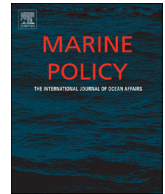




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Bigeye tuna catch limits lead to differential impacts for Hawai`i longliners

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ABSTRACT

Bigeye tuna (*Thunnus obesus*, Scombridae) are a globally important commercial fish. About 60% of the world's bigeye is caught in the Pacific Ocean, where stocks have been subject to overfishing and longline fleets are governed by increased conservation measures. One conservation measure entails multilateral bigeye quota reductions. Since 2010, quota reductions have resulted in four extended closures for Hawai`i longliners. Previous research indicated that regulatory closures may result in differential socioeconomic impacts, but little is known about how four extended closures may affect fishers and fishing trips in a diverse longline fleet with 142 active vessels. The purpose of this research is to assess the trip-level impacts of closures on Hawai`i longliners and determine whether impacts could be lessened while still meeting conservation measures. To do this, economic data and longline logbooks for Hawai`i longliners were analyzed from 2010 to 2015, and 28 longline fishers were interviewed in Fall 2015. Vessels allowed to fish during closures spent nearly two more days at sea not fishing compared to the same month in years without a closure, with no significant difference in trip length. Vessels with special permits are allowed to fish closer to port during closures, while the larger vessels (25% of the fleet) were restricted from retaining bigeye between 32 and 61 days a year, raising equity concerns across the fleet. Our findings also suggest that two levels of collective action may be needed to meet Pacific-wide economic and conservation goals for an economically and ecologically important pelagic common-pool marine resource.

1. Introduction

Pelagic marine fisheries present distinct regulatory challenges. Many pelagic fish migrate long distances across geopolitical and institutional boundaries, making them de facto common property shared across dozens of international fishing fleets [1]. Effectively managing pelagic marine fisheries is costly, requiring extensive resources for data collection, trained experts to conduct stock assessments, and effective governing institutions [2]. To be effective, pelagic fisheries management requires cooperation or collaboration on both science (stock assessments) and governing institutions [3], which are common attributes of a collective action problem [4]. There is no 'global governance' coercion or authority available to compel nation states to conserve or enforce quotas for pelagic species, restrict fishing from areas of the high seas, or assign catch shares.

Pelagic marine fisheries such as bigeye tuna (*Thunnus obesus*, Scombridae) are managed by Regional Fishery Management Organizations (RFMOs) that employ consensus decision-making to develop catch limits for international fishing fleets. The limits are negotiated among member nations and participating non-members of

RFMOs for two geographically distinct segments of the Pacific Ocean: the Inter-American Tropical Tuna Commission (IATTC) Area in the Eastern Pacific Ocean and the Western and Central Pacific Fisheries Commission (WCPFC) Area. Hereafter, these limits are referred to as quotas, following common usage in Hawai`i. Although nation states agree upon annual quotas and other conservation and management measures for bigeye within and beyond their respective Exclusive Economic Zones (EEZs) during WCPFC and IATTC meetings, these measures are intended to be implemented and enforced under national laws and regulations [5,6].

Approximately 60% of global bigeye tuna is caught in the Western and Central Pacific. In 2014, the WCPFC Scientific committee determined that bigeye tuna stocks in the Western Pacific required continued reductions in fishing [7], necessitating action to reduce bigeye tuna quotas [6,8] that were first implemented by the U.S. in 2009. To address bigeye overfishing in the Pacific, WCPFC members agreed upon phased catch reductions over a three-year period starting in 2015. The original U.S. catch limit from 2009 to 2014 implemented by the U.S. [9], and the subsequent decreasing catch limits in 2015 and 2016 [6], have coincided with bigeye tuna catch increases for the Hawai`i

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longline fleet, the primary U.S. fleet targeting bigeye tuna in the Pacific [10]. These catch increases have contributed to four effective closures for the Hawai'i longline fleet in the WCPFC Area since 2009.

The term “closure” is the commonly used to describe the U.S. regulatory action resulting from reaching a quota in the Hawai'i longline fishery. Closures restrict longline vessels from retaining, transshipping, or landing bigeye tuna when the quota is reached. Longliners may continue to fish for other species while discarding bigeye, but they almost never do. A closure is set for a date that the fleet is anticipated to reach the quota, since formal advance rulemaking procedures are involved in setting the closure date. The fishery may reach, not reach, or exceed the quota by the time the fishery closes.

In 2009, Hawai'i longliners were expected to reach their WCPFC quota before the end of the year, and the fishery was effectively closed in the WCPFC Area for the last three days of the year. Hawai'i longliners reached their WCPFC quota again in late 2010, effectively closing the WCPFC Area for the last 40 days of the year [11]. However, after the 2010 closure, Congress passed the Consolidated and Further Continuing Appropriations Act (CFCAA) in 2011, (Pub. L. 112–55, 125 Stat. 552 et seq.). Pursuant to this Act and National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NOAA/NMFS) regulations under 50 CFR 300.224, if the U.S. vessel landing the fish was included in a valid arrangement under Sec. 113(a) of the CFCAA, its catch in the WCPFC Area during those periods was attributed to the fishery of the U.S. Territory named in the arrangement [12]. This provision is based on the principle that the WCPFC quota for the U.S. Nation does not apply to U.S. Territories. A WCPFC Convention and the Conservation Measure exempts “Small Island Developing States and Participating Territories” such as American Samoa, The Commonwealth of the Northern Mariana Islands (CNMI), and Guam from any measure that would restrict their responsible fisheries development [13]. Hawai'i longliners fishing under this arrangement with these U.S. territories were required to make a negotiated payment to a sustainable fisheries fund in the respective territory to support fishing infrastructure and fisheries development [14].

Technically, the Hawai'i fishery in the WCPFC Area has been closed in the latter part of every year from 2009 to present, since longline catch limits were instituted (see Table 1). However, in many of these years, most vessels were allowed to continue fishing in the WCPFC Area under specified arrangements to attribute their bigeye tuna catch to a U.S. Territory. In this paper, the term “effective closure” refers to those situations where such arrangements were not in place at the time of closure, and most vessels ceased fishing in the WCPFC Area.

There was no WCPFC closure in 2011–2014 because of the CFCAA [12]. The bigeye tuna catch limits were forecasted to be met on the dates listed in Table 1. In 2014, the U.S. domestic fishery management body with authority in the region, the Western Pacific Regional Fishery Management Council (the Council), approved Amendment 7 to the Pelagics Ecosystem Management Plan that enabled the expiring CFCAA provision to be replaced with similar arrangements. U.S. Pacific

territories can share unused bigeye tuna quotas with Hawai'i longliners [14]. In exchange for a territorial quota, a group comprised of and representing all Hawai'i longliners, Quota Management, Inc., makes a negotiated payment into that territory's sustainable fisheries fund. After the CFCAA provision in 2011 and the Council approval of Amendment 7 to the Pelagics Fishery Ecosystem Plan in 2014, scholars predicted that Hawai'i longliners would no longer experience effective closures [11]. However, the fishery was effectively closed to fishing in the WCPFC Area for 65 days in 2015, for 49 days in 2016, and 39 days in 2017.

In recent years, effective closures affected many Hawai'i longliners. During effective closures, some Hawai'i longliners could fish for bigeye, while others could not, leading to differential socioeconomic impacts. Without an attribution arrangement, Hawai'i longliners are only allowed to fish for bigeye: 1) if they are willing to make long trips (greater than 800 km away) to the Eastern Pacific Ocean or 2) if they possess both a Hawai'i limited entry longline permit and an American Samoa limited entry longline permit (in other words are ‘dual-permitted’) which allows them to attribute their catch to American Samoa while landing in Honolulu. In 2017, just 23 of 146 active vessels (16%) were dual-permitted. Non dual-permitted vessels that chose to fish for bigeye during effective closures needed to travel to the IATTC Area, a one-way distance of at least 814 km. Further complicating these trips, longline vessels travelling to fish the IATTC Area during the 2015 and 2016 effective closures coincided with the peak of two of the most active hurricane seasons on record for the Eastern Pacific [15,16]. Since 2007, Hawai'i longline vessels greater than 24 m have been subject to a 500 metric ton bigeye tuna quota in the IATTC statistical Area. This quota was reached between August and November from 2013 to 2017, further restricting their options to fish during an effective WCPFC Area closure that overlaps in time with an IATTC Area closure (see Table 2).

Socioeconomic monitoring of fisheries can measure and anticipate future regulatory impacts and help understand drivers of change in marine ecosystems [17]. Data gathered during socioeconomic monitoring can be used to test hypotheses about regulatory policy and outcomes [18] and recognize the factors relating to successful regulatory programs [19]. Previous monitoring efforts in fisheries have estimated the effects of climate change and ocean acidification on fisheries socioeconomics [20] and examined the impact of spatial closures on commercial fisheries [21]. Scholars previously conducted socioeconomic monitoring on the Hawai'i longline fishery to document the impacts of regulatory closures on specific labor and ethnic segments [11,22]. Scholars also examined the applicability of catch shares to many Hawai'i fisheries in 2010, including the Hawai'i longline industry [23]. Socioeconomic monitoring was also conducted following the 2010 regulatory closure in Hawai'i [11]. After the 2010 closure, the authors concluded that future closures could be better anticipated and resolved using territorial quota sharing agreements such as CFCAA and later, Amendment 7.

