

## RESEARCH ARTICLE

# Rights-Based Management, Competition, and Distributional Equity in Hawai'i's Largest Commercial Fishery

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Many global fisheries have transitioned to rights-based management to improve bioeconomic outcomes, but several fishing communities have experienced negative social impacts. Negative social impacts are often attributed to a focus on economic efficiency and resource sustainability, with less focus on the distributional equity among fishery participants. Among rights-based systems, limited entry has been used for over a century to reduce excess fleet capacity. In 1991, a limited entry permit system was initiated in the Hawai'i longline fleet, following years of rapid growth. The Hawai'i system did not set an ownership cap, which presented a natural experiment to examine distributional equity in the fleet over time. We examined permit ownership changes in the Hawai'i longline fishery using 27 years of permit transactions, then linked it to logbook landings and commercial dealer data to examine revenue inequality using the gini coefficient. We also analyzed property rights components to better understand how institutional factors affected ownership changes. We found that three distinct permit ownership groups emerged and permits, landings, and revenue became increasingly consolidated among multiple permit owners. The gini coefficient indicated that how the fishery was analyzed significantly affected measures of revenue inequality. One measure indicated that revenue inequality in the Hawai'i limited entry system was similar to other U.S. fisheries managed by catch shares. Without an ownership cap, distributional equity in the Hawai'i longline fleet changed significantly over time. Our findings indicate that distributional equity should be considered prior to initiating rights-based transitions in other global fisheries.

**Keywords:** rights-based management; governance transitions; bigeye tuna; governance; pelagic fisheries; fisheries management; pacific islands; limited entry; consolidation; distributional equity

## 1. Introduction

In recent decades, many global commercial fisheries have transitioned to property rights-based management (hereafter rights-based management) to address management issues or problems related to open access. Transitions to rights-based management are based on bioeconomic theories that describe how long-term, secure privileges to harvest resources align stewardship incentives, increase economic efficiency, reduce the race to fish, and maximize resource rents (Grafton et al., 2000, 2006). Historically, overfishing was attributed to weak property rights (Gordon, 1954; Hardin, 1968; Scott, 1955) and did not consider rival factors that cause governance failures (Feeny et al., 1990, 1996; Ostrom, 2009). But, when properly designed, evidence suggests that rights-based management can conserve resources (Costello et al., 2008) and slow the race to fish, resulting in safer fishing conditions (Birkenbach et al., 2017; Pfeiffer & Gratz, 2016). Rights-based systems can be placed on a spectrum of increasingly exclusive resource harvesting privileges, starting with open access, followed by limited entry, then catch shares that allocate an amount of the total allowable catch or confer exclusive access to a fishing area, and finally, full resource ownership (Clay et al., 2010; Hilborn et al., 2005). More nuanced descriptions of rights-based systems may describe

the specific combinations of property rights components conferred through institutional arrangements, such as access (the right to enter a resource area), withdrawal (the right to harvest resources), management (the right to make and enforce resource rules), exclusion (the right to exclude others), alienation (the right to sell, lease or transfer any of the other rights), duration (the amount of time an entity has possessed a right), and quality of title (the strength of a property rights claim) (Schlager & Ostrom, 1992, 1999; Scott, 1988). Although the term 'property rights' is often used to describe and analyze fisheries institutional arrangements, harvesters rarely fully own a resource area or the resources they harvest. Thus the property rights components described above are more akin to 'privileges' ceded by governments via revocable permits (Bromley, 2009). We still use the term 'rights' due to its colloquial usage in fisheries governance.

Despite positive economic and resource outcomes in many rights-based management systems (Grimm et al., 2012), some fishing communities have experienced negative social outcomes following a rights-based transition. These include loss of community values, cohesion, and limited opportunities for new entrants (Carothers, 2015). Other transitions to rights-based systems in commercial fisheries have resulted in consolidation of fishing vessels or ownership of fishing businesses, the loss of social ties and fishing communities (Brinson & Thunberg 2016; Carothers & Chambers, 2012). Consolidation of fishing shares and permits contribute to decreases in total employment, and can result in a concentration of market power (Olson, 2006, 2011). Negative social outcomes are often attributed to a focus on economic efficiency and sustainable resource extraction, with comparably less attention paid to the distributional equity of resource allocations or how shares of revenue are divided amongst fishery participants (Allison et al., 2012; Grainger & Costello, 2016; Guyader & Thébaud, 2001). Although these negative social outcomes have been observed in a variety of rights-based commercial fisheries, some scholars claim that these social issues can be remediated through more attentive planning and consideration during institutional design (Bonzon et al., 2010; Turris, 2010). But, getting the rules right has proven difficult in rights-based fisheries, particularly when decades of policy interventions and limited access may trigger uneven adaptive capacity among fishers (Stoll et al., 2017) and erode the resilience of fishery participants (Stoll et al., 2016). Therefore, there is a need to examine the distributional effects of these institutional arrangements a priori to better inform institutional design and ease future transitions to rights-based systems.

Given the promise and peril of rights-based management transitions, it is important to monitor changes in ownership over time. Understanding ownership changes can help managers anticipate potential socioeconomic impacts of changing markets and regulatory actions. Most catch share programs in the U.S set an accumulation or consolidation limit for quota shares or permits to limit excessive ownership. These limits may also be called accumulation or share caps depending on whether they describe permits or quota (Brinson & Thunberg, 2013; Grimm et al., 2012). Without an ownership cap, consolidation often occurs, which limits competition, leads to a loss of diversity in fishing fleets and ports of landing, and has an adverse effect on coastal infrastructure and community (Brinson & Thunberg, 2016). There is no accumulation cap on limited entry permit ownership in the Hawai'i pelagic longline fleet, which offers a natural experiment to examine the distributional equity of resource revenue in a large commercial fishing fleet, an issue rarely explored in the rights-based fisheries literature (Grainger & Costello, 2016). Therefore, the Hawai'i longline fleet presents a compelling study of what happens to distributional equity in a commercial fishing fleet over three decades when access is managed via limited entry permits, a form of rights-based fisheries management. This research was driven by the following research questions:

1. How has Hawai'i longline limited entry permit ownership changed over time?
2. How have ownership changes affected the distribution of landings and revenue across the fleet?
3. Which property rights components are associated with Hawai'i longline limited entry permits?

We will answer these questions using a novel data source, a National Marine Fisheries Service (NMFS) database of Hawai'i longline limited entry permit transactions from 1991–2017. We combined this database with federal logbook data for Hawai'i permitted longline vessels that record set-level catch (PIFSC1, 2018) and fish dealer data from Hawai'i Division of Aquatic Resources (HDAR) that record commercial fish sales (PIFSC2, 2018). These data were used to determine how ownership changes in limited entry permits coincided with the distribution of landings and revenue in the fleet. We also used Gini coefficient to assess inequality in the revenue distribution across the fleet from 2002–2017. We conclude by using institutional analysis to analyze the property rights components associated with Hawai'i limited entry permits. Our findings will contribute to the literature on the rights-based management transitions and better inform other global fisheries considering transitions to rights-based management.

