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Economic characteristics and management challenges of the Hawaii pelagic longline fisheries: Will a catch share program help?

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ABSTRACT

To date, none of the fisheries in the U.S. Pacific Islands Region is managed under a catch share program. In light of the NOAA policy to encourage the use of catch shares as a fishery management tool, the Western Pacific Fishery Management Council (WPFMC) listed six commercial fisheries, including the Hawaii pelagic longline fishery, the largest in the region, as potential candidates for catch share programs. This study examines the baseline economic characteristics and the main challenges facing the Hawaii pelagic longline fishery and evaluates the impact of these on the desirability and feasibility of a catch share program for this particular fishery.

1. Introduction and purpose

Open-access fisheries are well-known examples of common property resource exploitation. The modern theory of fisheries economics, introduced by Gordon [1], showed that the common property nature of fisheries can result in unfettered competition, which can ultimately lead to overexploitation of fisheries resources and economic inefficiency [1,2]. An FAO report on the state of world fisheries in 2006 indicated about 25% of world fish stocks were overexploited or fully depleted [3]. In the United States, various forms of management have been undertaken to limit and control fishing mortality, especially since the Magnuson-Stevens Fishery Conservation and Management Act was established in 1976. However, a number of U.S. fisheries are under-performing biologically and economically. Recent stock assessments indicated that overfishing is occurring in 10% of fish stocks, and 19% of the fish stocks were classified as overfished in the U.S. [5]. The present productivity of U.S. fishery resources is 24% below long-term sustainable yield [6].

To improve fisheries management, NOAA released a policy in 2010 to encourage the consideration and use of catch shares as a fishery management tool. It stated: “The purpose of this policy is to provide a strong foundation for the widespread consideration of catch shares, which have proven to be an effective tool to help rebuild fisheries [6]”. ‘Catch shares’ is a generic term used for fishery management systems that dedicate to individuals, communities, or associations a secure privilege to harvest a specific area or percentage of a fishery′s total allowable catch (TAC). Catch shares are a rights-based management tool including individual transferable quotas (ITQs), individual fishing quotas (IFQs), territorial use rights fisheries (TURFs), limited access privileges (LAPs), etc. [6]. Theoretically, catch shares mitigate the problems associated with the common property nature of a fishery by providing security and exclusivity to the resource, hence providing an incentive for efficient and sustainable use of fish stocks [7]. The global expansion of the adoption of catch share management started around the 1970s [4]. Some countries, such as Iceland, New Zealand, and Australia, have made catch share programs their default management system. In the United States, the first catch share program was implemented in 1990. Up to 2010, when the NOAA catch share policy was published, catch share programs were adopted in 14 fisheries [6].

Research has found that the outcomes of existing catch share programs in terms of ecological, economic, and social impacts are varied [4,8,9]. Careful design and evaluation is required to ensure the success of a catch share program [9,10]. The NOAA catch share policy requires that the eight Regional Fishery Management Councils address the allocation of shares prior to the implementation of any catch share system, and that conservation, economic, and social criteria all be used in an allocation process.

In support of this requirement, this paper describes the detailed economic and operational characteristics of, and management issues facing, a high-value western Pacific fishery, the Hawaii pelagic longline fishery that targets tuna and swordfish. This fishery has faced several challenges (including catch limits on bigeye tuna to conserve the bigeye stock and regulations to limit interactions with protected species) and is not managed via catch shares. The question is whether, given the economic and

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operational characteristics of this fishery, a catch share regime would effectively address these management issues.

2. Background and context

The U.S. Pacific Islands Region extends from on the Hawaiian Archipelago in the north, to American Samoa in the south, includes the U.S. Pacific Remote Island Areas (PRIAs), and extends westward to the Mariana Archipelago, including Guam. The U.S. exclusive economic zone (EEZ) within this Region is an area of nearly 388 million square kilometers (150 million square miles), comprising 48% of the total U.S. EEZ in all regions [11]. Fisheries in the U.S. Pacific Islands Region EEZ are economically and culturally important to the people of the region. The total value of the U.S. commercial fisheries landings from the region, (including the high seas, but excluding the U.S. purse seine fishery) was nearly $101 million in 2011. The largest of these fisheries is the pelagic longline fishery of which Hawaii accounts for approximately 66% of landings. Even though the landings by weight are relatively low compared to other ports in the nation, Honolulu has ranked in the nation's top ten fishing ports in terms of value of landings for many years. It ranked fifth in the nation in 2008 and accounted for nearly three-quarters of the total value of the U.S. Pacific Islands Region fisheries, excluding the purse seine fishery [12].

None of the fisheries in the Pacific Islands Region operates under a catch share program. In response to the NOAA catch share policy, the Western Pacific Regional Fishery Management Council (WPRFMC) identified six commercial fisheries as potential candidates for catch share programs. One of the identified fisheries, the Hawaii pelagic longline fishery, is the largest commercial fishery in Hawaii and also the largest commercial fishery managed by the WPRFMC. The two sectors of the fishery target different species, bigeye tuna (*Thunnus obesus*, using deep-set gear) and swordfish (*Xiphias gladius*, using shallow-set gear), and also take and retain a variety of other pelagic species.

Management of the bigeye tuna stock in the Pacific Ocean has become a complex task. Bigeye tuna are a transboundary resource. Bigeye catch limits imposed on the Hawaii longline fishery are determined by two Regional Fisheries Management Organizations (RFMOs): the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). Each RFMO allocates a region-specific bigeye quota to the U.S. pelagic longline fishery operating in its area of jurisdiction.

3. Economic and operational characteristics

3.1. Development and effort trends

There were 128 active fishing vessels in the Hawaii pelagic longline fleet in 2011. These vessels landed 11.7 million kilograms (25.7 million pounds) of pelagic fish valued at $75.9 million in 2011 [14]. The average vessel length was about 24 m (80 ft), but some were as small as 15 m (48 ft) or as large as 30 m (98 ft). Bigeye tuna and swordfish, both high value products, are the main species caught in this fishery. Since 1992, the number of active vessels had been steady but the actual fishing effort (number of hooks employed) continued to increase.