Despite this, three extended closures have occurred since 2010; in

Table 1

Summary information on Western and Central Pacific catch limits, forecasted closure date, reopening dates, total days the fishery was closed, and percentage of the year that the WCPFC is closed.

Year	WCPFC catch limit (mt)	WCPFC forecasted closure date	Date the WCPFC reopened	WCPFC closure Total days	Percentage of the year that WCPFC Area was closed
2017	3138	September 1	October 10	39	11%
2016	3554	July 22	September 9	113	31%
2015	3502	August 5	October 9	83	23%
2014 [†]	3763	November 8	–	–	0%
2013 [†]	3763	December 13	–	–	0%
2012 [†]	3763	November 27	–	–	0%
2011 [†]	3763	November 17	–	–	0%
2010	3763	November 22	January 1, 2011	40	11%
2009	3763	December 27	January 1, 2010	4	1%
2005–2008	–	–	–	–	–

Table 2

Summary information on Inter-American Tropical Tuna Commission catch limits, forecasted closure dates, total days the fishery was closed, and percentage of the year vessels over 24 m are restricted from retaining bigeye.

Year	IATTC catch limit for vessels greater than 24 m	IATTC forecasted closure date	Total days IATTC closed to vessels greater than 24 m	Total days vessels greater than 24 m prevented from retaining bigeye in the IATTC and WCPFC Areas	Unless dual-permitted, percentage of the year vessels greater than 24 m were restricted from retaining bigeye
2017	500 mt	September 8	114	32	9%
2016		† July 25	71	46	13%
2015		August 12	141	58	16%
2014		October 31	61	61	0%
2013		November 11	50	50	0%
2012		–	–	–	0%
2011		–	–	–	0%
2010		–	–	–	0%
2009		–	–	–	0%

† In 2016, the IATTC Area was forecasted to close on July 25th, but more complete logbook data indicated that only 250mt was caught, so the fishery was reopened on October 4th. After the IATTC Area reopened, the 500mt quota for vessels greater than 24 m was never met.

2015, 2016, and 2017, all on or before September 1. Along with exceeding WCPFC catch limits, there is increasing evidence of a race to fish, overcapitalization in the longline industry, and anecdotally, safety concerns – none of which were present or as prevalent in 2010 [24]. Given these recent changes and potential socioeconomic impacts, there is a need to understand whether future impacts from regulatory closures could be lessened while still meeting domestic and international conservation goals for a commercially important common pool resource, bigeye tuna. The following three research questions guided this research:

1. How did the 2010 and 2015 regulatory closures affect fishing trips for Hawai'i longliners?
2. How do Hawai'i longliners perceive the regulatory, industry organization, and economic issues facing their industry?
3. What can fisher-developed solutions tell us about the current and future management of the Hawai'i longline industry?

The aim of this research is to provide better information for managers regarding the socioeconomic impacts of regulatory action, provide some insights about the current and future organization of the Hawai'i longline industry, and consider the implications of this research for future pelagic marine fisheries management in the Pacific.

2. Background

2.1. Hawai'i longline industry, bigeye tuna market value, gear

The Hawai'i longline fishing industry is a high value, fresh fish commercial fishery. Honolulu is regularly ranked in the top ten of United States ports in landed value, primarily due to bigeye tuna. Because of its high fat content, bigeye tuna is typically sold in sushi restaurants as high-end sashimi. Since 1991, Hawai'i longliners have been subject to a limited entry program, the first of its kind in the U.S. [25]. Limited entry permits are capped at 164 due to rapid growth and new entrants between 1989 and 1991, and are freely transferrable to existing fishers and new entrants [25]. In the early years of the limited entry program, Hawai'i longliners primarily targeted swordfish (*Xiphias gladius*) using new, shallow-set gear deployed at a depth of 30–70 m. Subsequent decreases in swordfish market demand, regulations to address sea turtle interactions, and high trip costs have shifted most of the longline effort to deep set gear at target depths of 400 m to catch bigeye tuna, which the fishery targeted in prior decades [26]. Along with the limited entry program, there is 100% observer coverage on shallow set (swordfish-targeted) trips and at minimum 20% observer coverage for deep set (bigeye tuna-targeted) trips.

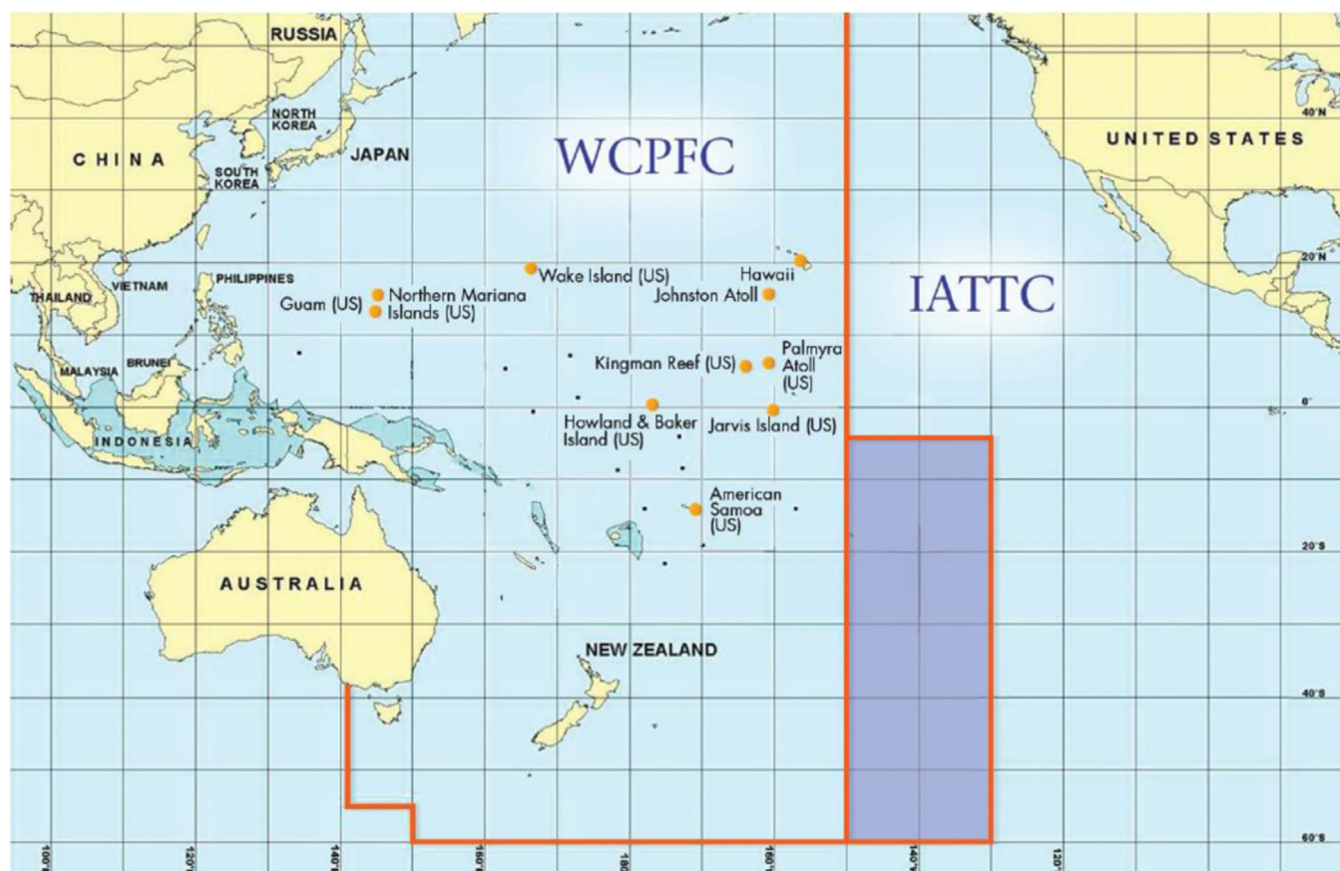
2.2. Magnuson-Stevens fishery conservation and management act and Bigeye tuna

The Magnuson-Stevens Act (MSA) is the legislation that authorizes NOAA and the Council to manage bigeye tuna, swordfish, and other “highly migratory species” domestically through Pelagic Fishery Ecosystem Plans. Other Fishery Ecosystem Plans typically specify annual catch limits (ACLs) for management unit species, but highly migratory species are exempted from MSA National Standard 1 in recognition that unilateral actions taken by the U.S. are ineffective in preventing overfishing and achieving optimum yield. Highly migratory species require cooperation by U.S. fishery management councils in the Pacific, member nations of the WCPFC, the IATTC, and cooperating non-members of both regional fishery management organizations in order to meet MSA National Standard 1 [27].