## **2. Background**

### **2.1. Recent trends of longline fishing in Hawai'i**

Hawai'i longline fleet is the most valuable commercial fishery in the U.S. Pacific Islands Region, and it was the 7<sup>th</sup> most valuable fishery in the U.S. in 2017 (National Marine Fisheries Service, 2018). The Hawai'i longline fleet has grown significantly in the past 15 years. The number of active vessels increased from 100 to 144 from 2002 to 2017, likely due to increased net returns that attracted greater fishing activity (Kalberg & Pan, 2016). Over that same period, total landings doubled from 17.5 to 35.5 million lb., and inflation adjusted revenue nearly doubled from \$59 million to \$108 million. There are two segments in the Hawai'i longline fleet, vessels that fish with deep-set gear that target bigeye tuna, and vessels that fish with shallow-set longline gear that target swordfish. The shallow-set longline fleet has greatly diminished in recent decades due to several time-area closures triggered by sea turtle bycatch (Chan & Pan, 2016). Among the 1,539 trips that occurred in 2017, 1,478 (96%) were deep-set trips, but just 61 (4%) were shallow-set trips.

### **2.2. Regulatory seascape**

Different regulations govern the Hawai'i longline fleet depending on gear type, fishing area, vessel permit, and vessel size. One of the most impactful regulations that affects the fleet is bigeye tuna catch limits. The Western and Central Pacific Fisheries Commission (WCPFC) sets catch limits that govern bigeye tuna stocks in the Western and Central Pacific Ocean (WCPO). Since the WCPFC catch limits were enacted in the WCPO in 2009, this area has been closed to Hawai'i longliners five times for a duration of 4 to 65 days. A different bigeye catch limit is set by the Inter-American Tropical Tuna Commission (IATTC) in the eastern Pacific Ocean (EPO) (east of 150°W). IATTC regulations closed the EPO to Hawai'i vessels greater than 24 meters from 51 to 142 days each year between 2013 and 2017 (Ayers et al., 2018; Richmond et al., 2015). Fishers have responded to decreased fishing days by changing gear and effort, with some suggesting a buyback program (Ayers et al., 2018), which indicates that overcapacity could be a concern. Although many U.S. fisheries have transitioned to catch shares, its lack of support in the Hawai'i longline fleet is potentially due to a lack of familiarity with catch share programs and uncertainty regarding the costs and benefits of such a transition (Kalberg & Pan, 2016).

### **2.3. Limited entry permits**

Among rights-based management systems available in marine fisheries, limited access and limited entry systems have been used for over a century globally to reduce fishing effort and waste associated with excess fleet capacity. The first limited entry program in marine fisheries was instituted in Japan in 1893, followed by South Africa (1953), Australia (1963), and in the U.S, Alaska (1973) (Cicin-Sain et al., 1978). One of the first limited entry programs in U.S. pelagic fisheries was initiated in 1990 in the Hawai'i pelagic longline fleet following rapid growth in the late 1980s (Ito et al., 1991). This growth led the Western Pacific Regional Fishery Management Council (Council), the management body charged with advising the NMFS in managing the Hawai'i longline fleet, to place a moratorium on new entrants. In December 1990, the Council initiated a limited entry permit system and a three year moratorium on permit transfers until 1994, after which permits became freely transferrable without a cap on permit ownership. In 1994, the Council and the NMFS Pacific Islands Regional Office (PIRO) capped permits at 164, reflecting the number of active vessels at that time. Limited entry permits must be renewed annually with PIRO, and as of 2018, applicants must pay a \$52 application fee (\$31 if paying online). Entities that sell or transfer permits must notify PIRO of the transaction and the entity receiving the permit must pay the application fee. Permits are considered active if they are renewed during a given year and are attached to a vessel with a valid US Coast Guard number. Permits not annually renewed become 'inactive' or 'latent', but do not revert back to PIRO. Entities retain latent permits until they are activated (by paying their annual fee, attaching them to a fishing vessel, and going fishing) or transferred (sold or merely transferred to another entity). PIRO retains a confidential record of all applications, transfers, and current permit status in a permit database that dates back to December 1990. For this research, we consider program inception to be 1991, since the first permits were issued a few weeks before the end of year in 1990 and 1991 was the first full year of the limited entry system.

### **2.4. 2010 NOAA meeting on catch shares in the U.S. Pacific Islands region**

In March 2010, Pacific Islands Fisheries Science Center scientists convened a meeting of fisheries experts to discuss implications of a 2009 NOAA policy directive to pursue the potential of catch shares management in the U.S. Pacific Islands region (Criddle et al., 2011). The experts concluded that most U.S. Pacific Islands

fisheries were not suitable for catch shares with the exception of Hawai'i longline fleet where, "It would be good to explore the feasibility and desirability of various types of individual or group catch and bycatch shares for that fishery" (Criddle et al., 2011, p. 25). The workshop also suggested that catch history or equal distribution among the sectors could be used to allocate catch shares in the commercial fisheries. Therefore, information related to catch distribution over time would provide fisheries managers valuable information if a catch share program is considered for the Hawai'i longline fleet in the future.

### 3. Methods

This research utilized a mixed method approach (Maxwell & Loomis, 2003) that combined multiple methods and datasets. The limited entry permit transactions database was coupled with landings from the Hawai'i longline logbooks and commercial fish sales from the HDAR dealer data. Below, we describe the data sources and how they were analyzed. We calculated the Gini coefficient for the Hawai'i longline fleet by examining annual revenue using three different parameters: individual permits, permit holders, and permit applicants in order to examine the distributional equity in the revenue distribution over time in the Hawai'i longline fleet. We conclude with an analysis of the property rights components associated with the Hawai'i longline limited entry permit system. We also shared our findings with several regional fisheries experts to ground truth results.

#### ***3.1. Analysis of the NMFS Hawai'i longline limited entry permit database***

In the early years of the Hawai'i longline limited entry permit system, a different number was assigned to a permit each time it was renewed or transferred, which complicated longitudinal permit tracking. In 2010, a NMFS-WPRFMC effort devised the concept of a 'permit slot', ordered 1–164, that enabled tracking of each permit transaction from 1991–2017 (WPRFMC, 2010a, 2010b). To measure ownership changes, we conducted an annual analysis of permit ownership using the permit slot, taking into account all permit transactions from 1991–2017. This dataset contained records of 6,171 transactions, including permit transfers, renewals, and permit status (active, inactive, renewed, and transferred) each year.

In addition, we conducted an ownership analysis on two permit database fields: permit holder and permit applicant. The permit holder is the entity whose name is on the permit, while the permit applicant is merely the entity that applied for the permit. For either permit holders or permit applicants, an entity may be an individual that owns the vessel, a business such as limited liability company (LLC), a limited partnership, a corporation, or an agent operating on behalf of an individual or business. But, there are notable differences between permit holder and permit applicant which warranted separate analyses. First, entities in the permit holder field were often limited liability companies or corporations that changed from year to year during permit transfers. But during many of these permit transfers, the name in the permit applicant field remained the same (about a third). Therefore, the permit holder field often varied, but the permit applicant field remained the same. Second, some permit applicants applied for multiple permits on behalf of individuals or businesses, and oftentimes, the entity in the permit applicant field remained tied to the same permit slot over time. Therefore, the permit applicant field exhibited lower interannual variability than the permit holder field.