Pelagic longline fishing has been conducted for a century from Hawaiian ports [15]. Prior to the late 1980s, the fleet consisted of wooden sampans, many of which had switched from pole-and-line gear to rope longlines. At that time, fishing was mainly conducted within 37 km (20 nm) of the coast. Participation in the fishery increased dramatically in the late 1980s, both in terms of number of vessels and their size and horsepower. Fig. 1 illustrates the trends in fishing effort by the Hawaii longline fleet from 1987 to 2011. The number of vessels in 1987 was 37; by 1991, the number of vessels had increased to 156. Concern about the rapid growth in vessel numbers and the even greater increase in fishing effort motivated the implementation of a limited entry program in 1991, with a cap of 164 vessels and a vessel size limit of 101 ft. Under this program, permits are annually renewable and freely transferable, but no new permits can be issued. Since implementation, the number of active vessels has stabilized; over a recent eight year period (2004–2011), the number of active vessels ranged from 124 to 129. The annual average number of trips per vessel has also remained nearly constant at around 12 trips per vessel. However, over the same time period, the total number of hooks deployed by the fleet has steadily increased. The total number of hooks deployed in 2011 was 42.2 million, which was more than three times the number deployed in 1991[1], while during the same time the number of active vessels declined from 141 to 129. That is, the number of hooks deployed per vessel increased even more dramatically than did the total number of hooks deployed.

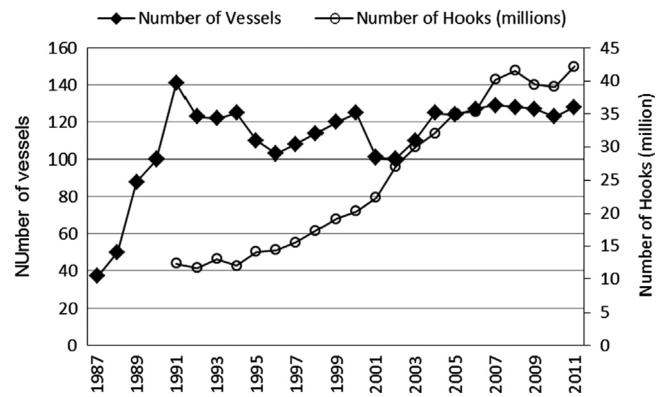

Fig. 1. Number of vessels and hooks in the Hawaii longline fleet, 1987–2011 [17].

Results of a 2004 survey of trends in the adoption of technological improvements in the Hawaii longline fleet indicated that advances in technology have facilitated the increase in fishing intensity (number of hooks per vessel) in the Hawaii pelagic longline fleet [16]. The adoption of and improvement in monofilament fishing line made it possible to deploy a longer main line with more hooks. Before the mid-1990s, monofilament main lines were limited to 1000 to 2000 hooks; current monofilament gear now allows 2000 to 3000 hooks per spool. The increasing number of hooks contributed to the improvement of productivity of each fishing set (usually one set for one fishing day). Data from the 2004 survey [16] and catch data were used to estimate the parameters of a Cobb–Douglas production function that describes the impact of variable inputs, capital stock, and technological factors on the productivity of longline vessels. The estimates suggest that the number of hooks per set (per fishing day), vessel speed, and fishing days per trip had significant positive contributions to productivity. These results suggest that fishermen had a strong incentive to invest in newer monofilament line and, in turn, increase the number of hooks they could deploy. As a result, the limited entry program, which capped the growth of the number, and size, of vessels, did not prevent the increase of active fishing efforts in the fishery.

In the meantime, the fishery expanded its fishing grounds mainly from the EEZ toward the high seas. By the early 1990s, the

[1] The data for the number of hooks are not available before the logbook reporting system was implemented in 1991.

area fished had expanded throughout and beyond the Hawaii EEZ in the western and central Pacific Ocean (WCPO) and into the eastern Pacific Ocean (EPO). Currently, this fishery catches more fish outside the U.S. EEZ than it catches inside the U.S. EEZ for most species [17]. For example, in 1991 the Hawaii pelagic longline fishery caught 41,000 bigeye tuna, of which approximately 33% came from outside of the EEZ. By contrast, in 2011 the fishery caught 156,000 bigeye tuna, 69% of which were taken outside of the U.S. EEZ. Another example is yellowfin tuna (*Thunnus albacares*): the Hawaii-based longline fleet caught about 13,000 numbers of yellowfin tuna in 1991 and caught more than double (31,000 yellowfin) in 2011, however, only 32% were caught outside the U.S. EEZ in 1991, while 51% were caught outside the U.S. EEZ in 2011 [17]. During the 1990s, fisheries managers grew concerned about the possible impacts of increases in fishing effort on local CPUE as the Hawaii longline fleet grew rapidly [15]. A study was conducted using a time series analysis from 1962 to 1992 but found that local catches had no significant effects on local abundance in the U.S. Pacific Islands region EEZ [18].

3.2. Market conditions

Traditionally, Hawaii residents have consumed substantial amounts of fresh bigeye and yellowfin tuna as *ahi poke* (bite-sized pieces of raw tuna mixed with seasoning) and *ahi sashimi* (sliced raw tuna). The majority of the fresh tuna consumed in Hawaii is supplied by the local industry and only limited amounts of fresh tuna are imported [19]. Annual total imports of fresh bigeye and yellowfin tuna in 2011 were less than 0.8 million pounds (not counting transshipments from the continental U.S.) [20], while the local commercial industry landed a total 14 million pounds of bigeye and yellowfin tunas annually in the same year [14].

A concern about the bigeye catch limit implemented by the WCPFC has been that it could result in shortages of fresh bigeye tuna in the local market, particularly during the peak season of demand (the Christmas and New Year holidays) [21]. Although this concern was addressed in 2011 and 2012 by Congressional action that kept the fishery operating at normal levels all year long, the future of bigeye tuna catch limits and supply is uncertain, and this problem could arise again in the future.

