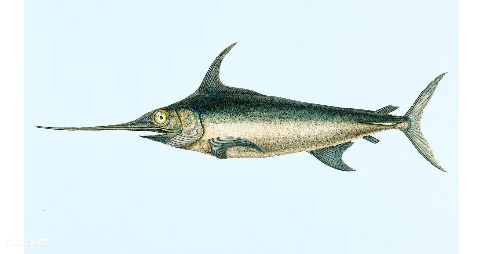
**Standardization of Western and Central North Pacific Swordfish (*Xiphias gladius*) Catch Per Unit Effort in the Hawaii Longline Fishery from 1995-2021**

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# Abstract

The swordfish (Xiphias gladius) catch per unit effort for the Hawaii-based longline fishery was standardized from the Pacific Islands Regional Observer data set. The fishery was divided into the tuna-targeting deep-set sector and the swordfish-targeting shallow-set sector. Additionally, the shallow-set sector was standardized in two time periods: an early period (1995–2000) and a late period (2005–2021) because the shallow-set fishery was closed from 2001 to 2004, and regulations caused changes in the fleet operations thereafter. Four different models were evaluated to standardize the CPUE for each time series: the delta-lognormal model, the negative binomial model, the zero-inflated negative binomial model, and the Poisson model. The delta-lognormal model provided the best model fits and explained the most percent deviance of those evaluated. The models explained between 26 and 65% of the deviance in the shallow-set sector and 35% of the deviance in the positive catches for the deep-set sector, but only 4% of the proportion of positive catches in the deep-set sector. The shallow-set standardized annual CPUE values show an increase in catch rates in the early period followed by a peak in 2006 after the closure. CPUE values increased again from 2010 to the present. The CPUE values for the deep-set sector were relatively flat and had high variability.

# Introduction

Broadbill swordfish (*Xiphias gladius*) inhabit the Pacific Ocean between 50° N and 50° S. They are a commercially important highly migratory species caught primarily by the Japanese, Taiwanese, and U.S. longline fisheries (Bigelow *et al.*, 1999). The swordfish stock in the North Pacific has been assessed as a single stock scenario and under a two stock scenario, with one stock in the western central Pacific Ocean (WCNPO) and one stock in the eastern Pacific Ocean (EPO). These stocks were assessed in 2009 and again in 2014 by the Billfish Working Group (BILLWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) (ISC BILLWG, 2009; ISC BILLWG, 2014). The 2018 assessment of North Pacific swordfish only considered the WCNPO (ISC BILLWG 2019), and subsequent discussions with the Pacific Community and the Inter-American Tropical Tuna Commission (IATTC) redefined the EPO stock as a primarily southern stock. The southwest Pacific stock (SWPO) and the EPO stocks were assessed in 2021 and 2022, respectively (Ducharme-Barth, *et al.*, 2021, Minte-Vera, et al., 2022).

The BILLWG of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC) has proposed to attempt a benchmark assessment of North Pacific swordfish Xiphias gladius in 2023. In preparation for the assessment, this working paper describes the standardization swordfish catch rates from the Hawaii-based longline fleet, which targets swordfish in the shallow-set sector and catches swordfish as bycatch in the deep-set sector. Swordfish are caught as targeted-species in the Hawaiian longline shallow-set fishery sector (< 15 hooks per float) and as bycatch in the tuna targeting Hawaiian longline deep-set fishery sector (≥ 15 hooks per float). This fleet has been described previously by Ito and Childers (2018) and also in a working paper submitted to the same BILLWG session (Ito 2023) and there have not been additional substantial changes to the fishery since 2018. Historically the Hawaiian longline fishery has targeted tuna; however, in the early 1990s the number of vessels targeting swordfish began increasing and the fleet accounted for 40% of the total US swordfish catch in 2012. Observers were first placed onboard longline vessels in 1994. Interactions with protected sea turtles caused the closure of the shallow-set swordfish fishery from February 2001 to May 2004 (Gilman *et al.,* 2007). During this time many vessels targeting swordfish began targeting tuna. A second closure occurred March–December 2006 when the Hawaii-based shallow-set longline fishery for swordfish reached the annual limit for interactions with loggerhead sea turtles, and additional closures of the fishery have occurred in recent years (NMFS, 2022). Several changes to the reporting regulations have occurred since its onset in 1994 (Pacific Islands Region Office, 2017). Observer coverage varied significantly prior to 2000, with observer coverage between 3.3 and 10.4 % for the entire fishery (NMFS, 2022). Starting in 2001, the observer program had a target of 20% observer coverage on deep-set longline vessels and mandatory 100% observer coverage on shallow-set longline vessels.

# Methods

## Data Sources

The US Federal logbook program to monitor the Hawaii-based longline fishing fleet began in November 1990 to manage US domestic fisheries for tuna, swordfish, and other economically important pelagic species. Logbooks are filed by all operators of fishing vessels conducting longline fishing operations on the High Seas and within the U.S. Exclusive Economic Zone in American Samoa, Guam, Hawaii, the Northern Mariana Islands, and U.S. possessions in the western Pacific and offloading in U.S. ports and provide set-by-set information on environmental and operational aspects of fishing operations. The Hawaii-based longline fishery can be divided into two sectors, the tuna-targeting deep-set sector comprises the majority of the fish fleet and the swordfish-targeting shallow-set sector. Data were extracted from the Oracle database on 2 September 2022. After filtering for incomplete and erroneous entries, there were 335,876 sets available for inclusion from 1 January 1995 to 31 December 2020.

The deep-set trips are typically further south than the shallow-set trips, which are concentrated around the sub-tropical frontal zone (STFZ) where large swordfish are caught (Sculley et al., 2019). After the closure, shallow sets were defined as sets with fewer than 15 hooks per float, however, prior to the closure most sets targeting tuna used 10 or more hooks per set. To be consistent with the fishermen behavior prior to 2004, deep-set trips were defined as using 10 hooks per float or more as the division prior to 2004, and using 15 hooks per float or more from 2004 through the present (Sculley, 2019).

The environmental variables used in the standardization were obtained from publically available data sets. Sea Surface temperatures (SST) from January 1994 present were based on monthly 0.5° resolution composites from the NOAA GOES-E/W satellite downloaded from Pacific Islands Fisheries Science Center (PIFSC) OceanWatch (2022). The Southern Oscillation Index (SOI), the Pacific Decadal Oscillation Index (PDO), and the el Niño Southern Oscillation Oceanic Niño Index (ONI) were monthly region wide indices (NOAA NCDC, 2022). Mixed layer depth (MLD) were based on 0.33° × 1° monthly means of GODAS data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA[[1]](#footnote-1). Lunar illumination data consisted of values between 0 and 1 which measured the proportion of the moon illuminated above Hawaii. It can be used as a proxy to indicate lunar stage with 0 indicating a new moon and 1 indicating a full moon (US Naval Observatory, 2022).

## CPUE Standardization

# Results

## Descriptive Catch Statistics

## CPUE Standardization

# Discussion

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# **Tables**

# Figures

1. http://www.esrl.noaa.gov/psd/ [↑](#footnote-ref-1)