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Towards fishery-independent biomass estimation for Hawaiian Islands deepwater snappers

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ABSTRACT

The Hawaiian deep-slope (75–400 m) Deep7 bottomfish fishery consists of seven (i.e., six snappers and one grouper) species. This study developed a sampling survey and modeling methodology for estimating biomass for this complex in the Main Hawaiian Islands. The island-wide fishery-independent sampling survey using two gears (commercial fishers with hook-and-line, 3D stereo camera) was conducted to generate estimates of relative abundance- and biomass-at-length for the complex. A length-based modeling approach was applied to the opakapaka fishery and survey size-structured abundance data, life history demography, and total fishery catches to estimate a feasible range of effective sampling area for the standard survey gear (i.e., cameras). These sampling area estimates were then used to expand survey estimates of relative biomass to population total biomass. The longer-term focus of this effort is to improve stock assessments of the Deep7 complex. The survey and modeling methods developed in this study provide the underpinnings of an integrated information and modeling system for assessment that enables multiple levels of comparison and validation with respect to data sources (fishery-dependent and fishery-independent) and modeling approaches (biomass-dynamic and cohort-structured).

1. Introduction

Commercial and recreational fishing are extremely important to the economy and culture of Hawaii (Haight et al., 1993). The Hawaiian deep-slope (75–400 m) Deep7 "bottomfish" fishery, a culturally and economically important domestic fishery, consists of seven (i.e., six snappers and one grouper) species (Western Pacific Regional Fishery Management Council, WPRFMC, 2010). Bottomfish have been targeted for hundreds of years throughout the eighteen islands of the Hawaiian archipelago by native Hawaiians, and have been under a formal federal fishery management plan since 2005, when it was determined that the stock was experiencing overfishing (Moffitt et al., 2006). Fishing became restricted to the eight Main Hawaiian Islands with the designation of the Papahānaumokuākea Marine National Monument in 2006.

The Pacific Islands Fisheries Science Center of the National Oceanic and Atmospheric Administration (PIFSC) is responsible for assessments of the Deep7 complex. These assessments include determination of resource status relative to management-determined reference points, and future projections of overfishing risks associated with various catch limits, which depend upon estimates of recent stock biomass. These findings are then presented to the Western Pacific Regional Fishery Management Council who recommends harvest control rules that ensure sustainability. The assessment process typically requires reliable time-series of fishery catches, effective fishing effort, and life history demographics to make these determinations and estimate abundance trends relative to sustainability benchmarks (Quinn and Deriso, 1999; Ault et al., 2014). Until recently, Deep7 assessments relied exclusively on fishery-dependent estimates of resource relative abundance (i.e., catch per unit effort CPUE) as the principal index of abundance and biomass (Brodziak et al., 2014). It is not clear whether these data were in fact proportional to resource abundance, for example, given the non-random effort distribution pattern of the fishery. Fishery-dependent CPUE data may be biased due to size and catch limits, gears, market forces and fisher's behaviors (Hilborn and Walters, 1992; Maunder and Punt, 2004). Quantitative assessments can greatly benefit from use of auxiliary abundance indices (e.g., average length in the exploited phase) estimated from fishery catch sampling and fishery-independent surveys (Ault et al., 2005, 2014). A key advantage of fishery-

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independent surveys is that they obtain similar size-structured abundance as those from catch sampling programs, but with greater statistical rigor (Ault et al., 1999; Smith et al., 2011). Fishery-independent surveys can also be designed to estimate relative and absolute population abundance, which provides an important calibration mechanism for assessment models that infer stock abundance from fishery catches and effort, and life history demographic characteristics.

In 2011, the PIFSC began to develop a multi-gear, fishery-independent survey for the Main Hawaiian Islands Deep7 complex to improve the data used for stock assessments (Richards et al., 2016), by estimating recent size-structured abundance and biomass. We present a new method for estimating biomass for the Deep 7 complex derived from the first Main Hawaiian Islands-wide fishery-independent survey of Deep 7 bottomfish. Survey relative abundance and biomass are calculated, and estimated total abundance and biomass based on feasible effective sampling areas for the principal survey gear are validated using a length-based modeling approach.

2. Methods and materials

2.1. Fishery independent survey

A fishery-independent sampling survey was conducted throughout the eight Main Hawaiian Islands (Fig. 1) to estimate key population metrics for the Deep7 bottomfish complex (Fig. 2). The development of the sampling methods and statistical design are detailed in Richards et al. (2016). The survey domain encompassed the full extent of mapped bottomfish habitats from 75 to 400 m depths, extending from the Big Island of Hawaii 600 km northwest to the island of Niihau. The survey frame was comprised of 500 × 500 m sample units (G) stratified according to three depth categories (75 to < 200 m, ≥200 to <300 m, ≥300 to 400 m), and three substrate composition-complexity categories (softbottom-all slopes, hardbottom-low slope, hardbottom-high slope) (Fig. 1, Table 1). Analyses of pilot experiments conducted in the Maui-Nui region during 2011–2015 showed that this stratification scheme effectively spatially partitioned the variance of Deep7 species density (Richards et al., 2016). Samples were allocated among strata following a Neyman scheme (Cochran, 1977), and sample units within strata were randomly selected without replacement from a discrete uniform probability distribution to ensure equal probability of selection (Law and Kelton, 2000). To ensure geographical coverage with respect to islands, sample units were proportionally allocated within strata to island area.