Despite this exemption, the Pelagics Fishery Ecosystem Plans still govern spatial effort within U.S. EEZs. Hawai'i longliners cannot deploy sets within 80–120 km of the Main Hawaiian Islands to minimize interactions with the small-boat fleet [28], within the expanded Pāhānumokuākea Marine National Monument, or within the Pacific Remote Islands Areas (PRIAs) south and west of the Hawaiian Islands (including the EEZs around Wake Island, Jarvis Island, Howland Island, Baker Island, Kingman Reef, Palmyra Atoll and Johnston Atoll). There is also a hard cap on the incidental take of endangered loggerhead and leatherback sea turtles, which triggers a fishery closure once the cap is reached. Hawai'i longliners must attend an annual Protected Species workshop, purchase a Marine Mammal Authorization Program Certificate, and carry a functioning Vessel Monitoring System (VMS). Hawai'i longline vessels fishing outside the U.S. EEZ on the high seas must carry a High Seas Fishing Compliance Act Permit. Hawai'i longliners are also prohibited from deploying – or even possessing – light sticks during deep-set (bigeye-tuna targeted) trips due to potential for increased interactions with sea turtles and potentially, sharks. These are only some of the domestic regulations related to reducing fishery interactions with protected species. Hawai'i vessels must maintain daily fishing logs and submit their logbooks to the NMFS Pacific Islands Fisheries Science Center (PIFSC) within 72 h of returning to port.

2.3. Regional fishery management organization membership

The WCPFC has 27 members, 9 cooperating non-members, and 7 participating territories. Only six of WCPFC members are subject to quotas (China, Indonesia, Japan, Republic of Korea, Chinese Taipei, and the United States). The others are exempted due to their status as “Small Island Developing States and Participating Territories” as mentioned above [13]. The IATTC has 21 members and 4 cooperating non-members and manages developing nation's small-vessels fisheries by exempting them from quotas based on vessel size [29]. The WCPFC and



The darker blue area is under both WCPFC and IATTC jurisdiction. Orange dots represent jurisdiction of the Western Pacific Regional Fishery Management Council.

Fig. 1. Bigeye tuna management jurisdictions in the Pacific Ocean. Image courtesy of the Western Pacific Regional Fishery Management Council.

the IATTC both adopt resolutions and recommendations for management, but regulations are not uniform across the Pacific (see Fig. 1 for boundaries and U.S.-based jurisdictions). Hawai'i-based longline fishers targeting bigeye tuna are subject to WCPFC or IATTC regulations, depending on where they are fishing.

2.4. WCPFC closures and regional fishery management organizations

Although the 2011 CFCAA provisions and 2014 Amendment 7 allowed quota sharing or territorial transfers of quota to Hawai'i longliners, the transfer process requires negotiation between Hawai'i longliners intending to fish under the specified agreement with a respective territorial government. Quota transfers from territorial governments to Hawai'i longliners also require a draft rule and a public comment period posted on the Federal Register. The quota sharing allowed the fishery to reopen in 2015, 2016, and 2017, but only after a delay, which resulted in an effective closure until the transfer agreement went into effect.

The 2015 regulatory closure occurred on August 5th, nearly five months before the end of the year. During this effective closure, Hawai'i longliners in the WCPFC Area could only fish for bigeye outside the United States EEZ around Hawai'i if they possessed both a Hawai'i limited entry permit and an American Samoa permit (see Fig. 2). These vessels are 'dual-permitted'. Dual-permitted Hawai'i longline vessels are allowed to fish outside the U.S. EEZ during an effective closure by virtue of their permits which makes these vessels "integral to the fishery" of American Samoa which is not limited by the U.S. WCPFC quota [30]. This is scenario 3 in Fig. 2. These vessels also possess a Hawai'i Limited Entry Longline and may still land fish in Hawai'i. This offers dual permit holders a competitive advantage over other fishers, whose only remaining option to fish for

bigeye necessitates increased travel costs to set their gear in the IATTC Area of the eastern Pacific. Dual-permitted vessels need only travel 370 km to set their gear outside of the Hawai'i EEZ, while the alternative is to fish at least 814 km east of Honolulu in the eastern Pacific. Dual permits are held by vessels that crossed the equator to fish in both the Hawai'i and the American Samoa fisheries, and these individuals happen to be predominantly from one ethnic group, leading to some resentment during effective closures. Regulations prohibit vessels greater than 24 m from retaining bigeye tuna in the IATTC Area once a 500 metric ton quota is reached (scenarios 3 and 4 in Fig. 2). This quota was reached between August and November in 2013–2017, which prevented approximately 25% of the Hawai'i longline fleet from retaining bigeye for 9–16% of the year (see Table 2). See Fig. 2 for a graphical description of bigeye tuna quotas for Hawai'i longliners in the WCPFC and IATTC management areas, including time/area closures for different segments of the fleet.

2.5. Local consumption and importance of fish in Hawai'i

An estimated 85–90% of consumed food in Hawai'i is imported [31], but most fish caught in and around Hawai'i is locally consumed. Hawai'i per capita fish consumption is double the U.S. average, which indicates the cultural importance of fish in Hawai'i [32]. Steady demand for bigeye tuna increases at the end of the calendar year during the holidays, which coincides with the end of the year for bigeye quotas [11]. Bigeye tuna is a highly valued product because of its high fat content, cultural importance, and market value for raw tuna products. Bigeye tuna is the next best substitute for *maguro* or Bluefin tuna (*Thunnus orientalis*, Scombridae) sashimi, and is the most desired species for many other raw tuna preparations. Bigeye tuna represents 60% of the landed value for Hawai'i commercial fisheries (\$60,668,484 in 2014) [33].

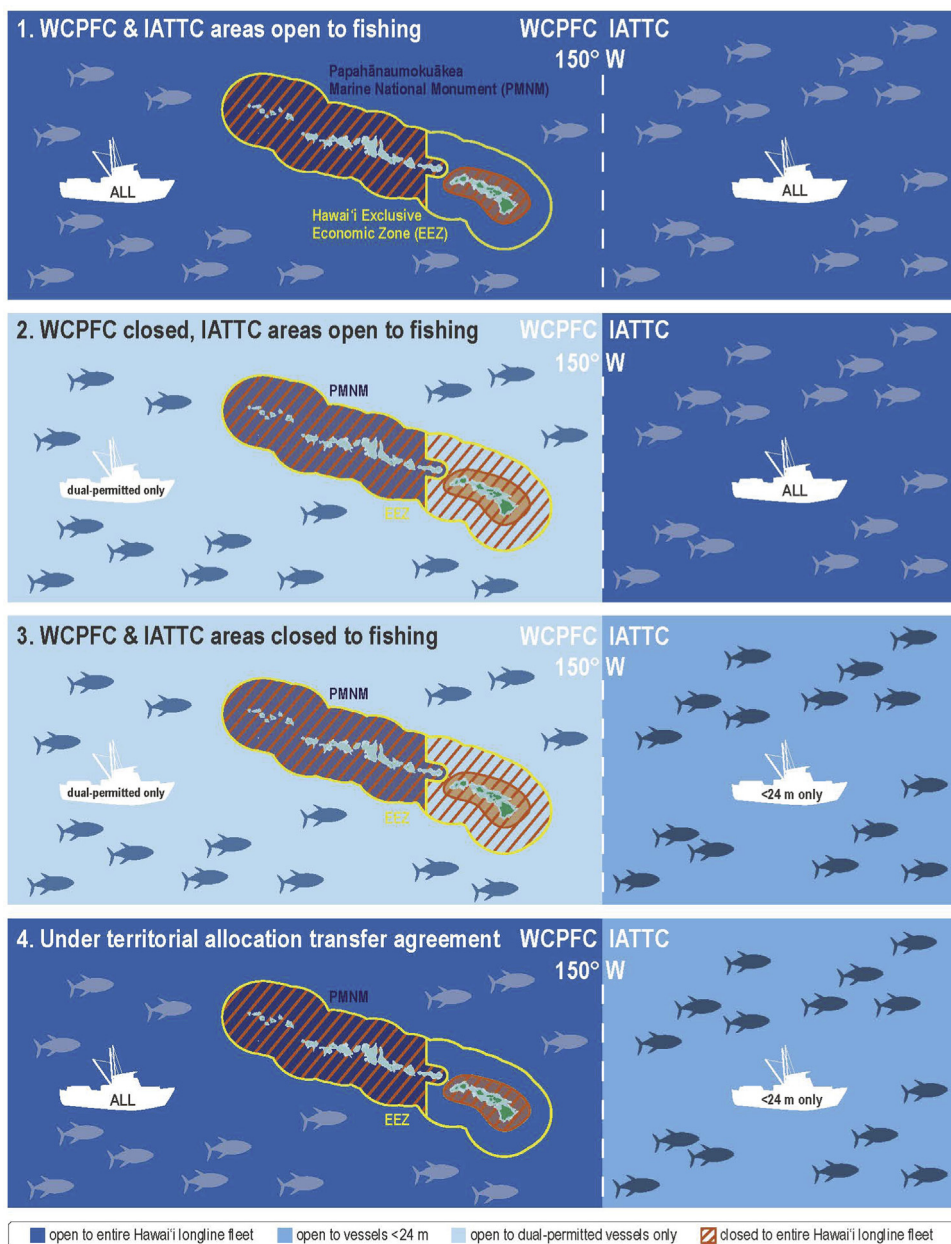


Fig. 2. Four common regulatory scenarios involving WCPFC and IATTC bigeye tuna quotas that impact various segments of the Hawai'i longline fleet: 1) when WCPFC and IATTC Areas are open to fishing, 2) when the WCPFC is closed but the IATTC Area is still open to all vessels, 3) when both the WCPFC Area is closed to fishing and the IATTC Area is closed to vessels greater than 24 m, and finally, 4) the WCPFC Area is reopened to fishing under a WCPFC territorial transfer agreement, while the IATTC Area remains closed to vessels greater than 24 m.

