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# Measuring productivity in a shared stock fishery: A case study of the Hawaii longline fishery

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ABSTRACT

Fisheries productivity is the result of many factors, including endogenous and exogenous elements, such as regulation and stock condition. Understanding changes in productivity and the factors affecting that change is important to fishery management and a sustainable fishing industry. However, no study has been conducted to measure productivity change in the Hawaii longline fishery, the largest fresh bigeye tuna and swordfish producer in the U.S. Using a Lowe productivity index, productivity change in the Hawaii longline fleet between 2000 and 2012 is measured in this study. In addition, a biomass quantity index is constructed to disentangle biomass impacts in a pelagic environment in order to arrive at an "unbiased" productivity metric. This is particularly important in the Hawaii longline fishery where catches rely mostly on transboundary (shared) stocks with little control on the total amount of extraction. As resource depletion of the transboundary stocks occurs, productivity loss may follow if less output is obtained from the same input usage, or more inputs are used to extract the same catch level from the fishery. Finally, the study compares productivity change under different fishing technologies.

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## 1. Introduction

Fisheries productivity is the result of many endogenous factors, such as fishing gear improvement, technical change for both electronics and engine power, and exogenous factors such as regulatory and stock conditions. Understanding the impact of both types of changes on productivity is important to fisheries management. While a domestic fishery may enjoy productivity gains from output control policies (such as catch shares) that lead to an ending of the "race to fish" and an increase of fish stock abundance [1], it may not be the case for a fishery that operates in an open ocean where fishermen face competition from foreign fisheries or different fishing gear that harvest the fish from the same stocks. This paper aims to measure the productivity change in the Hawaii longline fishery where catches are mostly from transboundary stocks, and examines the impacts of key elements, including stock conditions and fishing technology (e.g., species targeted), on productivity change. This information can contribute to fisheries management and a more sustainable fishery industry.

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## 2. Fishery synopsis

The Hawaii longline fishery, the largest fishery managed under the Western Pacific Fisheries Management Council, operates in the North Pacific Ocean harvesting fish inside and outside the exclusive economic zone (EEZ) of the U.S. From 2002 to 2012, the period included in this study, there were 100–129 active vessels that completed between 1162 and 1380 fishing trips annually, generating revenues ranging from $37 to $92 million per year [2]. Currently, the Hawaii longline fishery is managed under a limited entry program with 164 permits (permits are transferable) and a total allowable catch (quota) for bigeye tuna. The bigeye tuna quota was imposed on the fishery by two Regional Fisheries Management Organizations (RFMOs), the Western and Central Pacific Fisheries Commission (WCPFC), and the Inter-American Tropical Tuna Commission (IATTC), due to the overfishing status of bigeye tuna in the North Pacific Ocean [3].

Vessels in the Hawaii longline fishery are set up to conduct two types of fishing by adjusting the number of hooks on a fishing line and setting the lines and hooks to different depths in the water column. Deep-set lines target bigeye tuna and shallow-set lines target swordfish. Switching fishing targets during a trip is technically feasible. In practice, fishermen cannot set gear to target swordfish if they do not report that intent to the National Marine Fisheries Service (NMFS) prior to starting the trip because any swordfish targeted trips require 100% observer coverage. Currently, the majority of the fishing vessels of the Hawaii longline fishery target bigeye tuna. About 15% of vessels target swordfish during spring and summer seasons and target bigeye tuna during the rest of the year (with one or two vessels fishing for swordfish year-around), while the other 85% of the vessels target bigeye tuna year-round. In 2012, bigeye tuna alone accounted for 67% of total revenue at $62 million for the entire fleet, while swordfish accounted for 7% of total revenue at $6 million, and other pelagic species (including yellowfin tuna, albacore tuna, moonfish, mahimahi, and pomfret) contributed 26% to total revenue [2]. All the species caught by the Hawaii longline fleet are both highly migratory and shared stocks with other countries fishing in the North and Central Pacific Ocean. While the Hawaii longline fishery was responsible for the majority of total U.S. bigeye tuna and swordfish landings, the total fish caught by all U.S. fleets comprised only a small portion of the total catch for the two species from the North Pacific. In 2012, U.S. fishermen harvested 7534 metric tons (mt) of bigeye tuna and 1477 mt of swordfish, approximately 4% and 6% respectively of the total catch from the North and Central Pacific [4].

The Hawaii longline fishery is heavily regulated. Pan [5] provided a detailed description of the main management tools/regulations implemented in the fishery. A brief summary of the management tools imposed on the fishery during the period, 2001–2012, covered in this study is provided in Table 1.