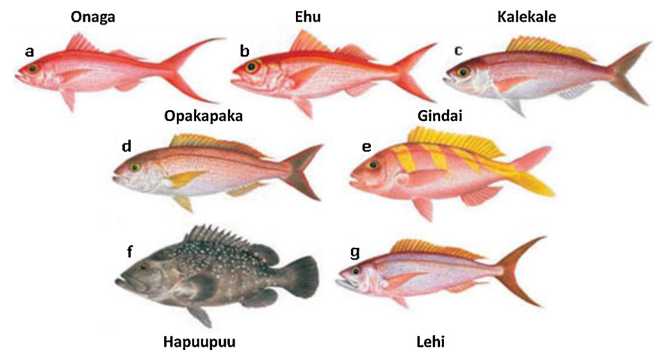

Fig. 2. Members of the Hawaiian Deep7 bottomfish (i.e., deepwater snappers and grouper) complex: (A) onaga (*Etelis coruscans*); (B) ehu (*E. carbunculus*); (C) kalekale (*Pristipomoides sieboldii*); (D) opakapaka (*P. filamentosus*); (E) gindai (*P. zonatus*); (F) hapu'upu'u (*Hyporthodus quernus*); and, (G) lehi (*Aphareus rutilans*). Artwork by Les Hata (Hawaii Department of Aquatic Resources/ Department of Land and Natural Resources).

Table 1
The total number of mapped 500 × 500 m grid cells (sample units, G) by substrate-slope-depth strata within the Main Hawaiian Islands bottomfish sampling survey domain.

Substrate	Slope	Depth	Strata Code	G_h
SB (softbottom)	A (high & low slope)	Shallow (S, 75 to <200 m)	SB_A_S	1863
HB (hardbottom)	L (low slope)	Shallow	HB_L_S	4562
HB	H (high slope)	Shallow	HB_H_S	4777
SB	A	Medium (M, ≥200 to <300 m)	SB_A_M	1449
HB	L	Medium	HB_L_M	2688
HB	H	Medium	HB_H_M	2412
SB	A	Deep (D, ≥300 to 400 m)	SB_A_D	1591
HB	L	Deep	HB_L_D	3801
HB	H	Deep	HB_H_D	2749
			$G = \sum_h G_h =$	**25,892**

At a selected sampling unit within a stratum, species-specific number and length composition were obtained using one of two principal survey gears: (1) hook-line fishing; or (2) stationary stereo-video

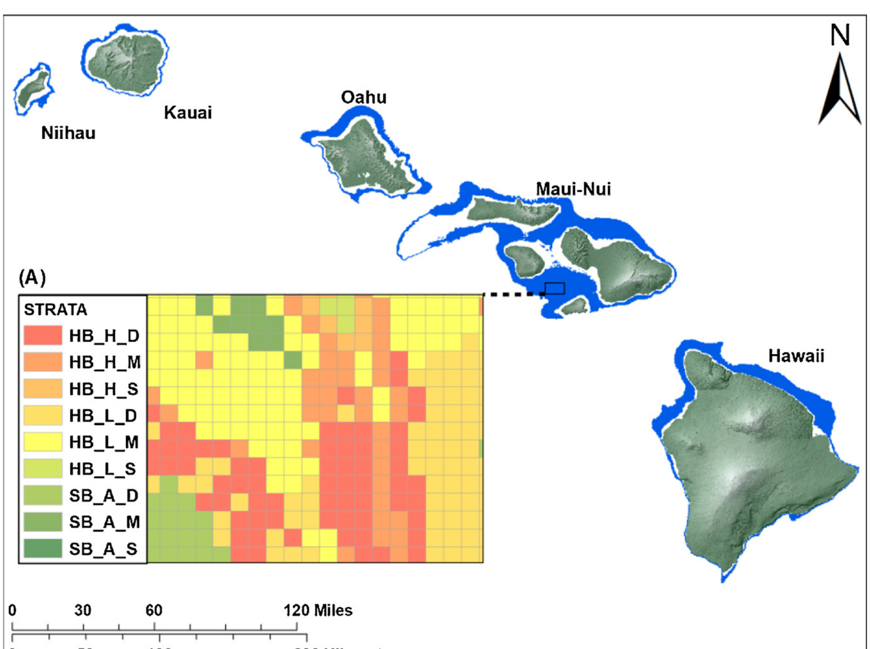

Fig. 1. The spatial frame of the Deep7 bottomfish survey domain (blue shaded region) extending from Niihau in the northwest to the island of Hawaii in the southeast. Inset shows a section of the survey frame in the Maui-Nui region (islands of Maui, Moloka'i, Lana'I, Kaho'olawe) showing the 500 × 500 m mapped grid cells classified by habitat-depth strata. Definitions of substrate-slope-depth strata in panel (A) are given in Table 1. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).