20 years of spatial and temporal changes in Hawaiʻi longline fishery catch and their potential for forecasting future fishery performance

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Using three fisheries-dependent data sets (logbook [1995-2016], observer [2006-2016] and dealer [2000-2016] data) allowed us to take a comprehensive look at spatial and temporal trends in the Hawaiʻi-based longline fishery over the past 20 years. Logbook data completed by fishermen provides catch, effort, and catch location data of landed species for all vessels in the fleet, while observer data provides lengths of every third fish caught, including discards, but only ~20% of vessels have an observer on board. Dealer data provides weight of all fish sold at the Honolulu Fish Auction and can be matched with logbook data for each vessel trip.

The deep-set longline fishery, which targets bigeye tuna, has expanded considerably over the past two decades. Not only has total effort increased from nearly 8.4 million hooks set in 1995 to over 47 million hooks set in 2015, but the spatial footprint of the fishery has expanded as well. At the beginning of the time series, nearly all (97%) of Hawaiʻi's deep-set effort was set in the fishery's core operating area south of 26°N and west of 150°W, whereas in 2015 over 40% of the deep-set effort was set either north or east of these bounds. This expansion is most prominent in the third quarter of the year (Fig. 1).

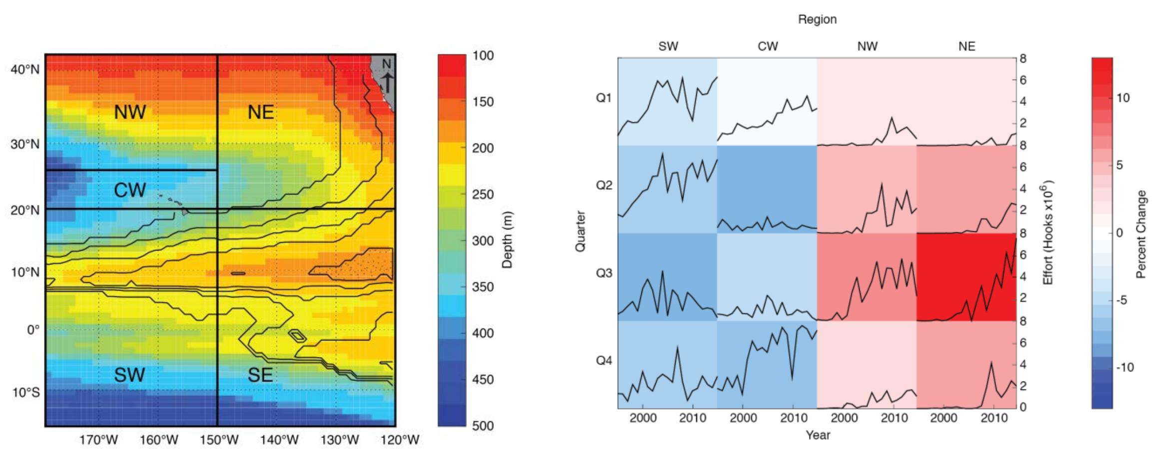

Fig. 1 Left: Map depicting the five regions by which the fishery is examined overlaid on the climatological (1995 – 2015) median depth of preferred bigeye thermal habitat (8 – 14 °C, shaded) and the depth of the 1 mL/L oxygen threshold (contoured every 100 m from 100 to 500 m, with stippling where the depth is less than 100 m). Right: The difference between the proportion of total annual effort set in each region and quarter from the beginning (1995 – 1997 mean) to the end (2013 – 2015 mean) of the time series is shaded. Total annual effort in each region and quarter is plotted in black. Note: nearly no effort is deployed in the SE region.

The marked northeastward expansion of the fishery appears to have several drivers. First, it is possible that waters closer to Hawaiʻi were unable to support an increase in effort due to both Hawaiʻi-based and international effort. Waters northeast of Hawaiʻi had little to no international competition. Second, bigeye catch rates within the fishery's core operating area are lowest in the third quarter of the year. However, during this quarter catch rates are still high in waters to the northeast of Hawai‘i. Finally, preferred bigeye thermal habitat and oxygen levels overlap most completely with deep-set gear in waters to the northeast of Hawai‘i (Fig. 1). This overlap could act to increase bigeye's catchability, and in turn catch rates, in northeastern waters. We can conclude that the fishery expanded spatially in the third quarter in response to low target catch rates. In waters to the northeast of Hawai‘i the fleet faced little competition and found a particularly efficient fishing ground due to its local oceanography.

One consequence of the fishery's spatiotemporal expansion has been an increase in the amount of lancetfish caught. Lancetfish have no commercial value and all catches are discarded. Lancetfish catch rates are highest north of 26°N and in the third quarter. Thus, the fishery is deploying more effort both in the region where lancetfish are most commonly caught and at the time when catch rates are highest. This has resulted in lancetfish catches exceeding bigeye catches for the past decade (Fig. 2).

