Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model. Biogeosciences 6:515–533.

Storelli, M.M., E. Casalino, G. Barone, and G.O. Marcotrigiano. 2008. Persistent organic pollutants (PCBs and DDTs) in small size specimens of bluefin tuna (*Thunnus thynnus*) from the Mediterranean Sea (Ionian Sea). Environmental International 34:509-513.

Stramma, L., Prince, E. D., Schmidtko, S., Luo, J., Hoolihan, J. P., Visbeck, M., Wallace, D.W.R., Brandt, P. & Körtzinger, A. 2012. Expansion of oxygen minimum zones may reduce available habitat for tropical pelagic fishes. Nature Climate Change 2(1):33-37.

Takeshita, Y., C. A. Frieder, T. R. Martz, J. R. Ballard, R. A. Feely, S. Kram, S. Nam, M. O. Navarro, N. N. Price, and J. E. Smith. 2015. Including high-frequency variability in coastal ocean acidification projections. Biogeosciences 12:5853–5870.

Tanaka Y, K Satoh, M Iwahashi, H Yamada. 2006. Growth-dependent recruitment of Pacific bluefin tuna *Thunnus orientalis* in the northwestern Pacific Ocean. Marine Ecology Progress Series 319:225-235.

Teuten EL, JM Saquing, DRU Knappe, MA Barlaz, S Jonsson, A Bjorn, SJ Rowland, RC Thompson, TS Galloway, R Yamashita, D Ochi, Y Watanuki, C Moore, PH Viet, TS Tana, M Prudente, R

Boonyatumanond, MP Zakaria, K Akkhavong, Y Ogata, H Hirai, S Iwasa, K Mizukawa, Y Hagino, A Imamura, M Saha, H Takada. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical transactions of the Royal Society of London. Series B 364:2027-2045.

Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. N. Erasmus, M. F. De Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. Van Jaarsveld, G. F. Midgley, L. Miles, M. a Ortega-Huerta, a T. Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature 427:145–8.

Tseng M-C and and PJ Smith. 2012. Lack of genetic differentiation observed in Pacific bluefin tuna (*Thunnus orientalis*) from Taiwanese and New Zealand waters using mitochondrial and nuclear DNA markers. Marine and Freshwater Research 63:198–209.

U.S. Geological Survey (USGS). 2000. Mercury in the Environment Fact Sheet 146-00 (October 2000), available at http://www.usgs.gov/themes/factsheet/146-00/ (last visited May 31, 2016).

Van Overzee HMJ, AD Rijnsdorp. 2015. Effects of fishing during the spawning period: implications for sustainable management. Reviews in Fish Biology and Fisheries 25:65-83.

Vizzini, S., C. Tramati, A. Mazzola. 2010. Comparison of stable isotope composition and inorganic and organic contaminant levels in wild and farmed bluefin tuna, *Thunnus thynnus*, in the Mediterranean Sea. Chemosphere 78:1236-1243.

Vojkovich, M. 1998. The California fishery for market squid (*Loligo opalescens*). CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS REPORT, 55-60. CalCOFI Rep., Vol. 39, http://www.calcofi.org/publications/calcofireports/v39/Vol_39_Vojkovich.pdf.

Warren, R., Price, J., Fischlin, A., de la Nava Santos, S., & Midgley, G. 2011. Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise. Climatic Change, 106(2), 141-177.

Warren, R, J VanDerWal, J Price, JA Welbergen, I Atkinson, J Ramirez-Villegas, TJ Osborn, A Jarvis, LP Shoo, SE Williams & J Lowe. 2013. Quantifying the benefit of early climate change mitigation in avoiding biodiversity loss. Nature Climate Change 3:678-682.

WCPFC. 2009. WCPFC CMM 2009-07, Conservation and Management Measure for Pacific Bluefin Tuna, https://www.wcpfc.int/system/files/CMM%202009-07%20%5BPacific%20Bluefin%20Tuna%5D.pdf.

WCPFC. 2013. WCPFC CMM 2013-09, Conservation and Management Measure for Pacific Bluefin Tuna, https://www.wcpfc.int/system/files/CMM%202013-09%20CMM%20for%20Pacific%20Bluefin%20Tuna.pdf.

WCPFC. 2014a. WCPFC CMM 2014-04, Conservation and Management Measure to Establish a Multi-Annual Rebuilding Plan for Pacific Bluefin Tuna, https://www.wcpfc.int/system/files/CMM%202014-04%20Conservation%20and%20Management%20Measure%20to%20establish%20a%20multi-annual%20rebuilding%20plan%20for%20Pacific%20Bluefin.pdf.

WCPFC. 2014b. Rebuilding Plan for Pacific Bluefin Tuna, Document WCPFC-NC10-2014/DP-07, 10th Regular Session of the Northern Committee, September 1-4, 2014. https://www.wcpfc.int/system/files/NC10-DP-07%20%5BUSA-Rebuilding%20Plan%20for%20PBF%5D.pdf.

WCPFC. 2015. WCPFC CMM 2015-04, Conservation and Management Measure to Establish a Multi-Annual Rebuilding Plan for Pacific Bluefin Tuna, https://www.wcpfc.int/system/files/CMM%202015-04%20Conservation%20and%20Management%20Measure%20to%20establish%20a%20multi-annual%20rebuilding%20plan%20for%20Pacific%20Bluefin.pdf.

Weilgart, L. S. 2007. The impacts of anthropogenic noise on cetaceans and implications for management. Canadian Journal Of Zoology 85:1091-1116.

Werner, C. and Stein, J. 2015. *Present oceanic conditions in the North Pacific*, Presentation to the Pacific Fishery Management Council, Sept. 2015, Supplemental Informational Report 12, http://www.pcouncil.org/resources/archives/briefing-books/september-2015-briefing-book/.

Whitlock RE, MK McAllister, BA Block. 2012. Estimating fishing and natural mortality rates for Pacific bluefin tuna (*Thunnus orientalis*) using electronic tagging data. Fisheries Research 119-120:115-127.

Whitlock RE, EL Hazen, A Walli, C Farwell, SJ Bograd, DG Foley, M Castleton, BA Block. 2015. Direct quantification of energy intake in an apex marine predator suggests physiology is a key driver of migrations. Science Advances 1:e1400270.

Worm, B., & Tittensor, D. P. 2011. Range contraction in large pelagic predators. Proceedings of the National Academy of Sciences 108(29):11942-11947.