We devised three groups to track distribution of permit ownership through time: single permit owners (entities attached to just one permit during a given year), multiple permit owners (entities attached to more than one permit during a given year, but not the top four permit owners), and the top four multiple permit owners (top four entities attached to the most permits during a given year). We also conducted a sensitivity analysis on top three and top five multiple permit ownership groups and found little change among the top three, four, and five. Permit holders and permit applicants were binned into single, multiple, and the top four permit holders/applicants because there were notable differences among them. In most years, the top four permit holders/applicants had far more permits than entities that owned just two. We calculated the share of permits held by each of these ownership groups from 1991–2017 for all permits (including active, latent, and unassigned permits in a given year), and also for active permits from 2002–2017 because the PIRO database lacked sufficient data to determine which permits were active in a given year prior to 2002. Latent permits are those not renewed with PIRO in a given year. Latent permits are retained by an entity if not renewed and never revert back to PIRO. If a permit was latent for several years, the entity attached to the permit was counted in the share of permit owners for all the years the permit was latent, because those entities still retained the permit. Unassigned permits were permits not attached to any entity in the permit database. Unassigned permits mainly occurred in earlier years of the permit database. For accounting purposes, unassigned permits are included along with single permit owners. The PIRO database contains



personally identifiable information, so the raw data are unavailable to the public. Our results are presented in an aggregated form.

### **3.2. Combining the NMFS Hawai'i longline limited entry permit database with logbook landings and commercial dealer data**

To examine how Hawai'i longline permit ownership was associated with landings and revenue, we created an integrated database that connected Hawai'i longline logbook and HDAR dealer data with the Hawai'i longline permit database for fishing trips between 2002 and 2017 (from the start of the HDAR dealer program until the latest completed logbook data available). To integrate the two databases, we matched the fishing trip date from the integrated database with the permit date in the permit database. From this new merged dataset, we were able to analyze longitudinal changes in permit ownership, aggregate landings/revenue, and average landings/revenue across the three ownership groups. We were also able to examine how these parameters vary when permit ownership was defined in different ways. All revenue values were inflation-adjusted using the Honolulu consumer price index with the base year of 2017.

### **3.3. Gini Coefficient**

The Gini coefficient is often used to assess distributional issues in rights-based commercial fisheries, such as individual transferrable quotas and individual fishing quota programs (Abayomi & Yandle, 2012; Adelaja et al., 1998; Brinson & Thunberg, 2016). We conducted a Gini coefficient analysis on revenue to assess the level of inequality in the revenue distribution among the Hawai'i longline fleet from 2002–2017, using revenue at the permit level, permit holder level, and permit applicant level. A Gini coefficient of zero represents a perfectly equal distribution of revenue among all permits/permit holders/permit applicants, whereas a coefficient of one represents a perfectly unequal distribution, with revenue concentrated in a single entity. Examining the Gini coefficient from 2002–2017 across these different parameters enabled us to assess longitudinal changes in revenue inequality when permit ownership was defined differently.

### **3.4. Property rights analysis**

We also used institutional analysis to analyze the property rights components ceded to Hawai'i longline fishers via revocable limited entry permits. Institutional analysis examines how rules affect behavior, management success, and environmental conditions at multiple scales (McGinnis & Ostrom, 2014). To analyze the property rights components (access, withdrawal, management, exclusion, alienation, duration, and quality of title) (Schlager & Ostrom, 1992; Scott, 1988) associated with Hawai'i limited entry permits, we reviewed archival regulatory documents and federal register notices to define which entities held or shared the various property rights components. We conducted the property rights analysis in order to better understand how the rights associated with Hawai'i limited entry permits may affect incentives and distributional equity over time in the fleet, as well as how they differ from other rights-based systems such as catch shares.

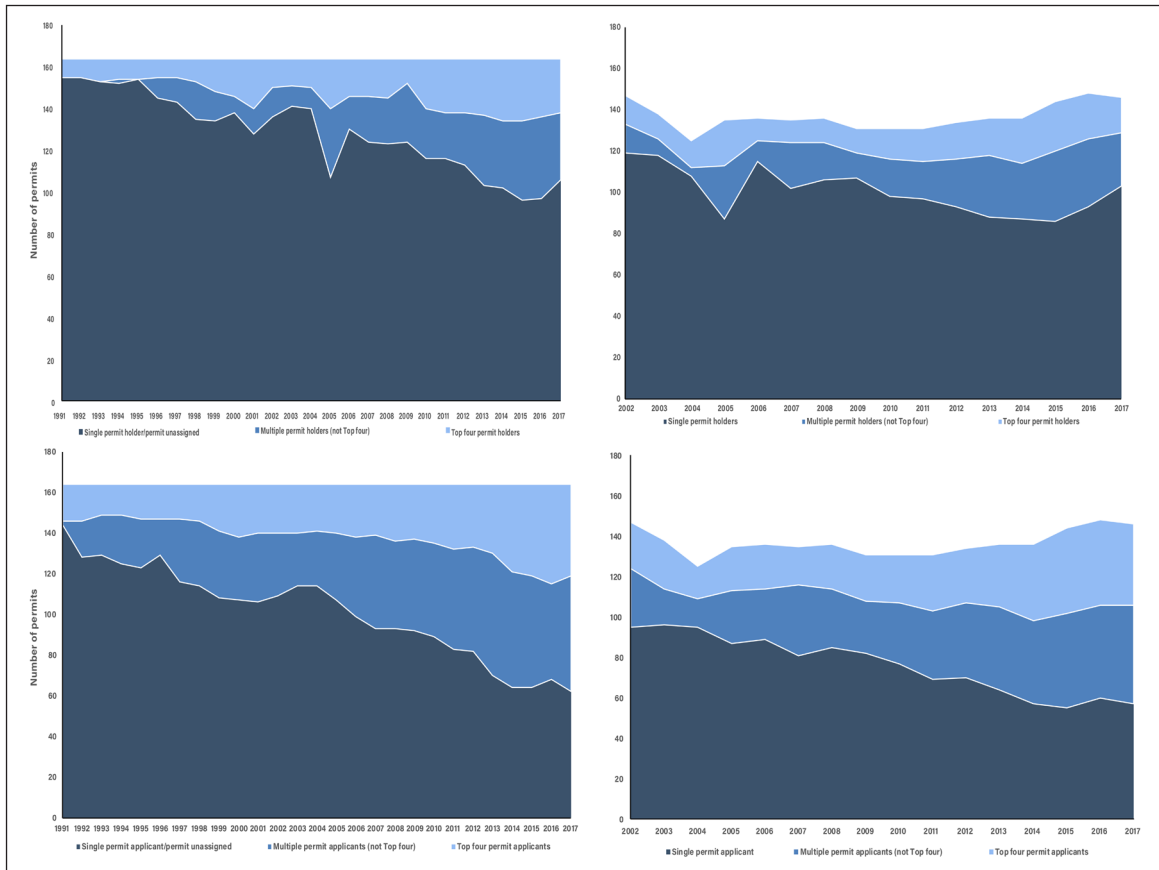
## **4. Results**

### **4.1. Permit Analysis**

Here we present the results of our analysis of Hawai'i longline limited entry longline permits. The permit analysis in **Figure 1** is separated into three distinct groups: single permit holders/applicants, multiple permit holders/applicants, and the top four permit holders/applicants. We display trends in permit ownership by permit holder and permit applicant groups from 1991–2017 including active, latent, and unassigned permits. We also present trends in active permit ownership by permit holder/applicant groups from 2002–2017.