One reason for the low level of fresh imports is that shipping fresh tuna to Hawaii is expensive. In addition to direct fresh imports, tuna may also be imported from foreign countries to Hawaii by way of transshipments via the continental U.S. A recent study reported that the amount of foreign transshipments of seafood to Hawaii via the continental U.S. was 75% of the edible weight imported to Hawaii [19]. Despite statistics showing a decline in tuna imported directly from foreign countries to Hawaii [20], market observations suggest that imported tuna is becoming more common in the marketplace. The trade data reveal that foreign imports of frozen tuna (including tuna fillets and steaks) into the U.S. West Coast have increased notably since the late 1990s [20]. Transshipments from West Coast ports could be contributing to the Hawaii tuna supply. The transshipped tuna imports could be frozen tuna being treated with carbon monoxide (CO) to enhance color. However, there was no official record of the amount of transshipped tuna imports [19]. The CO-treated product is often labeled as *Tasteless Smoke* and is sold in markets in a thawed form. Treated tuna has appeared in Hawaii markets since the late 1990s. The fresh *ahi poke* and previously frozen (and CO-treated) *ahi poke* are somewhat similar in appearance, and are commonly available in Hawaii markets. However, the price of *Tasteless Smoke*-treated tuna is $4.40 to $11 less per kilogram ($2.00 to $5.00 less per pound) than the price of fresh tuna landed by local vessels. From retail market observations, imported products were available and the price in the retail market stayed in a consistent price range even when the Hawaii longline fishery for bigeye tuna was closed for a protracted time in 2010. This price stability suggests that these (local and imported) products are substitutes and that imports increase quickly to meet demand when local landings are low, ensuring that prices remain steady. If the amount of imported tuna drops significantly, the fresh tuna price in Hawaii markets can surge up. As such, imports of treated tuna play an important role in the Hawaii fresh tuna market by preventing sharp price fluctuations.

Table 1
Cost-earnings for the Hawaii longline fleet per vessel in 1993 [22] and 2005 [23]*.

	2005 ($)	1993 ($)	Changes	
	(n=98)	(n=95)	$	(%)
Revenue	486,190	504,323	−18,133	−4
Costs	371,764	335,831	35,933	26
Variable costs	269,261	248,452	20,809	8
Fuel costs	111,998	52,174	59,824	115
Fixed costs	102,503	87,379	15,124	17
Net Revenue	114,426	168,492	−54,066	−32
Crew wages	58,632	92,872	−34,240	−37
Captain share	30,373	35,825	−5,452	−15
Cash return to owner	25,421	39,795	−11,536	−29
Vessel purchase Price	366,763	266,801		
Depreciation charge (3.33%)	12,103	8,804		
Net return on investment	13,318	30,991		
Return on investment (%)	4	12		

* Dollar values are reported as nominal; i.e., have not been adjusted to constant dollars.

3.3. Profitability of the fleet

Cost-earnings studies are conducted periodically on the main commercial fisheries in the U.S. Pacific Islands Region. These studies show that these fisheries garner small profit margins, and that these margins have tended to decline as operating costs have increased in recent years. Data from the two most recent cost-earnings surveys of the Hawaii pelagic longline fishery are presented in Table 1. The table lists the main cost-earnings items, such as variable costs, fixed costs, revenues, and net return, from studies that occurred in 1993 [22] and 2005 [23]. Compared to 1993, the revenue per vessel was 4% less in 2005[2]. Both variable costs (including fuel, ice, bait, provisions, etc.) and fixed costs were higher in 2005; fuel costs, in particular, doubled in the 12-year period. As a result, net revenues distributed among crew, captain, and owners were 32% lower in 2005.

Compared to 1993, the payments to crew were 37% lower in 2005. Lower crew labor costs in recent years result from (or have led to) increases in the number of crew positions filled by foreign nationals. Foreign crews are paid a fixed salary instead of crew shares traditionally paid to local crews. In 2005, nearly 75% of all crew positions in the Hawaii pelagic longline fishery were filled by foreign nationals, mostly from the Philippines. While costs increased for most items of input, the fishery might not have survived if the cost of crew had also increased.

Subtracting the captain's income and the depreciation charge for the vessel, the mean net income to owners was $34,303 in 2005, which was 29% lower than in 1993. Vessel owners earned about a 4% return on investment in 2005, whereas they earned 12% in 1993. In conclusion, the Hawaii-based pelagic longline fishery has come to operate under increasingly thin profit margins.

[2] Both revenue and cost data are reported in nominal terms.

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4. Main management issues

4.1. Sea turtle interaction limits

One of the main challenges facing the fishery is interactions with protected species, particularly sea turtles. The Hawaii longline fisheries interacted with several protected species, such as seabirds, sea turtles, and cetacean species (a newly emerged issue facing the fisheries). Some issues like the seabird interactions have been resolved with certain measures (rules) but without a great impact on the fishing activities. The discussion here focuses on sea turtle interactions since the fishery has been dealing with the issue for long period of time. The Hawaii pelagic longline fishery includes shallow-set gear (for swordfish) and deep-set gear (for bigeye tuna). Most of the vessels in these fisheries can switch targeted fish species with minor adjustments to their gear. The shallow-set fishery has a much higher turtle interaction rate than the deep-set fishery, which lead to partial closure of certain waters in November 1999, and then in April 2001 a complete shutdown of the swordfish fishery [24]. The fishery was reopened in April 2004 under a new set of restrictions and subject to annual interaction limits of 16 leatherback sea turtles and 17 loggerhead sea turtles [25],[3].