In the Hawai'i pelagic longline bigeye tuna fishery, landed fish are bought and sold fresh, not frozen, primarily to the United Fishing Agency Auction in Honolulu. After caught and brought aboard, fish are immediately packed in ice. On average, Hawai'i longline vessels are at sea for two-three weeks. Approximately 70–80% of bigeye tuna landed in Hawai'i are consumed locally [11]. Although a majority of bigeye tuna landed in Hawai'i is caught using deep-set longline gear, some small-scale or artisanal fishing for bigeye occurs on small boats. These boats target several species of juvenile and adult tuna, including bigeye tuna on seamounts and offshore fish aggregating devices around the main Hawaiian Islands [34]. These fishers may employ multiple gear types and fishing methods, including trolling, shortline, bamboo poles, dangles, and ika shibi [35]. A significant amount of juvenile bigeye is also caught as bycatch by purse seine vessels targeting skipjack tuna (*Katsuwonus pelamis*, Scombridae) in the equatorial Pacific [7].

2.6. Diversity in ethnic composition, fleet composition, trust

The Hawai'i longline industry is composed of three distinct ethnic groups, European-Americans, Vietnamese-Americans, and Korean-Americans [36], although the number of Korean-Americans has declined in recent years. There is a history of previous regulatory closures disproportionately affecting ethnic groups and a lack of trust and co-operation between different ethnic groups in the Hawai'i longline industry [22,36]. Crew members are predominantly Filipino; many are from Indonesia, Vietnam, and Kiribati [37]. About 75% of the Hawai'i longline vessels are 24 m or less in length, with the remaining 25% (35 vessels) greater than 24 m. Hawai'i longline permits also stipulate a maximum length limit of 30.8 m.

3. Methods

This research employed a mixed method research design [38], combining quantitative and qualitative data analysis. Bigeye tuna landings by Hawai'i longliners in the WCPFC and the IATTC areas were collected from 2005 to 2016 and a policy analysis was conducted on fishing regulations and governing institutions affecting the Hawai'i fishery. Interviews were conducted with 28 longline fishers and longline logbook data was analyzed to quantitatively assess the effects of WCPFC closures on longline trips. Quarterly trip costs gathered by Hawai'i longline observers during observed trips were also analyzed to assess the effect of closures on fishing costs.

3.1. Bigeye tuna landings and policy analysis

Twelve years of Hawai'i and territorial catch attributions for the WCPFC and IATTC statistical areas were gathered, including five years before the first extended closure in 2005 through 2016. In addition to the Hawai'i-based data, regulations and rules set by the WCPFC, the IATTC, and the Council were also analyzed to assess their potential socioeconomic impacts on Hawai'i longliners.

3.2. Semi-structured interviews and qualitative data analysis

A total of 28 semi-structured interviews were conducted with Hawai'i-based fishing captains, vessel owner-operators, and owners between September 5th and December 12th, 2015, in order to assess the industry perspectives of the 2015 WCPFC closure. Fishers were interviewed in their primary languages (English, Vietnamese, and Korean). Purposive sampling was employed to capture a cross-section of the industry. Purposive sampling was appropriate because the goal was to gather data from certain cross sections, subpopulations, or groups that meet specific criteria [39]. In this case, the cross-section included dual permitted vessels – those operated with both Hawai'i-based and American Samoa longline permits – that were allowed to fish in the WCPFC Area during the closure (5 interviews with individuals in charge of a total 17 vessels), vessels 24 m or less actively fishing in the IATTC Area (11 interviews with individuals in charge of 17 vessels), fishers that chose not to fish in the IATTC Area (3 interviews, 3 vessels total), captains or owners of vessels larger than 24 m that were too large to fish in the IATTC Area when it was closed to them by quota and regulations (7 individuals in charge of a total of 8 vessels), and knowledgeable crew members (2). Fishers were asked about their key concerns related to the regulatory closure, how the closure had affected them, and their outlook for the rest of the year. Interview notes were iteratively coded and categorized noting patterns or themes in the data [40]. Iterative coding followed a grounded theory approach [41]. Comments were first coded based upon very distinct themes or ideas ($N = 264$) and later organized into larger categories ($N = 10$), and finally, into the general categories: issues, impacts, and solutions ($N = 3$).

3.3. Logbook data analysis

After completing these interviews, logbook data was analyzed (trip

length and non-fishing days) from 2010 to 2015, during the months when a closure had occurred. Deep-set longline data (fishing trips targeting bigeye tuna) were also analyzed. The longline logbook data was gathered from limited entry logbooks by the PIFSC International Fisheries Program (PIFSC-IFP) from 2010 to 2015 (starting from the first effective closure of substantial duration in 2010) to assess trends in participation in the fishery, fishing effort, landings, and revenue. PIFSC-IFP collects, compiles, aggregates, and verifies logbook data collected from Hawai'i longline vessels.

To assess the effects of an effective closure on trip length and non-fishing days, the months a closure occurred (August, September, December) were compared against the same months in 2010–2015 when a closure was not in place. Mean trip length and mean non-fishing days were normally distributed, so a one-way ANOVA was used to compare mean trip length and mean non-fishing days from 2010 to 2015. Since the number of monthly trips from each year was not equal, a harmonic mean was used for trip length and non-fishing days. A Post Hoc Tukey HSD test was conducted to determine if the differences in means for trip length and non-fishing days were statistically significant at the $\alpha = 0.05$ level. Since the Levene statistic indicated that the population variances for the compared means were not homogenous, the adjusted F value in the Welch statistic was also calculated. The Welch statistic was significant at the $p < 0.001$ level, so the means could be reasonably compared. Thus the ANOVA was robust with respect to the violation of the homogenous variance assumption [42].

3.4. Analysis of quarterly trip costs

Average quarterly trip costs were also calculated from 2010 to 2015, from the Hawai'i longline industry ongoing economic data collection program [43]. Trip costs are voluntarily collected from vessel captains by Hawai'i longline observers, representing a subset of total trips. These expenditures include the cost of diesel fuel, engine oil, bait, ice, gear replacement, provisions, and communications equipment [44].

4. Results

4.1. Trends in bigeye tuna targeted trips by Hawai'i longliners

Summary data on active vessels, trips, catch per unit effort (CPUE), cumulative catch in metric tons, and landed value from 2010 to 2015 are presented below in Table 3. Cumulative bigeye tuna catch increased every year since 2011, peaking at 8,777mt in 2015. With the exception of a slight decrease in 2014, landed value increased between 2010 and 2015. Also, after a slight dip in 2012, CPUE (number of bigeye caught per 1000 hooks) has increased each year since 2011, peaking at 4.96 in 2015. The number of active vessels increased from 2012 to 2015, peaking at 143 active vessels in 2015 after remaining relatively stable from 2010 to 2012.

4.1.1. Recent trends in IATTC landings

Fig. 3 displays the growth in bigeye tuna landings for Hawai'i-based longline vessels 24 m or less in length between 2009 and 2015. Vessels greater than 24 m cannot catch more than 500 mt of bigeye tuna each

Table 3

Summary information for the Hawai'i longline fishery: 2010–2015.

Source: Pacific Islands Fisheries Science Center (PIFSC) Hawai'i-based longline logbook summary data.