**Figure 1** (upper left panel) displays the number of all permits (including active, latent, and unassigned permits) held by the three permit holder groups from 1991–2017. When holders of all permits are examined throughout the time series, there is a decreasing trend in single permit holders. During the beginning of the limited entry program, only a few entities held multiple permits, but the number of permits held by multiple permit holders (excluding the top four) exhibited the largest increase over time.

**Figure 1** (upper right panel) shows just the active permits held by permit holders from 2002 to 2017. The number and share of active permits held by entities that were attached to one permit decreased over the time series, whereas the number and share of active permits held by entities attached to more than one permit increased from 17 (14%) in 2004, to 58 (40%) in 2015. There are fewer active permits (upper right



**Figure 1:** Trends in Hawai'i longline limited entry permit ownership from 1991 to 2017: number of all permits (active, latent, and unassigned) held by the three permit holder groups (upper left panel); number of active permits held by the three permit holder groups (upper right panel); number of all permits (active, latent, and unassigned) held by the three permit applicant groups (lower left panel); number of active permits held by the three permit applicant groups (lower right panel).

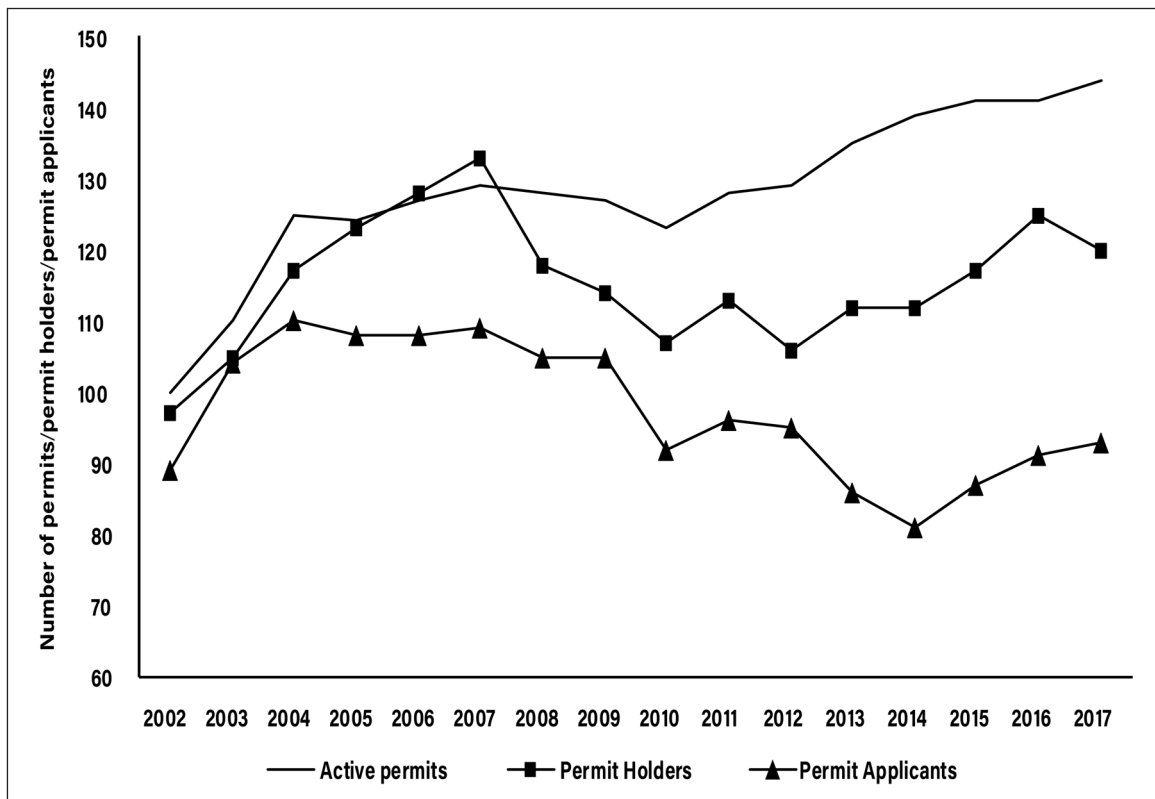
panel, lower right panel) than total permits (upper left panel, lower left panel), because a number of permits were latent or unassigned each year.

The share of all permits (active, latent, and unassigned) held by single permit applicants decreased considerably over time (**Figure 1**, lower left panel) when compared with the share of permits held by single permit holders (**Figure 1**, upper left panel). In general, there were fewer permit applicants than permit holders each year, because some entities applied for multiple permits. The number and share of permits held by single permit applicants was 144 (88%) in 1991, but decreased to 62 (38%) in 2017. Conversely, the number and share of permits held by multiple and top four permit applicants increased from 20 (12%) in 1991, to 102 (62%) in 2017.

But, when examining trends in active permit applicants from 2002–2017 (**Figure 1**, lower right panel), there is a more pronounced difference among the three permit applicant groups. The number and share of active permits held by single, multiple, and top four permit applicants was 95 (64%), 29 (20%), and 23 (16%) in 2002, respectively. By 2017, the permits held by the three groups were almost equally distributed.

We also analyzed trends in latent permits and found that the number of latent permits decreased over time as landings and revenue in the fleet increased. Latent permit holders did not follow the same ownership groups presented in **Figure 1**. There were far fewer entities holding multiple latent permits and there were never more than five multiple latent permit holders in any given year between 2002 and 2017.

**Figure 2** displays the number of active permits, active permit holders, and active permit applicants from 2002 to 2017 with fishing activity in a given year. The number of permits with reported logbook landings (active permits) was 100 in 2002, and increased to 144 in 2017. The number of applicants was lower than the number of active permits in all years because some applicants applied for multiple permits. Although the number of active permits showed an increasing trend, the number of applicants showed a decreasing trend, from the peak of 110 in 2004 to 93 in 2017, indicating that permit applicants were applying for multiple



**Figure 2:** Number of active permits, active permit holders, and active permit applicants from 2002 to 2017.

permits – and an increasing share of permits – over time. The number of permit holders was also lower than the number of active permits in all years except in 2006 and 2007 because those two years had a greater number of permit transfers. With more permit transfers, there was an increase in the total number of active permit holders in those years.