Swordfish was the primary target of the longline fishery in the early 1990s, and during that period most of the trips were swordfish trips or mixed trips that targeted both tuna and swordfish [17]. The Hawaii-based pelagic longline fishery was the largest U.S. domestic producer of swordfish in the Pacific [26]. Indeed, the rush to target swordfish stocks around Hawaii was the main factor that drove the expansion of the Hawaii longline fishery in the late 1980s [15]. Swordfish landings increased from nearly zero in 1987 to 5.9 million kilograms (13 million pounds) in 1993, which largely contributed to the increase of the total landings of the Hawaii longline fleet. However, fishery interactions with sea turtles and the associated subsequent regulations have led to instability and downsizing of the swordfish fleet in the recent decade [17]. Fig. 2 shows the trend of the Hawaii longline landings from 1989 to 2011. Between 1991 and 2000, the industry landed an annual average of 10.7 million kilograms (23.6 million pounds) valued at $46.2 million (nominal). During this period, the average total landings were comprised of 37% swordfish, 20% bigeye tuna, and 7% yellowfin tuna [14].

However, the swordfish fishery has been much reduced in recent years. The fishery was closed in April 2001, as a result of a lawsuit by conservation groups [24] and reopened in April 2004 with a suite of management measures to minimize sea turtle interactions [27]. These measures included an annual effort limit of 2120 sets and also the above-mentioned sea turtle interaction limits. By the time the fishery reopened, most fishermen who had previously targeted swordfish had switched to tuna fishing, and as a result, tuna again became the main component of the longline fleet, as it had been in the decades before 1990 [15]. In 2011, among the 1338 longline trips taken by the Hawaii longline fleet, only 82 trips targeted swordfish [17], and swordfish landings were about half their pre-closure levels. Since reopening under the sea turtle interaction limits, the fishery has been closed twice for reaching the limits. Although the limit on fishing effort (longline sets) was removed in 2009, the sea turtle interaction limits continue to constrain the swordfish fishery.

[3] NMFS recently revised the annual limit on incidental interactions with leatherback turtles from 16 to 26 and the limit on interactions with North Pacific loggerhead turtles from 17 to 34 interactions. This rule became effective on November 5, 2012 [25].

4.2. Bigeye tuna catch limits

As the Hawaii-based pelagic longline fishery expanded into the high seas, it eventually became subject to management under RFMOs. Bigeye tuna was the first species in the Hawaii longline fishery subjected to international management measures. The EPO and WCPO quotas were implemented by the IATTC in 2004 and by the WCPFC in 2009, respectively. The EPO quota was 150 mt from 2004 to 2006, and 500 mt after 2007. This quota in the EPO only applied to vessels that were longer than 24 m after 2007. In the WCPO for 2009–2011, the annual bigeye tuna quota was 3763 mt [28]. Table 2 presents the Hawaii-based pelagic longline fishery′s bigeye landings from the WCPO during 2006–2010 [29]. Data in Table 2 show that in the three years (2006–2008) prior to the imposition of the WCPO quotas by the US government, Hawaii pelagic longline catches of bigeye (4804 mt) exceeded 3763 mt by an average of 28%. Therefore, this imposition of the WCPO bigeye quota imposed substantial limitations on the Hawaii-based longline fishery. Bigeye landings fluctuated across years due to variation of catch per unit effort (CPUE) in different years. In 2007, the fishery landed 5381 mt of bigeye tuna. In 2009, the first year when the quota was implemented, the bigeye CPUE was relatively low at 3.12 fish per 1000 hooks (vs. 4.07 fish per 1000 hooks in 2007) and the fishery was closed for only two days before New Year′s Day. There was not much impact on the market since fishing was allowed to resume within three days after the closure and there was no interruption in landings (the rule stopped retention of bigeye tuna but landings were still allowed within the first two weeks during the closure). However, in 2010, Hawaii landings from the WCPO (as opposed to the EPO) were halted on November 22 when the catch limit was reached. Thus, there was less fish landed during the peak holiday season due to the closure. The Hawaii fishery had no effective limit in 2011 or 2012 because the Hawaii fishery was able to attribute a part of the bigeye catch to American Samoa or another U.S. Pacific territory [4].

Table 2 also shows the catch from the EPO in recent years (2006–2010) [30]. Landings of bigeye from the EPO have varied considerably. In 2006, EPO bigeye landings were 79 mt. In contrast, total landings of EPO bigeye reached 1310 mt in 2008. However, the bigeye quota in the EPO has not yet imposed restrictions on the Hawaii-based longline fishery because the quota only applies to the vessels longer than 24 m (78.7 ft). In the Hawaii longline fleet, about 84% of the vessels are smaller than the 24 m. The bigeye quota in the EPO could become a constraint if fishing effort continues to increase in the area. Also, additional catch limits could be imposed to conserve other species, e.g., yellowfin tuna [31].

4.3. Transboundary issues

Hawaii longline vessels fish both inside and outside the U.S. EEZ. The main targeted species (bigeye and swordfish) are pelagic and transboundary species harvested by multiple types of gear and by fishermen from many nations. Thus, management of these fisheries is not only domestic, but also international. In 2011, U.S. fishermen harvested 1785 mt of swordfish from the North and Central Pacific, approximately 6% of the total swordfish production of 27,916 mt (Table 3) [34]. The Hawaii swordfish fishery was responsible for the majority (about 82% in 2011) of total U.S. swordfish landings. Overall, Taiwan, Japan, and Philippines were the top swordfish harvesters in the North and Central Pacific Ocean, and together, they harvested 66% of the total swordfish catch in the North and Central Pacific. While Hawaii swordfish

[4] See Section 113 of the federal consolidated and Further Continuing Appropriations Act, 2012.