	2010	2011	2012	2013	2014	2015
Total Active Vessels (max = 164) [45]	122	129	129	135	139	143
Trips (partial or completed) [45]	1205	1306	1356	1441	1350	1448
CPUE (number bigeye tuna caught per 1000 hooks) [45]	3.64	3.81	3.62	4.02	4.73	4.96
Cumulative bigeye tuna landed (metric tons) [45]	5847	5701	5873	6494	7214	8777
Nominal Landed Value of bigeye tuna (in thousands) [33]	\$50,965	\$53,091	\$64,649	\$66,043	\$60,668	\$70,845
Inflation-Adjusted (\$2015) [33]	\$56,454	\$56,696	\$67,419	\$67,666	\$61,275	\$70,845

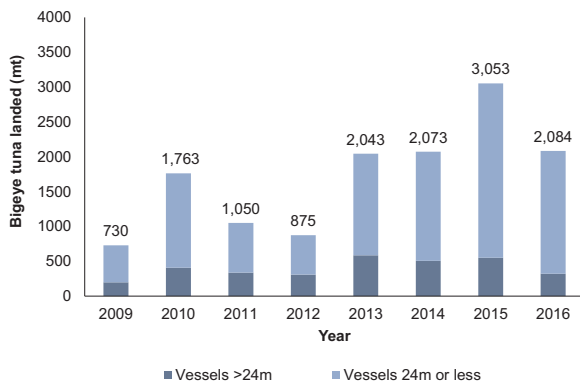


Fig. 3. Bigeye tuna caught (in metric tons) by Hawai'i permitted longline vessels within the IATTC statistical Area (the Eastern Pacific Ocean) from 2010 to 2016.

year. Once that amount is reached, these vessels cannot retain bigeye in the IATTC Area, which is why there is little interannual variation in bigeye tuna landings for vessels greater than 24 m. However, there is no IATTC quota for vessels 24 m or less. Bigeye tuna landings by vessels 24 m or less have risen in recent years, reaching 2,503 mt in 2015, before dropping slightly to 2,084 mt in 2016. Increases in landings by these vessels are driving increases in Hawai'i-based landings of bigeye tuna caught in the IATTC (see Fig. 3).

4.1.2. Recent WCPFC trends for U.S. and Territorial bigeye tuna landings

Table 4 displays some recent trends in U.S. and Territorial landings (fish caught in Hawai'i that were attributed to CNMI, Guam, and American Samoa through specified agreements with Hawai'i longline fishers). Although U.S. quotas have decreased, total bigeye tuna landings by Hawai'i-based longliners have increased through quota sharing agreements with territorial governments. In 2013, Hawai'i longliners caught just 492mt of their CNMI allocation, but they caught all 1,000 mt in 2014, 999 mt in 2015, and nearly all of it (884 mt) in 2016. In addition to catch attributed to the CNMI, Hawai'i longliners caught 856 mt that was attributed to Guam in 2015, and 939mt in 2016.

4.1.3. Hawai'i longline catch in the WCPFC and IATTC areas from 2011 to 2015

The data presented below in Table 5 include summaries derived from Fig. 3 and Table 4. When viewed individually, WCPFC and IATTC

Table 4

2005–2016 U.S. and Territorial bigeye tuna landings (in mt) catch attributions for the WCPFC statistical Area. S. Annual Report Part 1 to the WCPFC [46]. Source: Pacific Islands Fisheries Science Center (PIFSC) Hawai'i-based longline logbook summary data as submitted for the U.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
U.S. in North Pacific	4462	4381	5381	4649	3741	3577	3565	3660	3654	3823	3427	3761
CNMI in North Pacific	–	–	–	–	–	–	–	–	492	1000	999	884
Guam in North Pacific	–	–	–	–	–	–	–	–	–	–	856	939
American Samoa in North Pacific	–	–	–	–	156	507	1086	1338	305	236	441	588
American Samoa in South Pacific	134	181	218	132	161	178	178	164	84	82	116	98
Total (Hawai'i longline)	4462	4381	5381	4649	3897	4084	4651	4998	4451	5059	5724	6172
Total (Hawai'i and American Samoa longline)	4596	4562	5599	4781	4058	4261	4829	5162	4534	5141	5840	6270

Table 5

Total Hawai'i Bigeye tuna catch (mt) by Hawai'i vessels in the WCPFC and IATTC Areas (2005–2016).

Source: Pacific Islands Fisheries Science Center (PIFSC) Hawai'i-based longline logbook summary data.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WCPFC (includes territorial quota transfers)	4462	4381	5381	4649	3897	4084	4651	4998	4451	5059	5724	6172
IATTC	536	85	417	1277	730	1763	1050	875	2043	2073	3053	2084
Total (cumulative landings)	4998	4466	5798	5926	5435	5847	5701	5873	6494	7214	8777	8256

landings by Hawai'i longliners have fluctuated over the past five years (Fig. 3, Table 5). However, when Hawai'i-based bigeye landings from the WCPFC and the IATTC Areas are combined, total bigeye tuna catch has increased nearly 50% from 2010 to 2016 and 65% from 2005 to 2016.

4.2. Qualitative data from semi-structured interviews

Table 6 presents a summary of issues facing Hawai'i longline fishers, including the issues facing the industry, how they were affected by the regulatory closure, plus some of their own solutions for fixing the issues facing the industry. Some quotes from fishers are also provided to clarify the themes emerging from the interview data.

4.2.1. Issues

Hawai'i longline fishers identified the following general issues affecting the fleet: equity issues across the fleet (37 comments); Quota/Amendment 7 (28 comments); Hawai'i longline fleet is not the problem (27 comments); and fishers lack a voice/representation in the regulatory process (10 comments) (see Table 6). Out of all 28 fishers that were interviewed, a total of 19 fishers highlighted these issues. In terms of equity issues across the fleet, several fishers voiced concerns over regulations that prohibited certain size vessels from fishing the IATTC Area during the closure. Others perceived that those allowed fish – either with smaller vessels (24 m or less in length) or possessing dual permits – benefitted, while those without dual-permits or larger vessels (greater than 24 m) may have been adversely affected. One fisher affected by the closure succinctly described the situation: “some people are making lots of money [during the closure], but we are losing lots of money.” This comment may be alluding to the fact that some fishers are dual-permitted. However, there were only 16 active American Samoa permits in the Hawai'i fishery in 2015, which may have made these permits valuable causing some acrimony between those holding permits and those that do not. There seemed to be a perception that the process to obtain an American Samoa permit is unclear or unfair. Another fisher directly addressed the inequality issue and the advantages held by certain owners, stating that “...power, wealth provide affluent vessel owners more opportunities.”

Outside of equity issues within their own fleet, many of the Hawai'i longline fishers interviewed also raised equity issues regarding Regional Fishery Management Organization (WCPFC/IATTC) quotas. They viewed their relatively low impact on Pacific-wide bigeye tuna stocks in relation to foreign longline vessels as decidedly unfair:

Table 6Coded interview comments: issues facing Hawai'i longline fishers, how they are affected, and their solutions for fixing them ($N = 264$, by 28 respondents).

Issues ($N = 123$, by 19 respondents)	Impacts ($N = 74$, by 22 respondents)	Solutions ($N = 67$, by 12 respondents)
<p>Equity issues across the fleet ($N = 37$, by 11 respondents)</p> <ul style="list-style-type: none"> – Closure hurt vessels over 24 m – Vessels that could fish – either with a dual permit or in the IATTC Area – benefitted, hurt those that could not – Owners of multiple vessels more buffered from risk than single vessel owners 	<p>Financial ($N = 51$, by 18 respondents)</p> <ul style="list-style-type: none"> – Financial hardship from not being able to fish – Have to pay crew when not tied up (not fishing) – High travel costs to catch fish e.g., longer trips, higher fuel costs – Many owners are leveraged, indebted 	<p>Markets/Marketing ($N = 42$, by 10 respondents)</p> <ul style="list-style-type: none"> – Better market prices during closure when fewer boats were fishing – Market timing – Secure minimum prices at auction – Better marketing, education for Hawai'i-caught fish
<p>Quota/Amendment seven ($N = 28$, by 13 respondents)</p> <ul style="list-style-type: none"> – Fishing outside EEZ should not count against quota – American Samoa quota [Likely meant the 2000 mt attribution from the CNMI in 2015] will not last two months – Making up quota rules as they go – Industry should high grade; smaller fish do not have market value 	<p>IATTC/ENSO/Weather ($N = 23$, by 9 respondents)</p> <ul style="list-style-type: none"> – Regulatory closure compounded by the weather – Seasonally dangerous to fish in the IATTC Area – ENSO is increasing IATTC catch – Larger, more productive vessels unable to fish in the IATTC Area 	<p>Buyback program ($N = 13$, by 6 respondents)</p> <ul style="list-style-type: none"> – Fishery saturated; need a buyback program – Frustrated with latent permits, should be bought out – Boat buybacks would be a fair way to solve quota issue
<p>Hawai'i longline fleet is not the problem ($N = 27$, by 10 respondents)</p> <ul style="list-style-type: none"> – Foreign vessels are largely unregulated – Hawai'i longline fleet is the most regulated fishing industry in the world – Plenty of fish around Hawai'i 	<p>Regulatory costs, uncertainty ($N = 21$, by 11 respondents)</p> <ul style="list-style-type: none"> – Hawai'i fishers are the only fishers bearing regulatory costs for pacific bigeye – U.S. environmental groups only target domestically caught fish and quotas – “To fish here you need a lawyer first and hooks second” 	<p>Gear/Effort changes needed ($N = 12$, by 5 respondents)</p> <ul style="list-style-type: none"> – Favor two week trips or less – Limit hooks, not vessel size – Need uniform gear across the fleet
<p>Fishers lack a voice, representation in the regulatory process ($N = 10$, by 8 respondents)</p> <ul style="list-style-type: none"> – Government makes unilateral decisions – Quota outside EEZ makes no sense – Some fishers feel disenfranchised, that regulations unfairly benefit certain groups or vessels 		

I think everyone is aware of all the member countries of WCPFC, few...a number...comes to mind, pay sort of any attention to rules, and so we do. And of course this industry bears the brunt of, I mean, when you look at longline bigeye conservation as a Pacific-wide problem that is currently being handled by less than two percent of the boats. And so it is kind of funny. And further than that, although bigeye on a Pacific-wide basis is, in the Western Pacific is judged to be overfished; there is no overfishing in the waters where we are fishing.