As multiple permit holders and applicants applied for and held an increasing share of permits over time, their share of landings and revenue also increased. In the following section, we present results of our analyses of landings and revenue for the same three groups for both permit holders and permit applicants categories.

#### **4.2. Total landings and revenue, permit holders vs. permit applicants**

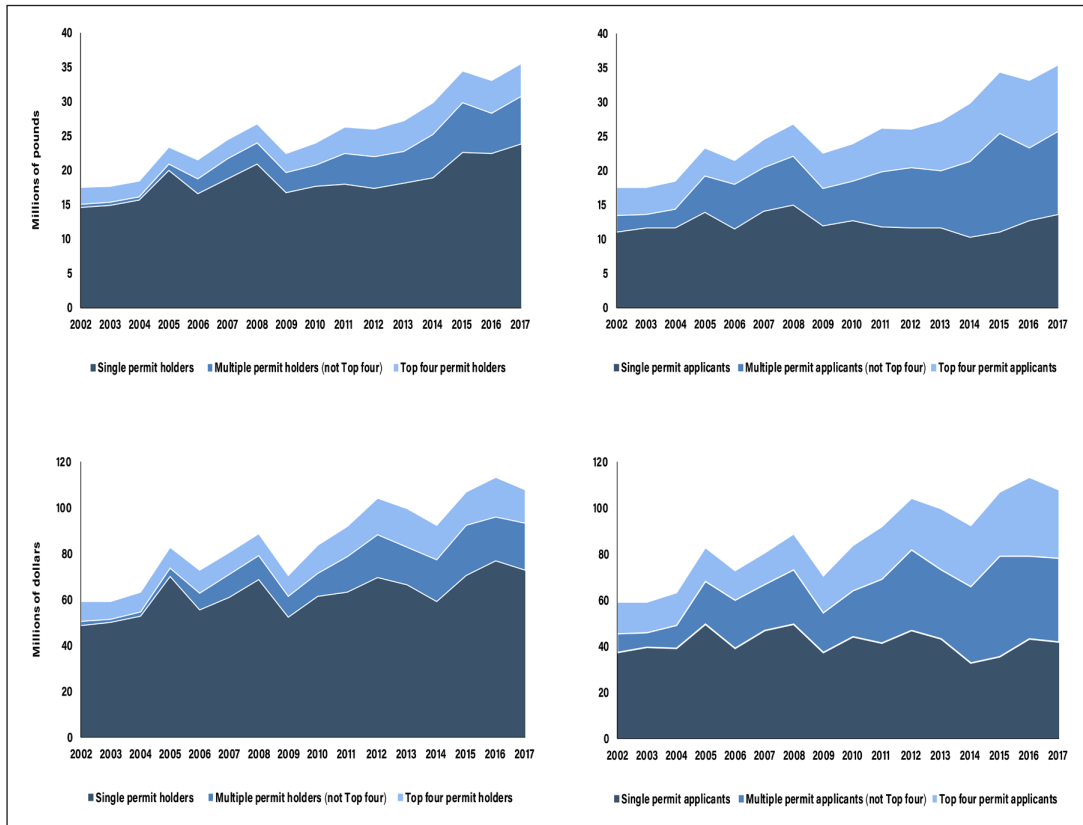
**Figure 3** (upper left panel) displays total landings by the three groups of permit holders from 2002 to 2017. Total landings for the Hawai'i longline fleet were 17.5 million lb. in 2002, and doubled to 35.5 million lb. in 2017. Single permit holders represented 83% of total landings in 2002 but only 67% in 2017. In 2017, multiple and top four permit holders represented 20% and 13% of total landings, respectively.

**Figure 3** (upper right panel) displays total landings for the three groups of permit applicants. In 2002, single permit applicants represented 63% of total landings, while multiple and top four applicants represented 14% and 23%, respectively. In 2017, the share of landings was almost equally distributed among the three groups, with single, multiple (not top four), and top four permit applicants representing 38%, 34%, and 28% of total landings, respectively. The share of landings for the top four applicants more than doubled the share of the top four permit holders (13%).

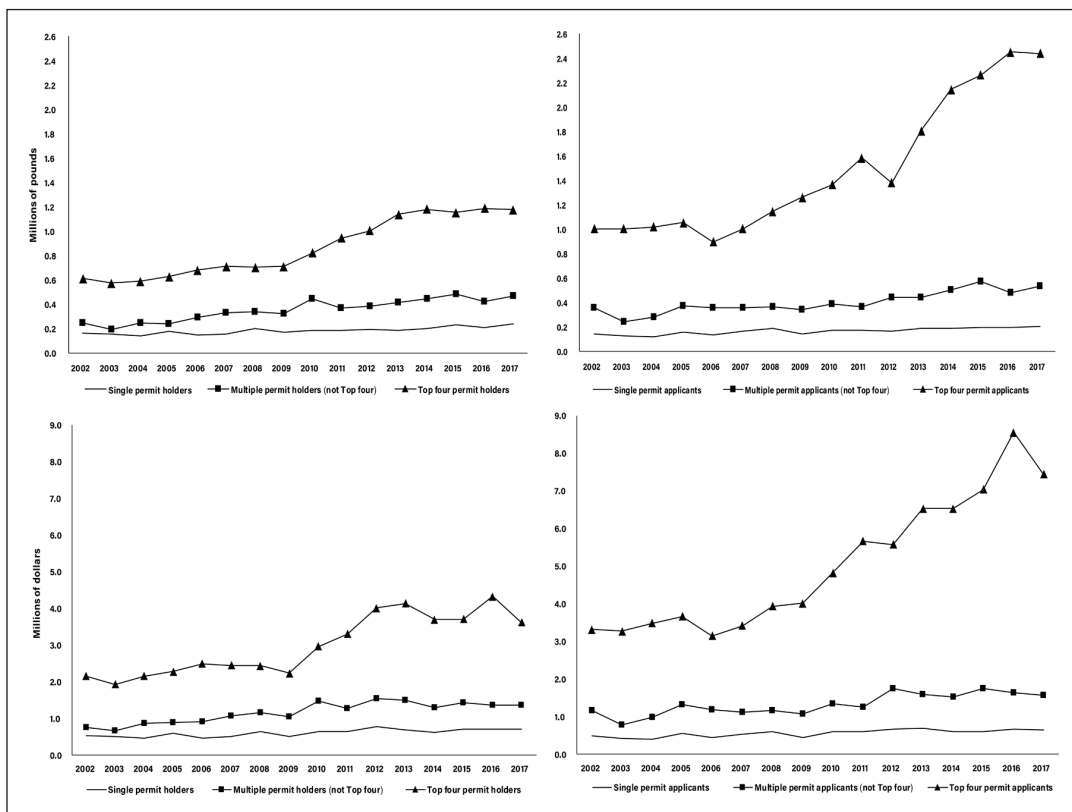
The lower left and lower right panels in **Figure 3** display total revenue (inflation adjusted) by the three groups of permit holders and permit applicants from 2002 to 2017, respectively. Total revenue in the Hawai'i longline fleet was \$59.0 million in 2002, and nearly doubled to \$107.9 million in 2017. Similar to the landings data, the share of revenue for multiple and top four permit applicants exhibited a marked increase over the 15-year period, and revenue was almost equally distributed among the three permit applicant groups in 2017.