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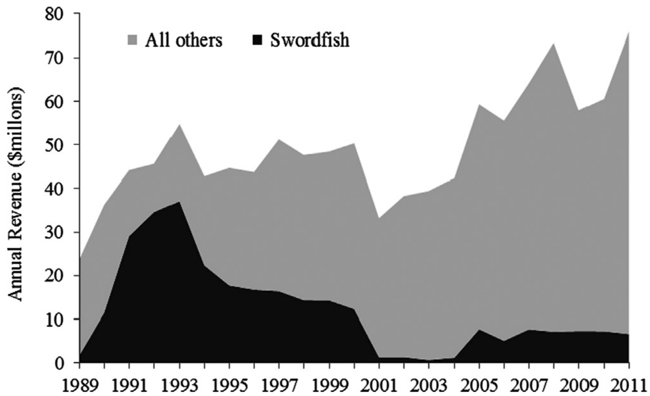

Fig. 2. Revenue of swordfish and other species in the Hawaii pelagic longline fishery, 1989–2011 [14].

Table 2
Bigeye landings (metric tons) by Hawaii-based longline vessels from both the WCPO [29] and EPO [30].

	WCPO		EPO		EPO	
	Harvest	Quota	Harvest	Quota	Harvest by vessels > 24 m	Harvest by vessels ≤ 24 m
2006	4381	N/A	85	150		
2007	5381	N/A	441	500	130	312
2008	4649	N/A	1310	500	331	979
2009	3374	3763	730	500	199	531
2010	3577	3763	1356	500	407	949

Table 3
North and Central Pacific Ocean catches of swordfish (2011) by nation [34].

Nation	(mt)	(%)
Taiwan	6,830	24%
Japan	6,702	24%
Philippines	4,916	18%
China.	2,173	8%
U.S.	1,785	6%
Korea	1,480	5%
Australia	918	3%
Indonesia	598	2%
Costa Rica	580	2
Mexico	526	2%
Other nations	1,408	5%
Total	27,916	100%

production has declined in recent years, it was observed that the decline has been offset by increases in landings by other nations in the North and Central Pacific area. Currently, Pacific Ocean swordfish stocks are in good condition [32] and there are no catch limits on swordfish production in the Pacific Ocean. However, the increasing swordfish harvest by other nations' fishermen can still affect the Hawaii swordfish fishery because the increases in swordfish fishing effort from other nations will be accompanied by increases in sea turtle interactions and possible further jeopardy of sea turtle stocks; thus the Hawaii swordfish fishery may face more pressure for sea turtle conservation. A recent study [33] demonstrated strong spillover effects such that a given decline in Hawaii swordfish production would increase foreign effort, which would generate more sea turtle takes by those fleets. The overall turtle interactions would likely increase because Hawaii fishing practices result in a lower rate of turtle interactions compared to the fishing practices of other nations fishing in the same areas.

Table 4
Pacific (WCPO and EPO combined) catches of bigeye tuna by nation, 2011 [34].

Nation	(mt)	(%)
Japan	34,810	15.6
Ecuador	32,284	14.5
Indonesia	25,568	11.5
Korea	20,054	9.0
Taiwan	16,667	7.5
China	14,164	6.4
Spain	10,247	4.6
Philippines	9,612	4.3
U.S.	8,778	3.9
Marshall Islands	7,780	3.5
Other nations	42,987	19.2
Total	222,951	100

Table 5
Total world imports of bigeye tuna in 2011 [35].

Nation	Tonnage		Value	
	(mt)	(%)	$ 1,000	(%)
Japan	92,347	59.2	699,839	81.5
Ecuador	28,195	18.1	28,195	3.3
Thailand	12,760	8.2	14,692	1.7
U.S.	6,584	4.2	58,390	6.8
Spain	6,167	4.0	9,867	1.1
Other nations	9,876	6.3	48,040	5.6
Total	155,929		859,023	

Table 4 shows the main countries that harvested bigeye tuna in the Pacific [34]. Japan was the primary bigeye tuna harvester, accounting for approximately 23% of the bigeye catch in 2007. Ecuador, Indonesia, and Taiwan also harvested significant amounts of bigeye (more than 10% by each country). U.S. bigeye production in 2007 represented only 7.5% of the bigeye landings in the Pacific. Separating WCPO and EPO catches, Japan and Indonesia are the major fishing nations in the WCPO, accounting for 26% and 23% respectively of the bigeye caught. In the EPO, Ecuador accounted for about 50% of the bigeye catch.

Japan was not only the primary bigeye tuna producer, but also the biggest purchaser of bigeye tuna in the world [35]. Based on 2011 data (Table 5), about 81.5% of world bigeye exports in terms of value and 59.25 in volume were sold to Japan. On the other hand, Taiwan was the biggest exporter of bigeye tuna, representing 73.7% of the world total, while Korea ranked as the second largest bigeye tuna exporter. The bigeye harvested by the Hawaii longline fleet mostly stayed in the local market [19]. In the same year of 2011, the Hawaii longline fleet landed 5458 mt [14], which was 2.4% of the total bigeye caught in the Pacific in terms of tonnage [34]. The ex-vessel value of bigeye tuna landings by Hawaii longline vessels was about $49.5 million in 2011. This amounted to about 5.8% of the total value of bigeye landings in the Pacific.

In addition to longlines, the other main gear that (often unintentionally) catches bigeye tuna in the Pacific is purse seines. These two gear types harvested over 90% of the bigeye tuna in the Pacific. Purse seine catches have seriously affected the bigeye tuna stock and the fish available to the longline fishery in recent years as purse seiners targeting skipjack tuna began to use fish aggregating devices (FAD) which increases the unintended catch of juvenile bigeye tuna [36]. Longline fisheries caught smaller amounts of bigeye, 80,304 mt, compared to 100,026 mt caught by purse seiners in 2011 [38](Table 6). However, the value of the longline catch ($1134 million) was much higher than the value of the purse seine catch ($239 million) [39], because the bigeye

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Table 6
Bigeye tuna catch and value by gear and area, 2011 [38,39].