In addition to regulatory conditions, productivity of the Hawaii longline fishery may be influenced by other exogenous conditions. An important exogenous factor is that the Hawaii longline fishery faces strong competition from foreign longline fleets and purse seiners that target the same species from a common pool resource [5]. These stocks have been subjected to overfishing for over a decade [3]. Although the bigeye tuna catch by the longline fleets in the West and Central Pacific Ocean (WCPO) declined in recent years due to imposed conservation measures, the total bigeye catch still went up because bigeye catches by purse seine fisheries increased in the same region and thus the overfishing has not been halted [6]. The Western and Central Pacific Fisheries Commission (WCPFC) called for further reduction in bigeye catch limits. The total available catch to the Hawaii longline fleet declined from the current level of 3763 mt to 3554 mt for both 2015 and 2016, and will further decline to 3345 mt for 2017 [3].

Another exogenous factor is regulations intended to protect endangered species. For example, a study by [7] shows that fishery closures during 2000–2004 and sea turtle caps instituted in the Hawaii swordfish longline fishery in 2004 in order to protect endangered sea turtle species led to spillover effects. The foregone production from the Hawaii longline fishery was replaced by foreign fleets that began fishing the same grounds where the Hawaii vessels used to fish before implementation of the regulations.

Third, a vast marine protected area, named the Papahānaumokuākea Marine National Monument, was established by U.S. President George W. Bush on June 15, 2006, which shrunk the fishing grounds in the EEZ that used to be available to the Hawaii longline fishery [9]. The monument encompasses an area of approximately 139,793 square miles (362,061 $km^2$) in the Northwestern Hawaiian Archipelago. This amounts to 23% of the total Hawaiian Archipelago EEZ where no fishing activities are permitted. Historically, 9% of the catch of bigeye and 17% of swordfish came from the EEZ of this Northwestern Hawaiian Archipelago area [8]. In addition, the False Killer Whale Take Reduction Team [10] established a “Southern Exclusion Zone” (SEZ) south of the Main Hawaiian Islands to prevent fishery interaction (bycatch) with False Killer Whales in 2012. Whenever the deep-set longline fishery reaches a specific level of observed false killer whale bycatch, the area will be closed for deep-set fishing.

Catch data show that Hawaii longline fishing increased its dependence on resources outside the U.S. EEZ. For example, in 2012 among the total bigeye tuna landed (kept) by the Hawaii longline fishery, 65% were caught outside of the U.S. EEZ (including the Hawaiian Islands EEZ and the Pacific Remote Islands Area EEZ), which is a 21% increase compared to 44% in 2002 [6].

Cost-earnings studies show the Hawaii longline fishery garners a small profit margin and that margin has tended to decline as operating costs have increased in recent years [5]. Because operating costs increased, small productivity gains in fishing industries can be important for maintaining or increasing profit levels for individual vessels. Therefore, it is important to understand productivity changes and factors that may affect the changes. The objective of this study is to measure productivity change in the Hawaii longline fishery over time and to distinguish the effect of technical efficiency (the rate of inputs converted into outputs) and the effects of resource abundance on that productivity.

Although there have been several economic studies on the productivity of the Hawaii longline fishery [11–13], all of the previous studies focused on examining the productivity performance in a static setting using a single year of data. Little attention has been given to measuring productivity changes in the fishery over time. Moreover, biomass was not considered as a variable in these previous studies. Productivity measures without considering the impact of biomass can be biased [14], as biomass changes may influence fishery industry productivity, often resulting in higher or lower outputs for the same amount of inputs. This paper provides the first comprehensive estimate of productivity changes in the Hawaii longline fishery where catches are mostly from transboundary stocks.

**Table 1**
Main management tools employed during 2001–2012.

| Date | Management tools employed | Related fishery |
|---|---|---|
| April 2001 | Partial closure of certain waters in November 1999, and a complete shutdown of the swordfish fishery in April 2001 due to the concerns of turtle interactions with the fishery | Swordfish |
| April 2004 | Reopen of swordfish fishing with a series of regulations (100% observed, cap of fishing effort, caps of sea turtles, bait and gear modifications…) | Swordfish |
| 2004 | Bigeye total allowable catch (TAC) in EPO imposed by the IATTC beging in 2004 and it only applied to vessels that were longer than 24 m. The annual TAC was 150 mt from 2004 to 2006, and 500 mt after 2007 to present. | Bigeye tuna |
| Jun 20006 | A vast marine protected area, named Pahānaumokuākea Marine National Monument, was established in NorthWestern Hawaiian Islands. | Swordfish and bigeye |
| 2009-2010 | Bigeye TAC imposed in WCPO in 2009 and the annual TAC was 3763 mt. The bigeye fishery was closed for two days before New Year in 2009 and closed on November 22 when the catch limit was reached. | Bigeye tuna |
| 2011-2012 | The Hawaii fishery had no effective bigeye TAC 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 | Bigeye tuna |
| November 2012 | NMFS revised the sea turtle catch caps (limits) for leatherback turtles from 16 to 26, and for loggerhead turtles from 17 to 34 | Swordfish |
| December 2012 | Established a “Southern Exclusion Zone” (SEZ) south of the Main Hawaiian Islands to prevent fishery interaction (bycatch) with False Killer Whales | Bigeye tuna |

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