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Stock Assessment of the Coral Reef Fishes of Hawaii, 2016

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Stock Assessment of the Coral Reef Fishes of Hawaii, 2016

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ABSTRACT

This report contains single-species assessments of 27 reef-associated fish stocks around the main Hawaiian Islands using data from various sources collected during the 2003–2016 period. Previous management actions have set acceptable biological catches (ABCs) at the family level using either a percentile of historical catches or a catch-MSY approach. Here, we used fishery-independent size composition and abundance data from diver surveys combined with fishery-dependent catch estimates to calculate current fishing mortality rates (F), spawning potential ratios (SPR), SPR-based sustainable fishing rates (F_{30}: F resulting in SPR = 30%), and catch levels corresponding to these sustainable rates (C_{30}). We used a length-based model to obtain mortality rates and a relatively simple age-structured population model to obtain the various stock status metrics. C_{30} were obtained by combining F_{30} estimates with current population biomass estimates derived directly from diver surveys or indirectly from the total catch. The overfishing limits (*OFL*) corresponding to a 50% risk of overfishing was defined as the median of the C_{30} distribution. A novel data-poor approach was used to estimate life history parameters for 11 species with either no or inadequate published growth and maturity studies. We used Monte Carlo simulations to incorporate all sources of uncertainty (i.e., life history parameters, average length, abundance, and catch). Of the 27 assessed species, 11 had median F/F_{30} ratios greater than 1 and therefore median SPR values below the minimum overfished limit of 30%. Another two were close to this limit (30% ≤ SPR < 35%). This suggests some stocks may be experiencing overfishing and, if at equilibrium, may also be overfished. Surgeonfishes and parrotfishes were the families with the most species with low SPR values, while goatfishes generally had higher SPR values. Typically, species with low SPR were the ones with long lifespan (i.e., surgeonfishes) or highly targeted (i.e., jacks, snappers). Species with shorter lifespans (i.e., goatfishes) fared generally better. As a final step, overfishing probability distributions for a range of catch limits were generated for all 27 species.

CONTENTS

INTRODUCTION

The 2006 re-authorization of the Magnuson-Stevens Fishery Conservation and Management Act calls for annual catch limits (ACLs) to be set for all exploited stocks in the United States and its territories in order to, among other goals, insure sustainable harvesting practices. In the U.S. Pacific, exploited stocks include a multitude of coral reef-associated finfish species inhabiting shallow-water areas around a large number of islands and atolls. The high species diversity, the mixture of commercial and recreational fishing effort, and the spatially diffused nature of the fisheries result in a comparatively data-poor situation for these stocks. This has led the Western Pacific Regional Fishery Management Council (WPRFMC) to set ACLs using basic analytical methods such as using the 75th percentile of historical catches or using catch-based methods applied at the family level (Sabater & Kleiber, 2013). However, recent efforts in fisheries-independent surveys and life history research by the Pacific Islands Fisheries Science Center (PIFSC) have improved this situation to the point where simple age-based assessment approaches can now be applied to individual coral-reef fish stocks (Nadon et al., 2015).

In this report, the status of 27 of the most commonly exploited coral-reef fish species of Hawaii was assessed using a length-based mortality model and a relatively simple numerical population model. Using this approach, we obtained estimates of fishing mortality (F) and spawning potential ratio (SPR) over the recent time period, F at SPR = 30% (F_{30}), catch associated with F_{30} (C_{30}), and overfishing risk tables for a range of catch limits (including a proxy overfishing limit, OFL, defined as the C_{30} level that results in a 50% chance of overfishing; see Table 1 for the definition of all parameters).

For the purposes of our SPR-based approach in this paper, we used a default definition of overfished and overfishing as recommended by Restrepo et al. (1998):

- Overfished limit: SPR = 30%, with overfished defined as $SPR < 30\%$
- Overfishing limit: F at SPR = 30% (F_{30}), with overfishing defined as $F > F_{30}$ or $F/F_{30} > 1$.