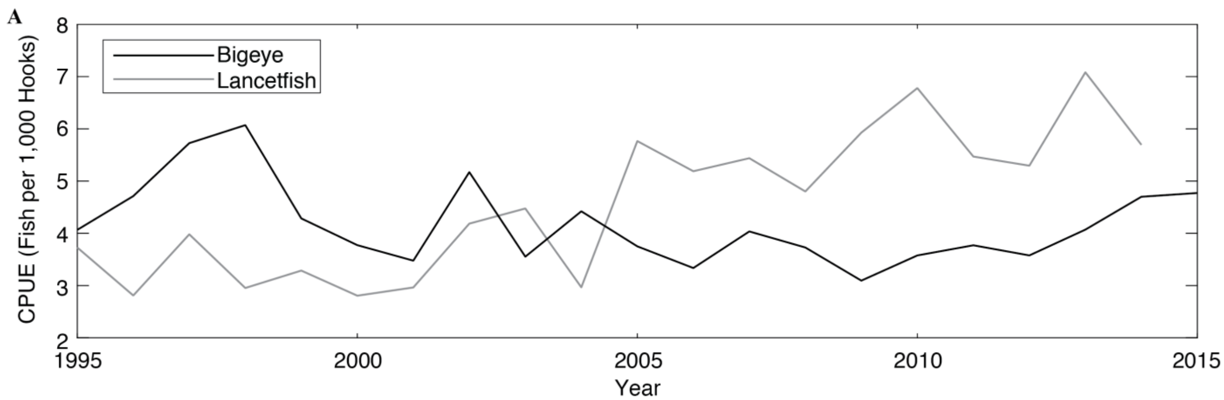

Fig. 2 Annual deep-set bigeye tuna (black) and lancetfish (grey) CPUE.

Trends in productivity and catch rates in the fishery over the past decades may be caused by spatiotemporal changes in the fishery itself, changes in the stock, or both. To better understand these trends we built General Additive Models (GAM's) to analyze time series of mean weight, catch per unit effort (CPUE, in number of fish caught per 1000 hooks) and weight per unit effort (WPUE, in kg caught per 1000 hooks). The GAMs allow us to tease apart trends caused by changes in the stock from those caused by changes in seasonality and geographic location of the fishery. Over the past 16 years, mean weights of commercially important fish in the Hawai‘i-based longline fishery have declined 10%. This is in part due to a decline in mean weight by 5 out of the eleven most commonly caught species, and partly due to a change in species composition of the catch. Smaller fishes, such as pomfrets and walu, are becoming more common while larger fishes, such as opah and striped marlin, make up a lesser proportion of the total catch (Fig. 3a). Because more small fish, and more small fish species are caught, the productivity of the fishery (WPUE) declined by 53% since 2000, but the shift in area and seasonality of fishing effort helped maintain productivity in the fishery (Fig. 3c).