This fisher's quote alludes to the idea of spatial management for bigeye tuna, a topic that has been addressed at Council meetings. A regional analysis conducted by WCPFC scientists indicated that excessive fishing mortality and reduced biomass are primarily tropical, and much of the Hawai'i fishery is north of the assessment model region (20°N Latitude) where fishing mortality is lower.

Many fishers also framed the quota management issue in terms of procedural justice. Specifically, fishers mentioned that they lack a voice when quotas are negotiated and mutually agreed upon at WCPFC meetings. One fisher questioned the fairness of the international regulatory process:

Why can we not fish in international waters [during the closure]? Other countries go fishing in the same waters. They don't follow the law. They use light sticks...We can't use light sticks. The hooks they use they don't care. The depth they don't care.

This fisher expressed frustration over the perceived unfair regulatory burden facing Hawai'i longliners in relation to foreign fleets. Particularly, this fisher felt that vessels from other countries do not follow the same gear, depth, and bait restrictions that have been adopted by the U.S. fleet to reduce non-target species interactions. Although Hawai'i longliners targeting swordfish are allowed to deploy light sticks during declared shallow-set trips, they may not possess light sticks aboard their vessel on declared deep-set trips.

4.2.2. Impacts

Many fishers were more specific when describing the financial impacts of the regulatory closure on their businesses and livelihoods (51 comments), the risks associated with displaced fishing effort to the IATTC Area, El Nino Southern Oscillation (El Nino) and weather (23 comments), and regulatory uncertainty and costs (21 comments). These more specific themes were categorized under the larger category 'impacts' (see Table 6) and were described by 22 out of 28 fishers. Some financial impacts described were higher fuel costs from longer trips to the IATTC Area, paying crew during the closure when they could not fish, and that paying off debt and mortgages was difficult when they were not allowed to fish for bigeye. One fisher described his current financial situation as “barely making it, I cannot plan past the present” while another explained that the closure “heavily impacts single vessel owners.”

Many fishers stated a perception that El Nino was increasing the numbers and prevalence of fish in the IATTC Area, but that it was very dangerous to fish there due to the active Hurricane season. The year 2015 was the second most active Pacific Hurricane season on record, with 26 storms and 11 major hurricanes. One fisher explained the IATTC trips were “very long and risky; it was cheaper not to fish.” Some fishers chose not to fish during the closure due to uncertainty about the weather plus the added fuel costs incurred to travel a minimum of 814 km each way to fish in IATTC waters. Illustrating this point, one fisher stated: “fuel limitations, weather, make the EPO risky for small vessels” and another described the drawback of owning an older vessel, explaining that “older, inefficient vessels can't travel great distances [to fish in the EPO].”

Regarding regulatory uncertainty and costs, one fisher stated, “To fish here you need a lawyer first and hooks second.” Many of those interviewed expressed frustration that U.S. environmental groups unfairly target their industry while international fishers do not have to play by the same rules. One fisher highlighted what he felt was hypocritical: “Hawai'i fishers are over-regulated yet allow dirty [less-regulated] foreign imports.” Quotes like this one demonstrate that some

Table 7

Total trips, mean days at sea, and mean non-fishing days while at sea from 2010 to 2015 for Hawai`i longline deep-set (bigeye tuna targeted) trips departing during the months of August, September, December, when a WCPFC regulatory closure may have been in place.

Year	August			September			December		
	Total trips	Mean trip length	Mean non-fishing days	Total trips	Mean trip length	Mean non-fishing days	Total trips	Mean trip length	Mean non-fishing days
2015	94	26.21	13.59 [†]	89	26.74	13.06 [‡]	137	19.21	6.74
2014	95	26.36	11.57	102	24.94	10.66	133	20.91	7.20
2013	108	25.78	11.16	102	26.85	11.71	116	21.17	7.21
2012	99	25.31	11.15	104	24.16	9.99	123	21.27	7.36
2011	100	25.86	11.25	94	23.43	9.14	97	20.44	8.09
2010	116	24.87	11.22	101	24.67	9.83	67	23.36	9.39 [§]

[†] Statistically significant difference from all other years at the $\alpha = 0.05$ level.

[‡] Statistically significant difference at the $\alpha = 0.05$ level from all other years except 2013.

[§] Statistically significant at the $\alpha = 0.05$ level from all other years except 2011.

fishers believe they bear an unfair regulatory burden in relation to other longline fleets in the Pacific. Some respondents felt that foreign longline fleets were subject to less regulation and less stringent observer coverage (5% on average across the Pacific versus 20% for the Hawai`i deep set trips, and 100% observer coverage for shallow set trips targeting swordfish), which may allow foreign fleets to ‘highgrade’ (discard smaller, less valuable fish), discard bycatch, or deploy gear that results in greater mortality of non-target species, such as sharks or sea turtles.

4.2.3. Solutions

Hawai`i fishers listed several solutions to fix the problems related to the fishery and the regulatory closure. These solutions were described by 12 of 28 interviewed fishers. As shown in Table 6, the solutions were binned into three general categories: markets/marketing (42 comments), a buyback program (13 comments), and gear/effort changes (12 comments). Some fishers noted that ex-vessel prices at the auction were higher during the closure due to fewer vessels fishing, while others noted that some vessel owners were already ‘timing’ the market by noting which vessels were out, which ones were tied up at the dock, and how much bigeye tuna had been sold each day at the auction. Others had very specific ideas on how to improve the market for Hawai`i-caught bigeye tuna. Some wanted to secure a minimum price for bigeye; others called for import tariffs on foreign caught fish; others wanted better labeling and public education about fish that are Hawai`i-caught. Many recognized that the market was better during the closure and felt that better coordination of effort throughout year could improve prices for everyone.

Some fishers felt that there were simply too many vessels out fishing, but with a buyback program, exiting fishers could be compensated for their equity in the industry. One fisher felt that “boat buybacks would be a fair way to solve quota fairness.” Others stated that just latent (inactive) permits should be bought out to ensure no more vessels enter the fishery. Fishers also mentioned gear/effort changes as an area that merited attention. Some fishers called for shorter trips (less than two weeks) to further improve the quality and freshness of the product. Multiple fishers stated that limits on hooks, not vessel size, would be a fair way to allow larger vessels (greater than 24 m in length) to fish the IATTC area during a regulatory closure. Other fishers felt that uniform gear would level the playing field and increase ingenuity.

4.3. Impacts of WCPFC regulatory closures on trips, trip length, and non-fishing days

During qualitative interviews, fishers described longer, riskier fishing trips during WCPFC regulatory closures. To assess the effects of closures on trip length and non-fishing days while at sea (a proxy for travel time), the logbooks for Hawai`i-based longline deep-set (bigeye tuna-targeted) trips were examined from 2010 to 2015. The results of

the analysis of total trips, mean trip length, and non-fishing days while at sea from 2010 to 2015 are presented below in Table 7.

Fisher behavior changed significantly during the two extended regulatory closures in 2010 and 2015. For bigeye tuna targeted trips departing during the month of August in the years 2010–2015, there was no significant difference in the mean trip length (total days spent at sea). However, mean non-fishing days in August 2015 (13.59) were significantly different than in other years. On average, longline vessels departing on declared bigeye tuna targeted trips in August 2015 spent two more days at sea not fishing compared to similar trips departing in August in other years. The mean duration of bigeye tuna targeted trips departing during the month of September for the years 2010–2015 were not significantly different. However, mean non-fishing days were greater during September 2015, which was statistically significant when compared against all other years, except for September 2013. On average, longline fishers departed on 10% fewer trips in September 2015 compared to 2010–2015. These data support what many fishers reported in semi-structured interviews regarding longer, riskier trips to the IATTC Area, trips made by dual-permitted vessels to fish outside the EEZ on the high seas, or a decision not to fish at all during a WCPFC regulatory closure. Trips departing during December 2010 (67 total trips) were nearly 40% shorter than trips departing in December in other years. Mean non-fishing days at sea for bigeye tuna targeted trips were longer for trips departing in December 2010. December 2010 was significantly different than all other years except December 2011.