Area	Longline	Pole-and-line	Purse seine	Other	Total
EPO					
Catch (mt)	25,216	0	56,527	2	81,745
Price ($/mt)	12,756	2371	1,791	1681	
Value ($ million)	322	0	101	0	423
WCPO					
Catch (mt)	63,688	3881	77,073	2379	147,021
Price ($/mt)	12,756	2371	1,791	1681	
Value ($ million)	812	9	138	4	963
Entire Pacific					
Catch (mt)	80,304	4054	100,026	3012	187,396
Value ($ million)	1,134	9	239	4	1,386

Data source: catch data from [38] and price data from [39].

caught by longliners is usually sold to the fresh sashimi market while bigeye caught by purse seiners is primarily sold to canneries. Also, as the purse seine catch of bigeye is almost exclusively juvenile bigeye, it reduces the potential maximum sustainable yield (MSY) of the bigeye stock by lowering the yield per recruit [36,37].

As Table 6 shows, in 2007 in the WCPO, approximately 56% of the bigeye catch was by longliners and 28% was by purse seiners in 2007. In contrast, in the EPO, 71% of the bigeye catch was by purse seiners and only 29% was by longliners in 2007. Moreover, bigeye catches by the WCPO purse seine fleet have increased over the last 40 years (Fig. 3). In the 1960s and 1970s, bigeye catches by purse seiners were inconsequential; catches were instead dominated by longliners. Since then, bigeye catches have increased in both sectors but to a much greater degree in the purse seine fleet. In fact, purse seine catches of bigeye exceeded longline catches in 1996. While longline landings of bigeye have steadily declined since 2002, purse seine catches have remained high. The WCPFC has attempted to reduce bigeye fishing mortality; however, it has been very difficult to reach agreements that will drive reductions in catches in the purse seine fishery and other fisheries that target skipjack and yellowfin tuna [40]. Up to now, bigeye tuna catch limits in the WCPFC have only applied to longline fisheries. However, while the bigeye quota is currently assigned to the longline fleets, catches of bigeye in the purse seine fleets are difficult to identify or estimate, since they are not the target, and are not subject to specified quotas. Instead, effort limits and FAD restrictions are imposed to reduce purse seine bigeye tuna catch.

4.4. Switching between targeting bigeye tuna and swordfish

There are a variety of options for Hawaii longline vessels to continue fishing even if the bigeye fishery is closed when the WCPFC catch limit has been met: (1) they can fish in the EPO (where fishing grounds are farther away than the WCPO) if the EPO fishery is still open; (2) they can continue fishing for tuna in the WCPO by targeting yellowfin tuna rather than bigeye tuna; (3) they can target swordfish in the WCPO or EPO; (4) they can obtain a fishing permit from a U.S. Territory, fish in the WCPO outside the Hawaii EEZ, and their catch will not be subject to the US WCPO limit, even if landed in Hawaii; and (5) they can be party to an agreement with a U.S. Territory, such that their catch in the WCPO will be attributed to that Territory and be exempt from the U.S. WCPO limit, even if landed in Hawaii. Option 4 was in effect in 2009 to 2010, and Congress implemented option 5 for 2011 and 2012, when the Hawaii-based fishery continued to operate without interruption all year long. The first two options are operationally feasible but may not be economically feasible. Yellowfin tuna has been shown to act as a substitute for bigeye tuna in the Hawaii market [19]. However, the price of yellowfin is

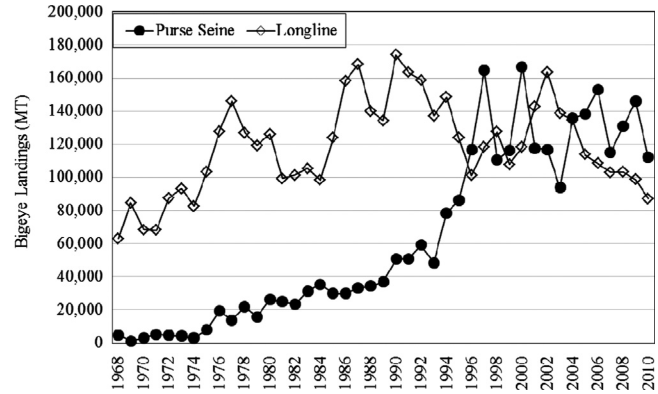

Fig. 3. Trends in bigeye tuna catch by longliners and purse seiners in the WCPO (1968–2010) [6].

considerably lower than the price of bigeye ($5.55/kg vs. $8.07/kg in 2009) ($2.52/lb vs. $3.66/lb in 2009). Consequently, the fleet may not be profitable unless yellowfin CPUE is much higher than bigeye CPUE, which it generally is not. Fishing costs in the EPO are higher than fishing costs in the WCPO due to longer travel distances, and thus switching to the EPO may not be financially viable.

While there is no strong evidence that either of the first two options is economically feasible, the third option of targeting swordfish has been a historically successful strategy [22]. Given the fact that the gear in Hawaii longline vessels is easily adjusted between swordfish or tuna fishing[5], it is interesting to consider whether the swordfish fishery would expand if bigeye fishing becomes more constrained. One challenge to this strategy is that, as noted above, expansion of swordfish effort could lead to heightened interactions with sea turtles. In addition, a second major challenge is that swordfish prices have been falling [14], as illustrated in Fig. 4. The weakened swordfish market is a disincentive for Hawaii fishermen to reengage in the swordfish fishery. Unlike bigeye tuna, which is mainly consumed in the local market in Hawaii, the majority of the swordfish landed is exported to the U.S. mainland where it competes with imports from other nations as well as landings from the Atlantic. In the period from 1987 to the mid-1990s, bigeye prices and swordfish prices in the Hawaii wholesale market were similar, at $6.61–$7.71 per kilogram ($3.00–$3.50 per pound). However, a price differential has developed in recent years. For example, in 2009 the exvessel price of bigeye tuna was $8.07 per kilogram ($3.66 per pound) while the exvessel price of swordfish was only $4.17/kg. ($1.89/lb). Fig. 3 shows bigeye and swordfish exvessel (real) prices from 1987 to 2009. Since 2004, swordfish prices have continued to decline while bigeye prices have increased almost constantly. Unless the relative price of swordfish to bigeye increases, there may not be much economic incentive to increase fishing effort for swordfish.