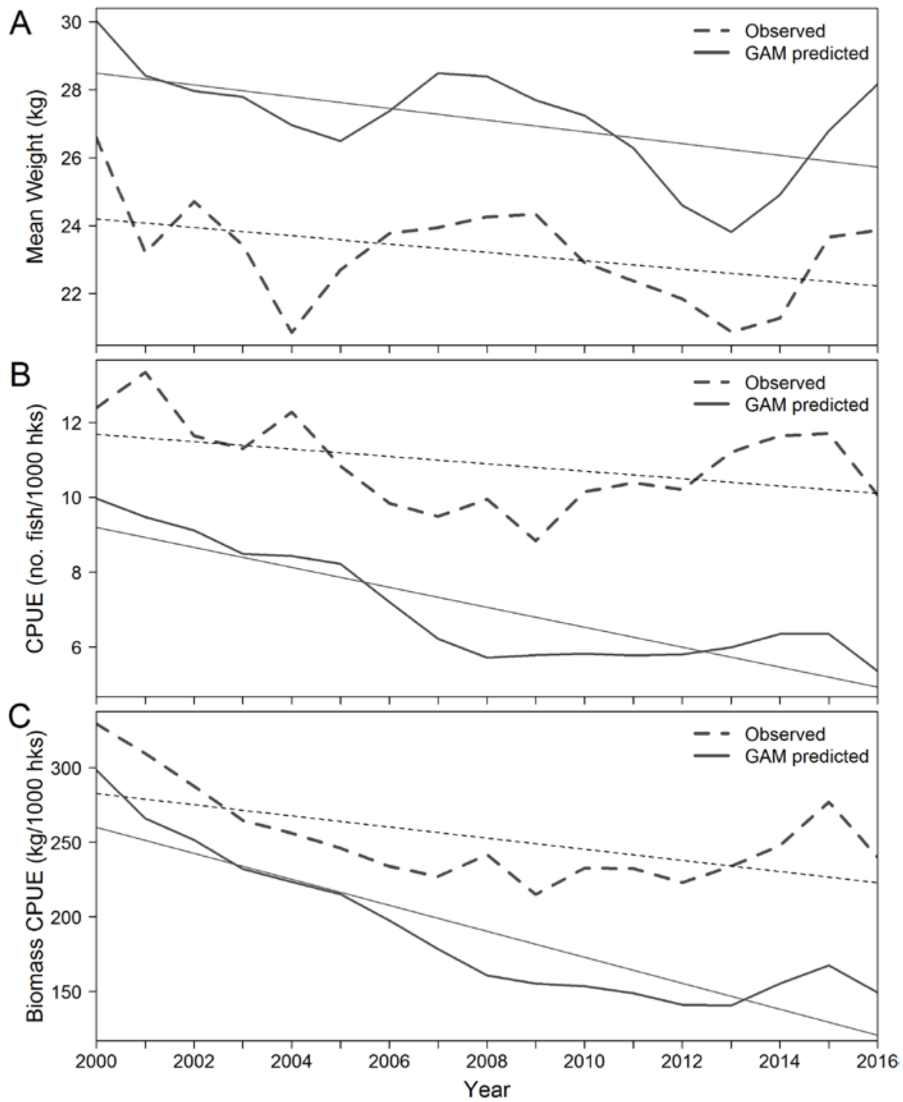

Fig. 3. Mean weight (A), catch per unit effort (B) and weight per unit effort (WPUE) for all fish in the Hawaiʻi-based longline fishery from dealer provided data. The dashed lines show the annual values from the dealer data with a linear trend line, and the solid line shows the GAM predicted annual values with linear trend lines.

CPUE has increased slowly since 2008, but when accounting for the increase in effort and geographic shift of the fishery, CPUE has remained stable (Fig. 3b). The recent peaks in both CPUE and WPUE are largely due to a strong recruitment pulse of bigeye tuna entering the fishery in the third quarter of 2013. We can follow this recruitment pulse in the fishery through 2016, where it provides an increase in first CPUE then WPUE. We were able to generate a recruitment index for bigeye tuna that provide a forecast of fishery performance. A peak in small bigeye tuna (<=15kg) is an indication of an increase in CPUE and WPUE in the following two years (Fig. 4).

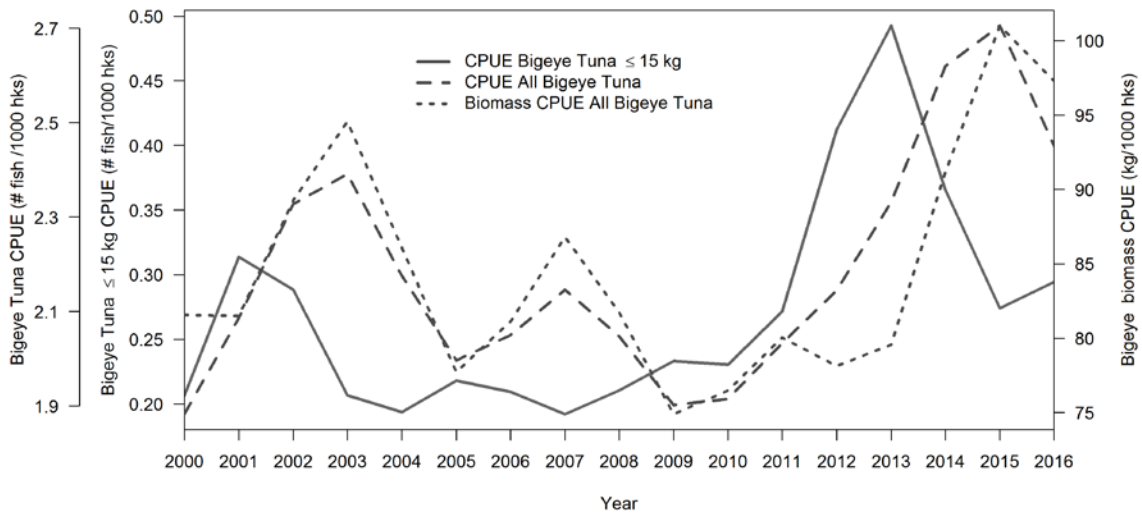

Fig. 4. Temporally and spatially adjusted annual catch per 1000 hooks (CPUE; dashed line), and biomass per 1000 hooks (WPUE) for all bigeye tuna and bigeye tuna 15 kg or less (solid line) from the GAM from 2000-2016.