#### **4.3. Average landings and revenue, permit holders vs. permit applicants**

The differences in landings and revenue among the three groups of permit holders and permit applicants are more notable when examining their average annual values. **Figure 4** displays the average landings by permit holder group (upper left panel) and permit applicant group (upper right panel) from 2002 to



**Figure 3:** Trends in total landings and total revenue from 2002 to 2017: total landings by permit holder group (upper left panel); total landings by permit applicant group (upper right panel); total revenue by permit holder group (lower left panel); total revenue by permit applicant group (lower right panel).



**Figure 4:** Trends in average landings and average revenue from 2002 to 2017: average landings by permit holder group (upper left panel); average landings by permit applicant group (upper right panel); average revenue by permit holder group (lower left panel); average revenue by permit applicant group (lower right panel).



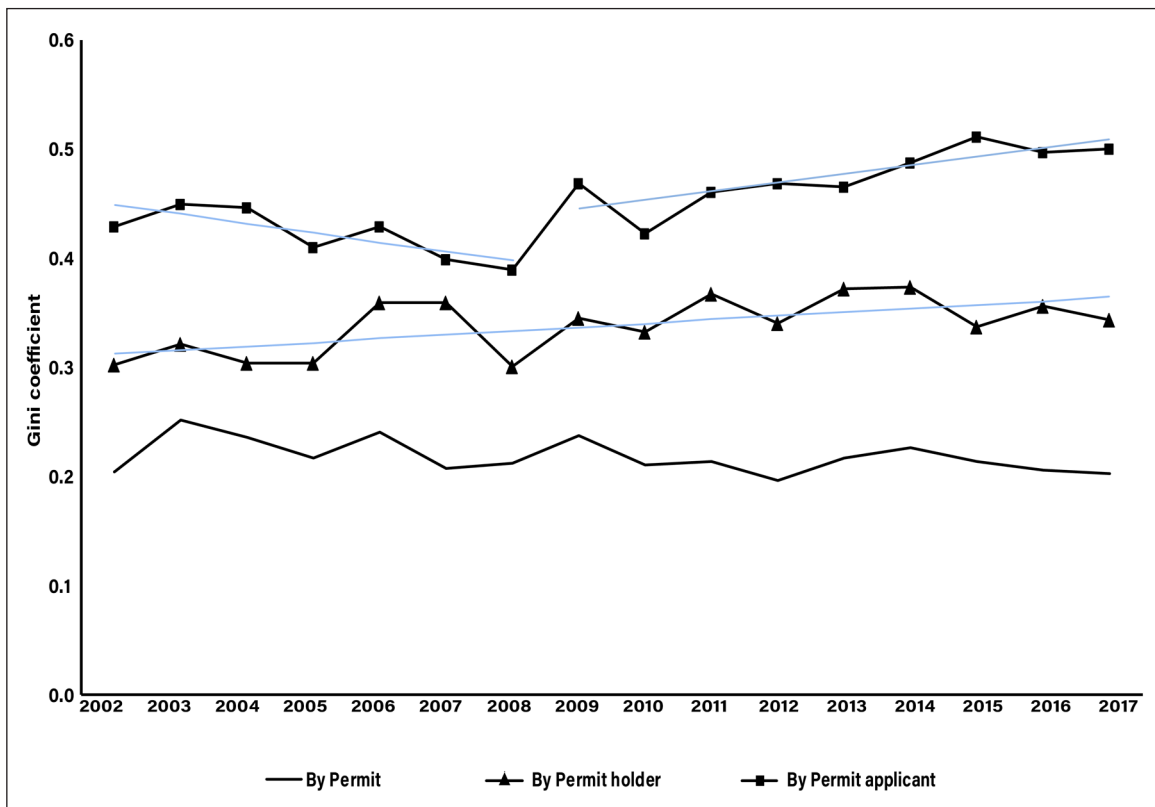
2017. The most noticeable change was the increase in average landings by the top four applicants, from 1.0 million lb. in 2002 to 2.4 million lb. in 2017, which was twice as high as the average landings by the top four permit holders (1.2 million lb.).

**Figure 4** also displays the average revenue by permit holder group (lower left panel) and permit applicant group (lower right panel) from 2002 to 2017. Similar to the average landings, average revenue for the top four applicants more than doubled from \$3.3 million in 2002 to \$7.4 million in 2017, and the 2017 value was twice as high as the average revenue for top four permit holders (\$3.6 million).

#### 4.4. Gini Coefficient

The Gini coefficient was calculated to measure inequality in the revenue distribution of the Hawai'i longline fleet between 2002 and 2017. When using revenue at the permit/vessel level as the measurement unit (a vessel is associated with one permit), the Gini coefficient fluctuated between 0.20 and 0.26 over the whole sampling period, which indicated a relatively stable distribution of revenue among vessels over time. When revenue was analyzed by permit holder, the Gini coefficient was higher and fluctuated between 0.30 and 0.37 from 2002 to 2017, and a significant positive time trend was found with an average increase of 0.003 per year. The Gini coefficient was highest when revenue was analyzed by permit applicant, ranging between 0.39 and 0.51 over the 15-year period, which indicated the revenue distribution was more uneven when examining revenue by permit applicant.

Over the 15-year period, the largest annual change (in both absolute and percentage terms) in the Gini coefficient occurred in 2009, when the Gini coefficient increased significantly from 0.39 in 2008 to 0.47 in 2009. Therefore, we estimated two regressions with a cut-off point in 2009 to detect whether different time trends existed before and after 2009. The estimated time trend using the time period before 2009 displayed a significant negative trend with an annual decrease of 0.01 in Gini coefficient per year. The other estimated time trend using 2009-2017 Gini coefficients exhibited a significant positive trend with an annual increase of 0.006. This indicated that consolidation was ongoing in the fleet and increased after the WCPFC catch limit was established in 2009. **Figure 5** displays the Gini coefficient from 2002 to 2017 by permit, permit holder, and permit applicant, along with the estimated significant time trends. The estimation results are displayed in the Supplemental information section.



**Figure 5:** Gini coefficient by permit, permit holder, and permit applicant, 2002–2017.

**Table 1:** Analysis of property rights components as described by Schlager & Ostrom (1992); Scott (1988) that are applicable to Hawai'i longline limited entry permit system (Title 50—Wildlife and Fisheries, 2018).

<b>Property right component</b>	<b>Status in Hawai'i longline limited entry system</b>
<i>Access: the right to enter a resource area</i>	Permits allow fishing with pelagic longline gear <sup>1</sup>
<i>Withdrawal: the right to harvest resources</i>	Permits allow harvesting and retaining pelagic management unit species for commercial sale <sup>1</sup>
<i>Management: the right to make and enforce resource rules</i>	Permits do not confer management rights
<i>Exclusion: the right to exclude others</i>	Permit holders cannot exclude others
<i>Alienation: the right to sell, lease or transfer any of the other rights</i>	Permit holders may only sell or transfer their limited entry permits
<i>Duration: the amount of time an entity has possessed a right</i>	Renewed annually, may be held indefinitely <sup>2</sup>
<i>Quality of Title: The strength of a property rights claim</i>	Permits confer access, withdrawal, some alienation privileges, and may be held indefinitely <sup>1,2</sup>

<sup>1</sup>Subject to state, federal, and international regulations.