Furthermore, trip revenues for swordfish fishing have strong seasonal variations, because the CPUE fluctuates throughout the season. Fig. 5 shows the monthly CPUE variation based on average 1994–2006 data [41]. The CPUE in the first four months (Jan. to April) is usually high, and the trip costs lower because swordfish are closer to Honolulu in those months. Therefore, swordfish fishing can be profitable in the early season of a year, but that is not necessarily the case in later months of the season [41].

[5] A longline vessel sets the fishing gear (baited hooks hanging from a horizontal line) deep in the water (~300–400 m) to target bigeye and yellowfin tuna or at a shallower depth (< 100 m) to target swordfish.

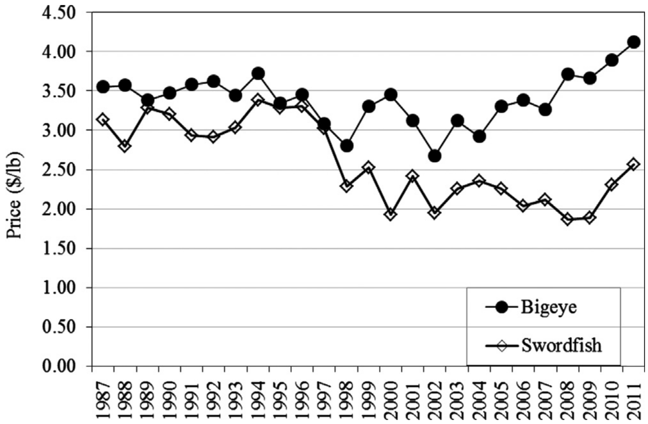

Fig. 4. Swordfish and bigeye tuna real ex-vessel prices, 1987–2009 (price over the years adjusted to 2009 dollars using the Honolulu CPI) [14].

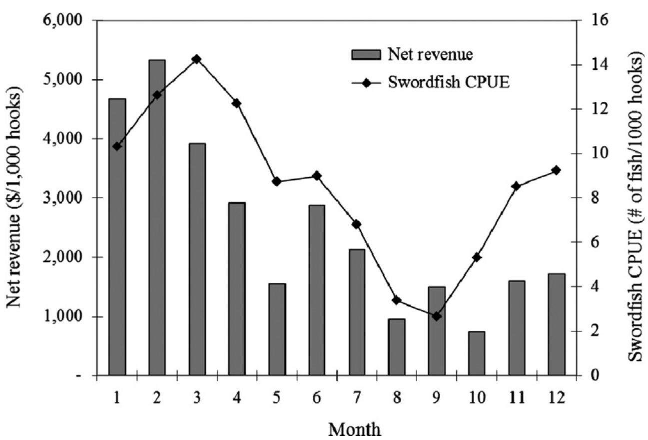

Fig. 5. Monthly variation of economic returns and swordfish CPUE (catch per 1000 hooks) in the Hawaii shallow-set longline fishery (1994–2006 average) [1].

During 2005 to 2009 when effort in the shallow-set longline fishery was limited to 2120 sets (counting only the years when the effort limit was in place for the full year))[6], the cost to obtain the required shallow-set (swordfish) certificates may have been a factor in keeping the actual fishing effort below the limit. The fishermen only used 75–80% of the available certificates, even though the total allowable effort was about half of the historical effort level [42]. A review of the certificate program illustrated the difficulty and cost for fishermen to acquire a sufficient number of certificates [42]. Of the 164 eligible for permits, about 122–142 requested and received the certificates. As a result, only 14–17 certificates were issued for each permit holder annually. Typically only 28 of the 130 active longline vessels consistently conducted shallow-set trips, and each trip used an average of 16–17 certificates per year. This meant that each vessel received barely enough certificates for one trip from the initial distribution. Fishermen who planned for swordfish fishing usually needed to get additional certificates from other fishermen. Although the certificates were freely transferable between permit holders, fishery managers did not set up a mechanism to facilitate any trading or transfer for the certificates. Fishermen needed to search and purchase for unused certificates from other fishermen, which made the certificates valuable even though the fishermen received the certificates at no cost. No data was officially collected on the transfers; however, the trading price was traced by the Economics Program of the Pacific Islands Fisheries Science Center through a voluntary data collection program [43]. Table 7 lists the average costs per certificate in different years recorded in the survey. It may have been difficult or relatively costly for the relatively small group of swordfish vessel owners to acquire a sufficient number of certificates. In some way, the shallow set (swordfish) certificate program may be viewed as a catch share program that restricts and allocates effort (as opposed to catch). As one of the main goals of catch shares is to prevent catch from exceeding established limits, it may result in underuse of a catch allocation and forgone fishing opportunity.

5. Concluding discussion on the desirability and feasibility of a catch share program in the Hawaii pelagic longline fishery

This paper has discussed important economic characteristics and the main issues in the management of the Hawaii pelagic longline fishery. It is the largest fishing fleet in the U.S. Pacific Islands Region, yet it faces substantial challenges. We now explore whether a catch share program could be expected successfully to manage these challenges.

It is commonly recognized that the benefits of a catch share program as a fisheries management tool are twofold: to end a derby-style fishery condition and associated overcapitalization in the short run, and to promote resource conservation in the long run [6,42]. To ascertain whether a catch share regime is appropriate, from an economic perspective, for the Hawaii pelagic longline fishery, we first consider whether the operational and economic characteristics of the fishery suggest that a 'race-for-fish' is emerging and whether catch shares are an appropriate management tool given those characteristics.