It is important to note that since our analyses assumed populations were at equilibrium a stock that is experiencing overfishing was also considered overfished (and vice-versa).

For this approach, we used fishery-independent size composition and abundance data provided by NOAA diver surveys as well as fishery-dependent data from the State of Hawaii commercial fishing database. These 27 species, from 8 different families, were selected based on the availability of length data from either data sources and the availability of reliable life history parameters related to growth, maturity, and longevity. In the situation where no published life history parameters where available, a new data-poor estimation approach developed at PIFSC and the University of Miami was implemented (Nadon & Ault, 2016). Additional species could not be assessed due to data limitations, but this situation may change as new data sources become available. Although most of these species' depth range occurs within the 3 nautical mile

limit defining State waters, species inhabiting depths beyond 50 m have significant portions of their range (18–26%) in federal waters, mainly on Penguin Bank and in the channel waters between Maui, Molokai, and Lanai (see Table 3, Figure 2, and Figure 3).

Description of the Fisheries

The Hawaiian Archipelago is a large island chain extending 2600 km along a SE-NW axis from 19°N, 155°W to 28°N, 178°W (Figure 1). The archipelago is composed of 18 islands and atolls which are typically divided into two broad regions: the inhabited main Hawaiian Islands (MHI; 1.4 million individuals; dbedt.hawaii.gov/census) and the mostly un-inhabited Northwestern Hawaiian Islands (NWHI). The MHI consists of 8 geologically young, high (4,205 m maximum elevation) volcanic islands while the NWHI have low elevation (275 m max elevation). The MHI were settled by people around AD 1250, and reef fish communities in the MHI have been exploited since that time (Kittinger et al., 2011). The NWHI were never permanently inhabited. However, they were the focus of commercial fishing, especially in the 19th century (Kittinger et al., 2011). Presently, the coral reef ecosystem around the MHI are critical to both fishing and tourism activities (Cesar & Beukering, 2004).

The coral reef fishery around the MHI involves near-shore recreational/subsistence fishing combined with a small commercial fishing sector. Almost a third of Hawaii households are involved in recreational-subsistence fishing (Hamnett et al., 2006), and their catches are estimated to exceed those of the commercial sector significantly (Friedlander & Parrish, 1997; Zeller et al., 2005; Williams & Ma, 2013). The recreational-subsistence sector is composed of (mostly) shore-based fishers using a variety of gears such as spears, hook-and-line, traps, and small gill and cast nets. The primary targeted families include larger jacks and snappers, and, to a lesser extent, smaller reef-associated families such as surgeonfish, goatfish, soldierfish, and parrotfish (Friedlander & Parrish, 1997). Commercial marine landings in Hawaii are mostly composed of coastal-pelagic species (> 80% of catches; DeMello, 2004), but also include the reef fishes targeted by the recreational-subsistence sector. The direct monetary value of the near-shore fishery is only 10–20% of the pelagic fishery (Gulko et al., 2002), but it is culturally and socially important to the local population.

METHODS

The general assessment approach used in the present document recognizes the relatively data-poor status of most of the coral-reef fish stocks in Hawaii. We specifically focused on the best available data sources which are the ongoing NOAA-PIFSC diver surveys (2005–2016) and the recent commercial data from the State of Hawaii (2003–2015). Since these two data sources contain relatively short time-series, our assessment approach was limited to equilibrium models that assume relatively constant fishing mortality and recruitment. The validity of this assumption was investigated for each species by looking at temporal trends in average length in the catch and abundance index from diver surveys as illustrated in the Species Report section at the end of this document. Furthermore, the lack of stock-recruitment relationships meant that we had to rely on a biological reference point (BRP) based on per-recruit spawning stock biomass (SSBR) and the ratio of current SSBR to un-exploited SSBR (spawning potential ratio, *SPR*, a measure of the spawning potential of a stock). The general assessment approach consisted of three main steps: 1) calculate current fishing mortality rates (F) using diver and commercial data derived average length estimates in a length-mortality model, 2) calculate *SPR* and F_{30} (the fishing mortality rate resulting in SPR = 30%) using published life history parameters in a population simulation model, and 3) calculate the catch limit associated with a given F_{30} (C_{30}) by combining the F_{30} estimate with an estimate of current population biomass (derived directly from diver surveys or indirectly by relating the current total catch with the current F). A Monte Carlo procedure was used to integrate the uncertainty in each individual parameters related to length, population size, and life history. The median of the C_{30} distribution is the overfishing limit (*OFL*) value, by definition, since it corresponds to a 50% chance of overfishing. A schematic of these steps and decisions are presented in Figure 4. The following sections explain this approach in greater details and describe the various data sources.