4.4. Average quarterly trip costs

Table 8 displays average quarterly trip costs for Hawai`i-based longline fishing vessels from 2010 to 2015. The highest average quarterly trip costs for 2010 and 2015 occurred during WCPFC regulatory closures Quarter 4 (2010) and Quarter 3 (2015), respectively. Also, 2010 was the only year where average quarterly trip costs for Quarter 4 exceeded all other quarters for the year. Hawai`i longliners frequently fish closer to the Hawaiian

Table 8

Average quarterly trip costs for Hawai`i-based longline fishing vessels from 2010 to 2015 in 2015 dollars (excluding labor costs).

Source: PIFSC/PIRO continuous expenditure data for sampled longline fishing trips.

Year	Quarter 1:	Quarter 2:	Quarter 3:	Quarter 4:
	Jan 1-March 31	April 1-June 30	July 1-September 30	October 1- December 31
2015	\$23,723	\$26,559	\$26,964	\$24,746
2014	\$28,098	\$29,243	\$32,729	\$29,799
2013	\$28,244	\$30,169	\$33,152	\$28,791
2012	\$30,639	\$34,991	\$31,207	\$30,750
2011	\$26,555	\$31,500	\$31,544	\$30,627
2010	\$21,945	\$25,668	\$25,993	\$26,549

archipelago in Quarter 4 and Quarter 1 which coincides with the North Pacific winter. Longline fishing trips departing then are likely influenced by bigeye tuna migration patterns, cooler waters at the depths they prefer to inhabit, and availability of food.

5. Discussion

Enhanced WCPFC conservation measures via phased quota reductions have not decreased the total amount of bigeye caught by Hawai'i longliners, but they have led to four partial regulatory closures from 2010 to 2017, which have affected Hawai'i longliners. More active longline vessels, improved catch efficiency, and territorial quota transfer agreements resulted in a 50% increase in total bigeye landings from 2010 to 2015. Bigeye landings increased 65% between 2005 and 2016. Much of this growth can be attributed to increases in bigeye landings in the IATTC region, Northeast of the main Hawaiian Islands, a region of the high seas with little international competition and high target catch rates [47]. Average trip costs increased during quarters of years when a regulatory closure was in effect. During months when a WCPFC regulatory closure was in place, Hawai'i longliners spent an average of two extra days at sea not fishing (travelling to fishing areas) with no significant difference in trip length. Although trip costs and non-fishing days help illustrate the economic effects of the partial closure for vessels choosing to fish, findings from semi-structured interviews revealed differential impacts for certain segments of the longline fleet. Longliners with dual permits indicated favorable market conditions and strong earnings during closures, while many vessel owners were not able to fish due to the size of their vessel and WCPFC/IATTC regulations. Favorable market conditions may have incentivized smaller vessels to undertake long, risky trips to fish in the IATTC Area during one of the most active hurricane seasons on record for the Eastern Pacific [15]. The following sections consider how socio-economic impacts may be amplified by misaligned incentives, fishing fleet heterogeneity, and Pacific-wide regulatory equity. The discussion concludes by considering industry solutions and what the implications of the findings have for cooperative management of highly migratory tunas, common pool resource theory, and collective action.

5.1. Misaligned incentives

The 2014 WCPFC bigeye stock assessment determined that bigeye landings exceed maximum sustainable yield in the Western and Central Pacific [7]. If bigeye are overfished, incentives are currently misaligned for Hawai'i longliners. First, as in most fishing industries, captains and crew contracts in the Hawai'i longline industry are tied to the amount of fish they catch. The more Hawai'i longline captains and crew catch, the more money they make, so they are incentivized to fish more often to catch more fish. Thus, their livelihoods are tied to consistent, year-round fishing trips.

Second, market prices for bigeye tuna are higher during WCPFC regulatory closures [11], which potentially leads to a situation where Hawai'i longliners may race to catch the WCPFC quota before the fishery closes for an undetermined amount of time, e.g., 40 days in 2010, 68 days in 2015, 49 days in 2016, and 39 days in 2017. Interview data suggested that closures can be a financial boon for longliners who own dual permits. A potential unintended result of the current regulatory regime could entail these boats racing to reach the quota to make even more money during a WCPFC regulatory closure, since they only need to travel 370 km to catch fish on the high seas outside the U.S. EEZ.

Third, longliners without dual permits are faced with the choice of long trips to the Eastern Pacific Ocean or staying tied up at the dock. Further, if the IATTC quota for vessels greater than 24 m (500mt) has already been, or is close to being reached when the WCPFC Area is effectively closed, then these boats cannot fish for bigeye tuna anywhere. Vessels greater than 24 m may be incentivized to race to catch

both the WCPFC and IATTC quotas so they can maximize revenue before they are forced to stop fishing during a dual WCPFC/IATTC closure scenario. (Described in scenario 3 of Fig. 2.)

Fourth, longline vessels 24 m or less that are not dual permitted may be incentivized to race to catch the WCPFC quota to make more money fishing the IATTC Area during the closure, especially since the IATTC Area is a quota-free zone for vessels 24 m or less. Interview data indicated a perception that vessels fishing the IATTC Area during the closure were taking longer and riskier trips and spending less time fishing during WCPFC regulatory closures, which resulted in differential socioeconomic impacts.

Lastly, the number of active permits has increased in recent years (see Table 3). An assessment of excess harvesting capacity, completed in 2004 when the industry was operating with just 124 vessels, determined that both excess capacity and overcapacity existed in the Hawai'i longline industry [48]. Recent increases in active permits (up to 143 in 2017) suggest that the industry is substantially overcapitalized. Several of the issues described above were mentioned in the interviews, and others could be inferred from examining the regulations governing different vessel classes, permits, and geographic areas.

5.2. Fishing fleet heterogeneity

As mentioned in the previous section, there is significant variation in the regulations that govern the Hawai'i longline fishery. Regulations govern where longliners can fish within the U.S. EEZ. International quotas govern the tonnage of bigeye tuna vessels can catch in the WCPFC area and vessels greater than 24 m in the IATTC Area. Territorial quota transfer agreements allow Hawai'i longliners to keep fishing after they have caught their WCPFC quota. Fishing vessels that own an American Samoa permit can continue to fish in the WCPFC Area outside the Hawai'i EEZ during a regulatory closure, before a specified territorial transfer agreement is in effect. However, the Hawai'i longline regulatory structure may trigger socioeconomic impacts during certain times of the year, for discrete segments of a heterogeneous longline fishing fleet. The Hawai'i longline fleet exhibits significant heterogeneity in terms of the permits owned by various fishing vessels, the ethnic composition of the Hawai'i longline fleet, and the presence of different ownership factions due to permit and vessel ownership consolidation. In the following subsections, fishing fleet heterogeneity and how certain segments of the industry may experience differential socioeconomic impacts are discussed. Many of these factors may interact or compound each other in different ways, which can impact collective action. These issues are described in detail below.

5.2.1. Dual permitted vessel owners

Acquisition of dual permits (vessels owners or captains that own both American Samoa Limited Entry Longline Permits and a Hawai'i Limited Entry Longline Permit) is one issue that may divide the Hawai'i longline industry. According to fishers, due to recent WCPFC regulatory closures and the scarcity of available permits (American Samoa Permits are capped at 48), American Samoa Limited Entry Longline permits are becoming increasingly valuable as they provide more flexibility and a competitive advantage in the event of a WCPFC regulatory closure. Some Hawai'i longliners felt that the process for obtaining American Samoa Longline Permits was unclear and potentially unfair. In 2016, one ethnic group, (European-Americans) owned 88% of the 16 Class C or D American Samoa Longline Permits (for longline vessels greater than 15.24 m).

5.2.2. Ethnic composition of the Hawai'i longline fleet

The Hawai'i longline fleet includes a majority of Vietnamese-Americans, a significant number of European-Americans, and a declining number of Korean-Americans. Most of the vessels greater than 24 m formerly targeted swordfish using shallow set gear, but many converted to deep set gear after the Hawai'i shallow set fishery was

closed between 2001 and 2004, due to litigation over incidental leatherback and loggerhead sea turtle interactions [49]. Most of the vessels targeting swordfish were owned by Vietnamese Americans, a minority population (in Hawai'i), who were disproportionately affected by the swordfish closure [22]. Although Vietnamese-Americans are a minority ethnic group in Hawai'i (0.7% of the state population) [50], they now comprise a majority of the fishery. The Vietnamese-Americans who own the larger fishing vessels may be disproportionately affected by periodic WCPFC regulatory closures (see Table 2, Fig. 2). Previous research documented a lack of trust and communication among the three different ethnic groups [37] which may complicate collective action and the industry solutions described in Table 6.