Some of the evidence presented above suggests that such a derby fishery is nascent or emerging. The Hawaii fishery twice reached its bigeye quota before the end of the year for first two years when the WCPO bigeye quota was imposed. This closure also risked creating a shortage during the holiday season (Christmas and New Year′s Day) when the demand for fresh tuna was high in Hawaii, and this could happen again in possible future scenarios. Such early closures due to reaching quota limits are a hallmark of the 'race-for-fish'. However, it′s not clear that two years of closures indicate a trend. CPUE for bigeye tuna varies from year to year, and contributes to non-negligible year-to-year variations in bigeye landings. For example, the bigeye CPUE in 2010 was 3.52 fish per 1000 hooks, which was 17% higher than the 2009 CPUE (3.01 fish per 1000 hooks) [44]. Thus, the fishing season was shorter (by 10%) in 2010 with the same amount of TAC. As such, early closures could be due to normal CPUE variations rather than a derby fishery.

The increase in effort resulting from an increase the number of hooks per vessel also suggests movement towards a 'race-for-fish'. That is, vessels are catching more fish in less time due to more hooks. In this case, however, even if a derby fishery were identified, this particular driver of the 'race-for-fish' may not be responsive to catch-share management. In general, while a catch share program could remove the incentive to overcapitalize, doing so may be more complex when an increase in capacity is due to technological innovations that are easily deployed on existing vessels. Indeed, the increase of effort in this fishery appears to be driven by just such a technological innovation, the stronger, lighter monofilament main lines. In addition, such innovations may be a reaction to an increasingly globalized and competitive market and necessary to retain competitive economic edge. Imposing catch shares on such a fishery may not address

[6] The swordfish certificate program began in April 2004 and ended in January, 2010. Therefore, the period with swordfish certificate program effectively implemented for a full-year was from 2005 to 2009.

Table 7
Average price of swordfish certificates sold.

Year	Price per certificate $/certificate	Number of trips collected
2004	N/A	N/A
2005	123	25
2006	170	24
2007	96	46
2008	84	33
2009	98	50
2010	85	7

Data source: [43].

overcapitalization because it stems from a different economic driver than the 'race-for-fish'.

Other economic and operational characteristics of the fishery suggest that a 'race-for-fish' is unlikely in this fishery, at least under current conditions. Specifically, this fishery has other fishing opportunities in the event that a bigeye closure does occur. Hawaii longline vessels may be able to switch to the EPO once the WCPO is closed, and vice versa. Also, some of the Hawaii longline vessels (about 12 of them) hold permits for both the Hawaii and American Samoa longline fisheries. These dual permit holders can continue to fish for bigeye because American Samoa permit holders are not bound by the U.S. bigeye quota as long as they fish outside the U.S. EEZ. Moreover, the Hawaii fishery can fish all year every year now – avoiding any limit – by attributing catch to American Samoa or another U.S. territory. In summary, there is, as yet, mixed evidence for a nascent 'race-for-fish' in the short run.

The other benefit of a catch share program in promoting resource conservation in the long run. There is some evidence that the current longline catch quotas may not be sufficient to control overall bigeye fishing mortality stock-wide [45]. This is because not all nations or participating territories or fisheries have been assigned quotas of this shared stock, and some that have been assigned quotas, like the US, have successfully found ways to transfer catches to other entities that do not have assigned quotas, such as the small island developing countries and participating territories. Indeed, stock assessment experts have concluded that, overall, the Western Pacific stock of bigeye is overfished and is undergoing overfishing [45]. They suggested that the bigeye fishing effort needs to be reduced by at least 32% from the average levels for 2006–2009 to ensure long-term sustainability [40,45]. As such, we now explore whether catch shares would be an effective long-run conservation strategy for this stock and this fishery.

Achieving the conservation goal identified above – a 32% reduction in effort – for this transboundary stock will require effective cooperation among nations [13]. The previous Section 2.3 discussed the competition among longline fleets of multiple countries, and the conservation measures that have been implemented in the longline fishery. The transboundary nature of this fishery and the associated economic context presents several problems in managing overfishing via a catch-share regime. First, due to the presence of spillover effects, any unilateral reduction in one nation's quota would prompt other (foreign) fleets, unless similarly restrained, to fill the market niche left vacant by the imposition of the quota. Such a unilateral reduction in the Hawaii fleet quota would further erode the Hawaii fleet's share of the market. Development of any domestic or international catch-share regime would need to take these elements into consideration.

Perhaps an even greater future challenge involves developing cooperation across gear groups. An important source of uncertainty in WCPO bigeye stock assessment is due to uncertainty in catches of bigeye tuna by purse seines. This is in part because the purse seine fleet takes juvenile bigeye, and that may reduce the potential yield of the WCPO bigeye stock [40,46]. Although the purse seine fisheries primarily target skipjack and yellowfin, they take large numbers of juvenile bigeye and that may have disproportionately large impacts on bigeye sustainable yield. Again, the transboundary, multiple-gear nature of this stock means that applying a catch-share program to the Hawaii longline fishery alone would not resolve overfishing because the stock is shared among multiple fisheries, even within the same nation.

A third concern stems from the uncertain nature of quotas and regulatory regimes when managed multinationally. When catch shares are defined as transferable durable entitlements, the expected value of the resource over the duration of the entitlement is capitalized into the value of the catch share. Thus, a catch share system can give an incentive to fishermen (share owners) to conserve fish resources. However, due to the nature of shared international fish stocks, the capital value would be subjected to allocation decisions by RFMOs and actions taken by member nations to regulate their own fishermen, both of which are highly uncertain in this particular fishery. This uncertainty could reduce the conservation incentive of individual fishermen.

Even if a capital value is acquired by adopting a catch share program, it is necessary to consider the distribution of the value. The purchase price of the permit (or share) becomes one of the costs faced by fishermen wishing to participate in the fishery. If initial shares are given to current participants, this confers value to existing participants and imposes costs on new entrants. Even though the expected price (the discounted net present value of further profits) of the permit/share would be low when expected profits are low, it still presents a higher entry barrier for newcomers. For new entrants, paying off the cost of catch share purchases could further reduce the already thin profit margins in this fishery, unless there is an offsetting increase in ex-vessel prices. As catch shares may result in higher entry costs, they could reduce the competitiveness of Hawaii longline fisheries and create a disadvantage for the domestic fishery relative to foreign fleets.

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