<sup>2</sup>Subject to the discretion of the NMFS Regional administrator.

#### 4.5. Property rights

Hawai'i limited entry permits offer vessels with permits the privilege to target highly migratory species using pelagic longline gear subject to manifold state, federal, and international regulations. A summary of the relevant property rights components is described in **Table 1**.

### 5. Discussion

Many studies have examined rights-based management in commercial fisheries from a variety of economic, social, and ecological lenses. These studies have identified the potential economic and ecological benefits (Costello et al., 2008), as well as the negative social and cultural impacts (Carothers & Chambers, 2012; Olson, 2006) of varying levels of rights-based management in commercial fishing industries. Comparably less research has empirically examined distributional inequality following a transition to a rights-based management system (Grainger & Costello, 2016). We examined how ownership of limited entry permits changed over nearly 30 years in a high value, commercial pelagic longline fleet operating without an accumulation cap. We also measured how the distribution of landings and revenue was affected by these ownership changes. Our results indicated that permit consolidation has increased over time. And we discovered that consolidation varies depending on how distributions are analyzed. In our case, whether you examine distributions across permit holders or permit applicants. In addition, our study extends previous research on consolidation in rights-based fisheries by demonstrating empirically how permit consolidation increased revenue inequality over time, which likely decreased fleet competition and created financial barriers to new entrants. We also demonstrate which property right components were conferred in Hawai'i and how they may have fueled consolidation over time. Below we discuss our evidence of consolidation, consider the distributional effects of consolidation, examine free transferability and distributional equity in rights-based systems, and finish with implications for rights-based management.

#### 5.1. Evidence of consolidation

Three distinct permit ownership groups emerged over time in the Hawai'i longline fleet: single permit owners, multiple permit owners, and the top four owners of multiple permits. Our analysis of Hawai'i longline limited entry permit ownership indicates increasing consolidation among entities holding or applying for multiple permits over time. Consolidation in the fleet over time was revealed when examining the number and share of permits, landings, and revenue at the permit applicant level, and to a lesser extent, at the permit holder level.

Consolidation did not lead to fewer vessels fishing, but in general, fewer entities applied for the same number or more limited entry permits each year. This trend began in 2004, after the shallow-set fleet reopened following a three-year court-ordered closure. The number of permits showed a monotonic increase, whereas the number of applicants showed a monotonic decrease, and the gap between them widened over time.

This trend was more evident after the WCPFC initiated bigeye catch limits in 2009, which resulted in the first WCPFC closure in the Hawai'i longline fleet. Four more closures occurred after 2009 (2010, 2015, 2016, and 2017) that lasted more than a month. These closures resulted in economic losses for many segments of the fleet and higher market prices for bigeye tuna (Ayers et al. 2018). The number of permit applicants decreased at the highest rate between 2009 and 2010 following these closures. Thus, the WCPFC catch limits and closures thereafter likely induced a race to fish and triggered greater fleet consolidation. With an increasing number of permits and a decreasing number of permit applicants, there was more concentration of permits among applicants of multiple permits. The share of active permits held by single, multiple, and top four permit applicants were 68%, 14%, and 18% in 2002, respectively. But, by 2017, the permits held by the three groups were almost equally distributed.

The increasing concentration of applicants with multiple permits was also reflected in the landings and revenue. In 2002, close to 65% of landings and revenue came from single permit applicants, 14% from multiple permit applicants (not top four), and around 20% from the top four permit applicants. In 2017, landings and revenue were almost equally distributed among the three groups. Increases in average annual revenue earned by the top four permit applicants were also substantial. Average revenue for single and multiple permit applicants (not top four) increased over 30% between 2002 and 2017, while the average revenue for top four permit applicants more than doubled during the same period to \$7.4 million in 2017.

Increases in the number of applicants applying for multiple permits – an indicator of permit consolidation – were likely driven by increasing profits. Kalberg and Pan (2016) estimated that at least two-thirds of Hawai'i longline vessels realized positive net returns in 2012 and the direct net returns had increased 233 percent from the 2005 level. Although the annual profit for each vessel is unknown except in the years when cost-earnings survey were conducted, evidence suggests that catch limits may have led less profitable operations to exit the fleet, which led to a greater concentration of profitable operations. Multiple permit owners may have been more buffered from shocks stemming from institutional change and capitalized on an opportunity to increase their market share.

### **5.2. Distributional effects of consolidation**

Although several inequality measures exist, the Gini coefficient is valuable for managers because it provides a quantitative measure of inequality in the revenue distribution over time. When the Gini coefficient was analyzed at the permit level between 2002 and 2017, it was relatively stable with no significant trend. When the measurement unit was revenue per permit holder, the Gini coefficient was higher, and we found a slight positive trend. This indicates a slight increase in inequality over time among permit holders. But, the Gini coefficient was greater when the measurement unit was revenue per permit applicant. For permit applicants, a steeper positive time trend was found in the Gini coefficient after WCPFC catch limits were enacted in 2009, indicating that revenue inequality intensified after this policy change. Furthermore, our analysis reveals that how you analyze a commercial fishing fleet (in this case, permit vs. permit holder vs. permit applicant) significantly affects measures of inequality and distributional equity.

Although the Hawai'i longline fleet is not managed using catch shares, we compared its Gini coefficients with other U.S. catch share fisheries to assess its standing against them. Brinson and Thunberg (2016) reported that Gini coefficients ranged from 0.15 to 0.89 for the 16 U.S. catch share programs in 2013, with a mean of 0.51. Using revenue per permit applicant in the Hawai'i longline fleet, the Gini coefficient indicated that revenue inequality in recent years was close to the average of other U.S. fisheries managed via catch shares. If catch shares were implemented in the Hawai'i longline fleet, revenue inequality might increase further. The Gini coefficient increased an average of 12% during the first year the catch share program was implemented for nine catch share programs, primarily due to a decrease in the number of entities holding shares that first year (Brinson & Thunberg, 2016). Therefore, any management decisions regarding catch shares for the Hawai'i longline fleet should consider the potential distributional effects prior to program implementation.

### **5.3. Free transferability and distributional equity in rights-based systems**

Previous scholarship has demonstrated how limited entry alone does not address issues related to overcapitalization in commercial fisheries (Wilens, 1988). In recent years, catch shares have supplanted limited entry systems as a more effective way to curtail overcapitalization, improve safety at sea, and increase economic efficiency (Birkenbach et al., 2017; Pfeiffer & Gratz, 2016). But, our analysis of the Hawai'i longline limited entry system indicates that limited entry can exhibit distributional issues similar to those observed in catch shares systems. Free transferability is a component of many catch shares systems and is

allowed in the Hawai'i longline limited entry system. In our property rights analysis, this was conferred through the alienation component. If a fishing fleet managed via rights-based management remains viable, profitable, and permits or shares are freely transferrable, an amount of permit consolidation may be inevitable without an ownership cap on permits or quota (an additional constraint on the alienation right) during the institutional design phase.