5.2.3. Different ownership factions

There is increasing evidence of longline permit and vessel consolidation in the Hawai'i longline industry. Some respondents mentioned this in their interviews. Some captains or owner-operators lamented that they were forced to defer maintenance and continue fishing because they have loans and contracts with captains and crew. These individuals made long trips to fish the IATTC Area in smaller vessels during the WCPFC regulatory closure, while owners of multiple vessels could offset the losses of one vessel with the profits of another or merely write off the losses as part of a larger portfolio of assets. Meanwhile, owners of multiple vessels could coordinate and concentrate effort in an attempt to time landings for better market returns. Owners of single vessels do not have this luxury. Many single vessel owners explained that they have to fish to pay off their loans, even during times of high supply and lower prices. There is evidence from publically accessible permit data that some individuals, organizations, or corporations may own anywhere from 5 to 10 vessels/permits and upwards of 20 or more. As much as one quarter of Hawai'i longline vessels/permits may be owned by a handful of owners or businesses. Documenting historical permit consolidation in this fishery is the subject of future work by scientists at PIFSC.

5.3. Pacific-wide regulatory equity

Many Hawai'i longliners expressed concerns that they face an unfair regulatory burden in relation to foreign fishing fleets. Observers must accompany Hawai'i longliners on 20% of deep-set (bigeye-tuna targeted) trips, which exceeds the mandatory, institutionalized observer coverage of just 5% of longline trips for both the IATTC and WCPFC Areas. The WCPFC and IATTC have mandated 5% coverage for all vessels, but data are currently unavailable to evaluate whether the 5% observer coverage goal is being reached [51]. Although observers do not assist with stock assessments or enforcement per se, their presence reduces infringements, and illicit behaviors are curtailed. Further, several U.S. environmental laws are in place to mitigate bycatch or non-target catch. These laws prohibit Hawai'i longliners from using light sticks on deep-set trips (which attract sea turtles and perhaps sharks) while other regulations require that they use circle hooks, rather than J-hooks, and other fishing practices to reduce bycatch. Prior to mandatory circle hook regulations, many Hawai'i longliners voluntarily switched to circle hooks, indicating their commitment to reduce impacts on non-target species. There are also special equipment and mandatory annual trainings that teach proper seabird and marine mammal handling procedures. Although there are WCPFC and other international conservation measures in place for protection of seabirds and sea turtles in longline fishing, they are not as thorough or as carefully monitored as in the U.S.

Regardless, the domestic regulatory burden left many interview respondents feeling disadvantaged competitively in relation to foreign fleets. In addition, Hawai'i-based bigeye tuna landings represent just 4% of the total Pacific-wide bigeye tuna landings in the Western and Central Pacific [11], and the Hawai'i longline industry is considered one of the most regulated fisheries in the Pacific, with a limited entry

permit system, mandatory logbook reporting, 20% observer coverage, spatial closures, vessel monitoring, and gear restrictions. It is relevant to mention that another U.S. fishery, the purse seine fishery, also heavily regulated, catches a larger fraction of the Pacific-wide bigeye tuna total, and is also subject to closure based on the WCPFC bigeye tuna conservation measure. Regulatory equity will likely remain a challenge for the Hawai'i longliners as long as domestic and regional regulations remain asymmetric.

5.4. Industry solutions

Many fishers discussed solutions that they felt would address pressing industry issues. Six fishers mentioned limited entry permit or vessel buybacks as an option to reduce latent permits or to reduce effort in the fishery. It is unclear if fishers would consider exiting the fishery if they received compensation or how much money it would take. Ten fishers mentioned markets and marketing, which was among the issues most frequently mentioned during interviews. Many fishers had multiple comments on the subject. Some fishers reported trying to time the market, while others just fish as much as they can to try and pay off debt obligations. Many fishers felt that the limited entry program was not effective enough at curtailing effort. Those able to fish – dual permitted vessels and vessels 24 m or less travelling to the IATTC Area – enjoyed higher prices for their catch. Others reported displeasure with foreign imports and how their perceived lower quality hurts their product. Yet all fishers would agree that higher prices for Hawai'i-caught tuna would benefit the industry, which would require co-ordinated effort and collective action. At this time, social network analysis suggests that social capital does not exist within the industry for self-organization, consensus-building around potential solutions, and collective action towards industry solutions [52].

However, there is a Hawai'i Longline Association, which boasts 600 members, including all active vessel owners. This organization has acted collectively each year since 2011, to raise money and collectively enter into specified agreements through Quota Management LLC with U.S. territories in order to continue fishing during WCPFC effective closures. Clearly there is mutual interest in keeping the fishery open to all active Hawai'i vessels. If bridges could be built between some of the different industry factions, an industry-wide organizational structure already exists that could facilitate dialogue, representation, and voting on industry-wide initiatives. The industry could perhaps capitalize on the shared benefits of American-caught seafood relative to foreign imports in order to find common ground and achieve collective action towards actionable solutions. Instead of focusing on differences, the HLA could focus on their shared interests and successes in securing specified agreements with territories and in providing a unified presence with the Council and the WCPFC [30,53]. This was brought up in the interviews, both in the issues ('Hawai'i longline fleet is not the problem') and solutions ('Markets/Marketing') (see Table 6). It is important to note that catch shares may not necessarily facilitate the solutions proposed by fishers. Market-based and marketing solutions could only be achieved through collective action and industry-wide agreements.

From an institutional perspective, if the Hawai'i longline industry determined that the costs associated with collective action are less than the costs associated with inaction [54,55], then collective action would be an easier decision. Although the Hawai'i longline industry is ethnically heterogeneous, it may not be a limiting factor. Global collection action research in another common pool resource system (forests) found that group heterogeneity was not a limiting factor for achieving collective action [56]. Their study and others of collective action in fisheries suggest that a group size threshold may exist at which collective action may become too difficult [56–58]. The upper bound of group size for collective action is thought to top out at 500–600 individuals. Thus, evidence from other resource systems suggest that the Hawai'i longline industry should not be limited by heterogeneity or

group size.

Recently, the industry catalyzed around allegations that it was using forced labor and human trafficking to develop a universal crew contract and code of conduct required for selling at the United Fishing Agency Auction [59,60]. Since most, if not all of the industry sells their fish at the auction, it represents a consensus of the entire industry and collective action in the broadest possible sense. If an economic argument is made for collective action as it did when the industry reputation was called into question in 2016 [59,60], then the industry has the capacity to act decisively as a group. The collective action challenge facing Hawai'i longliners and the solutions many cited during interviews is to organize around less pressing but very important issues, such as markets and marketing and perhaps self-governance, to ensure the industry remains viable and to maximize economic rents for the fishery while ensuring future sustainable harvests.

6. Conclusion

Three questions guided this research: How did the 2010 and 2015 regulatory closures affect fishing trips for Hawai'i longliners?; How do Hawai'i longliners perceive the regulatory industry organization and economic issues facing their industry?; and What can fisher-developed solutions tell us about the current and future management of the Hawai'i longline industry? Analysis of longline logbooks revealed that on average, Hawai'i longliners spent about two more days at sea not fishing with no significant difference in length of fishing trips during months when a WCPFC regulatory closure was in effect. This finding supported what fishers reported during interviews about taking longer, riskier trips during WCPFC regulatory closures. Mean trip costs were also higher during quarters of the year when a WCPFC regulatory closure was in place. During semi-structured interviews, Hawai'i longliners were aware of the heterogeneity present in their industry and how it may complicate the design and implementation of equitable regulations. Hawai'i longliners also indicated frustrations with WCPFC and IATTC quotas and the perceived disparity between national and international fishing regulations. In terms of fisher-developed solutions, Hawai'i longliners primarily conceived of market-based and marketing solutions, which would require industry-wide collective action to implement.

Given collective action challenges in the industry, developing palatable industry solutions that minimize socioeconomic impacts will be difficult. The Hawai'i longline industry is very competitive and the fleet is heterogeneous in terms of vessel size, ethnicity, and different ownership factions. Fishers are incentivized to fish more to maximize profits, even in potentially dangerous conditions. Given the changing conditions in the fishery in recent years and NOAA's policy on catch shares, rights-based management bears mention. Much has changed since scholars examined the applicability of catch shares to Hawai'i fisheries in 2010 [23,61]. Since then, catch per unit effort is up, there is evidence of the race to fish, overcapitalization, exceeding quota earlier in the year, and safety issues have emerged as Hawai'i longliners are pushed further from port to catch fish. But there is little industry support for catch shares at this time and a general lack of understanding about the potential costs and benefits of different allocation scenarios. Several fishers mentioned buyouts, perhaps indicating a desire to exit the industry if reimbursed for their perceived equity. In terms of catch shares, one of the biggest fears of rights-based management, consolidation, may already be occurring as permits and vessels are being held by businesses or firms.

In summary, longline fishing for bigeye tuna presents a case study that indicates the regulatory and organizational challenges of Pacific-wide pelagic marine resource management. Similar to carbon-emitting industries and regulation, longline fishing and regulatory actions may result in unintended negative social and environmental externalities at different scales. Likewise, domestic and international regulations are not uniformly implemented, requiring collective action at two levels to

be successful: both internationally among member nations and at the domestic level by heterogeneous fishing fleets.

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