Stock Area

The first step of any stock assessment is typically to define the geographical extent of the stocks being analyzed. It is still not entirely clear to what level the reef fish populations around the MHI are connected and if significant larval exchanges or adult movements exist between the different Hawaiian Islands, although it is generally accepted that fish populations between the MHI and NWHI are disconnected (see Discussion section for details). In this report, all 27 stocks were analyzed at the MHI scale (Figure 1) mainly due to data limitations, as well as to follow current management stock definitions. Further stock connectivity studies may suggest that future stock assessments be conducted at different spatial scales for certain species.

Another consideration for these assessments was the extent of each species' geographical range that fell in federal vs. state waters. For each species, we obtained depth range estimates from Baited Remote Underwater Video (BRUV) and bottom-fish camera (BotCam) exploratory surveys conducted by PIFSC (J. Asher, pers. comm.) and the University of Hawaii (J. Drazen, pers. comm.). We also used the mesophotic deep diving exploratory work conducted by Pyle et al. (2016). We did not attempt to quantify abundance-at-depth given the limited coverage of

these surveys. We simply reported the maximum depth that individual species can inhabit, which may be fairly marginal in certain cases, and calculated the sea floor area to this depth. In the Species Report section, we provide both the maximum depth and the percentage of sea floor area in federal vs. state waters for all species (see Table 3, Figure 2, and Figure 3 for a summary).

Size Selectivity in the Fishery

The State of Hawaii has minimum size regulations on some of the species included in this report. However, it is uncertain to what degree these are respected by fishermen. To infer on the selectivity pattern in the reef fish fishery, we used the indirect abundance-at-length data from the State commercial data set (see Data Source section below for details) and, to a lesser extent, the Hawaii Marine Recreational Fishing Survey (HMRFS). Fishing records were utilized from the 3 main fishing gear types used in inshore areas: hook-and-line (44% of fishing reports for the species targeted in this study, DAR gear code: 1–6, 8–10, 61–63, 70, and 91–93), spearfishing (40%, gear code: 13 and 14), and various nets (15%, gear code: 20–23, 25-27, 30, 32, 33, 40, 41, and 45). Other gears, such as traps, represented less than 1% of reports for the species selected in the current study and data from these reports were not used. From what is known about the reef fish fishery and the size composition in the catch, it was clear that some form of logistic selectivity curve was most appropriate (i.e., there was no indication of reduced selectivity at larger sizes). We therefore used the following formulation of logistic selectivity:

$$S = \frac{1}{1 + \exp\left(-\ln(19)\,\frac{L - L_{S50}}{L_{S95} - L_{S50}}\right)} \qquad (1)$$