In another U.S. Pacific island fishery, the American Samoa longline limited entry program, a 10% ownership cap was implemented during the institutional design phase. In American Samoa, there are only 60 limited entry permits, thus a single entity may only hold six permits at any given time. No such ownership cap was initiated at the onset of the Hawai'i limited entry system, and three decades later, it would likely be politically challenging to implement. If free transferability is not a component of a rights-based system at the onset of the program, future changes to address consolidation can be difficult to implement as ownership factions and interests become entrenched. This indicates the importance of foresight during institutional design, particularly if distributional equity is a management concern (Clay et al., 2010).

#### **5.4. Implications for rights-based management**

Our analysis reveals that consolidation has not led to fewer longline vessels fishing in Hawai'i, but it has led to reductions in annual permit applicants. At the least, this is evidence of greater administrative coordination among permit groups in the fleet. These groups may be somewhat concealed when examining permit holders, but they emerge when permit applicants are examined over time. Further, fishery managers, scientists, and fleet participants reviewed and corroborated our data presented on permit applicants. There may be even fewer permit owners than our permit analysis suggests, and thus greater consolidation of permit ownership, suggesting even greater coordination in business operations.

From a governance perspective, this coordination could be viewed in several different ways. In terms of collective action, contacting or meeting with an entity or agent in charge of multiple vessels can reduce transaction costs, particularly when a pressing management issue arises in the fleet. Likewise, an apparent reduction in the number of permit owners has not triggered reductions in the active vessels, the labor force (captains or crew), or led to significant geographic shifts in fisheries operations as it has in other rights-based commercial fisheries (Olson, 2011). But, reductions in single permit applicants and to a lesser extent, single permit holders may be evidence that it could be more difficult for smaller fishing operations to compete against larger fishing operations, particularly in the contemporary era of reduced WCPFC bigeye tuna catch limits. Since permit transactions were our primary data source, it is unclear whether Hawai'i limited entry longline permits were being purchased when they were transferred from one entity to another, or if permit holders leased out their permits akin to quota leasing in other global rights-based fisheries (Emery et al., 2014; Pinkerton & Edwards, 2009).

When examining distributional effects of fisheries policy, it is important to consider the management goals. As suggested in Brinson and Thunberg (2016), imposing caps on the use of quota would be a more effective way to deal with excessive consolidation than imposing caps on the ownership share. Therefore, when considering rights-based management options for the Hawai'i longline fleet or other global fisheries, imposing caps on the use of quota could be an important consideration, since nearly a third of total landings in the Hawai'i longline fleet were captured by the top four permit applicants in 2017.

## **6. Conclusion**

Three questions guided this research: How has the Hawai'i longline limited entry permit ownership changed over time, how have ownership changes affected the distribution of landings and revenue across the fleet, and which property rights components are associated with Hawai'i longline limited entry permits?

When examining limited entry permit transactions, we found increasing consolidation of permit ownership, particularly when all permits were analyzed (active, latent, and unassigned). In addition, we found considerable differences in ownership changes depending on whether we examined permit holders or permit applicants. There were more pronounced differences among the three ownership groups when the permit applicant field was used as a proxy for ownership rather than the permit holder.

The distribution of total landings among the three groups for permit holder and permit applicant closely reflected the changes revealed in the ownership analysis: multiple permit applicants (both multiple and top four applicants) landed an increasing amount of fish over time, to the point that they landed a majority of fish fleet-wide. These differences were more evident in average landings per applicant. When revenue was examined at the vessel level, there appears to be little revenue inequality across the fleet. But, when permit applicants are used to analyze the fleet, there is increasing evidence of permit consolidation and revenue inequality over time. This consolidation appears more evident after the WCPFC bigeye tuna catch limits

were instituted in 2009. Similar to the findings from landings, average revenue per applicant exhibited the greatest increase over time.

Our property rights analysis revealed that free transferability of limited entry permits and a profitable fishery likely propelled permit consolidation. Over time, this led to distributional equity concerns, similar to those observed in other U.S. catch shares systems. Constraining the free transferability portion of the alienation property right component via an ownership or share cap during the institutional design phase could prevent future consolidation and distributional concerns.

One of the concerns for implementing catch shares in the Hawai'i longline fleet (Criddle et al., 2011) and in other global fisheries are the distributional issues associated with initial allocation (Lynham, 2014). Our study provides a longitudinal analysis of landings and revenue distribution associated with permit holders and permit applicants for management consideration, particularly if catch shares are ever implemented for the Hawai'i longline fleet. We also demonstrate empirically how free transferability in a rights-based management system resulted in increased concentration of landings and revenue into the hands of fewer entities over time across a profitable commercial fishing fleet. Decreased competition did not reduce longline vessels in Hawai'i, and it is unclear how consolidation will affect overall resilience in the fleet over time. This may be an area for future research. Nevertheless, our findings should be important considerations for fisheries managers in Hawai'i and elsewhere across the globe considering transitions to rights-based systems.

### Supplementary Information

Regression Results for Time Trend for Gini Coefficient Using Different Parameters.

The time trend for Gini coefficient is specified as follows:

$$Y_t = a + bt + \varepsilon_t, \quad (1)$$

where  $Y_t$  is Gini coefficient in period  $t$ , where  $t = 2002$  to  $2017$  ( $N = 16$ ), and  $t$  stands for year.

**Table S1:** Regression Results for Time Trend for Gini Coefficient when Using Revenue per Permit Holder as Measurement Unit,  $t = 2002$  to  $2017$ .

<u>Independent Variable</u>	
$a$	-5.245*
	(-2.48)
$b$	0.003*
	(2.64)
$R^2$	0.33

*Note:* Numbers in parentheses are  $t$ -ratios; \* significant at the 5% level.

We estimated two time trends for the Gini coefficient when revenue per permit applicant was used as the measurement unit. The first used the time period  $t = 2002$  to  $2008$ , and the second used the time period  $t = 2009$  to  $2017$ .

**Table S2:** Regression Results for Time Trend for Gini Coefficient when Using Revenue per Permit Applicant as Measurement Unit,  $t = 2002$  to  $2008$ .

<u>Independent Variable</u>	
$a$	19.754*
	(3.37)
$b$	-0.010*
	(-3.30)
$R^2$	0.69

*Note:* Numbers in parentheses are  $t$ -ratios; \* significant at the 5% level.



**Table S3:** Regression Results for Time Trend for Gini Coefficient when Using Revenue per Permit Applicant as Measurement Unit,  $t = 2009$  to 2017.

<u>Independent Variable</u>	
$a$	-12.273* (-2.78)
$b$	0.006* (2.89)
$R^2$	0.54

Note: Numbers in parentheses are  $t$ -ratios; \* significant at the 5% level.

## Competing Interests

The authors have no competing interests to declare.

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