where L is the length at which selectivity is estimated, L_{S50} is the length at 50% selectivity, and L_{S95} is the length at 95% selectivity. To estimate these two parameters, we first searched for a discontinuous break in the size composition histogram obtained from the commercial data set (and HMRFS data set, if it had sufficient observations) to obtain an initial estimate of L_{S95}. We then looked at the smallest size bin in the size composition graph and split the difference between this size and L_{S95} to obtain an initial estimate of L_{S50}. For example, the commercial catch size structure for *Parupeneus porphyreus* did not have individuals below 20 cm, had a few individuals in the 20–22 cm and 22–24 cm ranges (~ 50), and a significantly higher number of individuals in the 24–26 cm range (close to 200 fish). The number of fish in size bins above 24–26 cm increased in a continuous manner. This discontinuous jump between 22–24 cm and 24–26 cm appeared to be related to selectivity; consequently a first estimate of L_{S95} was set at 26 cm. The smallest size bin was 20–22 cm and we therefore set L_{S50} at 23 cm (i.e. the midpoint between 20 and 26 cm). To test the validity of the L_{S95} and L_{S50} parameters, we simulated a size structure using our population simulation model with these parameters (see Population Simulation section) and compared it to the actual size structure data. If the size structures did not agree, we adjusted the L_{S50} and L_{S95} parameters and ran further simulations. Typically, one or two runs were necessary to obtain an appropriate estimate of the selectivity parameters. For most species, sensitivity analyses were also used with different selectivity parameter pairs.

Finally, the length-mortality model used to obtain an estimate of total mortality (see Total Mortality section below) requires an estimate of length at full selectivity ("L_{S100}"). Since it is impossible to differentiate between L_{S95} and L_{S100}, given their similarity and the limited resolution of our length data, we simply used L_{S95} as our estimate of length at full selectivity for the length-mortality model. This made our total mortality estimate slightly lower than if L_{S100} was known.

Data Sources

Size composition, density, and total biomass from diver surveys

The main source of fisheries-independent data came from the diver surveys conducted by the Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Program (CREP). The diver surveys were used to obtain size structure data (from which average length in the exploited phase could be calculated - $\overline{L}$) and abundance data (from which population biomass estimates could be derived). Below is a brief description of the survey protocol. An in-depth description is available in Ayotte et al. (2015).

Starting in 2005, trained divers from the NOAA Pacific Islands Fisheries Science Center (PIFSC) have been conducting visual surveys around the MHI. Survey sites were randomly selected within strata defined by depth-bins (shallow, 0–6 m; mid, 6–18 m; and deep, 18–30 m). All coastlines from all islands in the MHI were surveyed, except for the small, restricted island of Kaho'olawe. For practical and safety reasons, surveys were limited to depths above 30 m. During a typical CREP survey day, a NOAA ship deployed 3 to 4 small dive boats that sampled pre-assigned random sites along 10 to 12 miles of coastline. The daily starting location of the ship along different coastlines of the MHI was set in as systematic manner, with the goal of covering as much of the shoreline as possible. At each site, stationary point counts were implemented by two paired divers inside contiguous 15-m diameter cylinders that extended from the bottom to the surface (Brandt et al., 2009; Smith et al., 2011; Williams et al., 2011). Divers first listed all observed fish species during an initial 5-minute period. The divers then went through this list, one species at the time, recording the number of individuals and estimating sizes of all fish seen within the cylinder. Fish sizes were recorded as total lengths to the nearest cm. Fishes from species not listed during the initial 5-minute period, but observed later in the survey, were also recorded but classified in a different data category (i.e., non-instantaneous count). Divers were continuously trained between cruises in size estimation using fish cut-outs of various sizes. Diver performance during research cruises was evaluated by comparing size and count estimates between paired divers.

Average length in the exploited phase ($\overline{L}$) was obtained from the abundance-at-size data by averaging all length observations (weighted by count) from 2005 to 2016 for a species inside each of the 4 subregions of the MHI (see Figure 1, Table 2 for subregion descriptions). Only lengths above size at full selectivity (L_{S95}) were kept. The overall $\overline{L}$ was obtained by averaging all 4 sub-regional $\overline{L}$ weighted by the respective size of each subregion's shallow reef area (Table 2). This was done to account for differences in size composition due to uneven fishing pressure

(inferred from humans per reef area values—Table 2) and uneven sampling effort between regions. The standard deviations of $\overline{L}$ estimates were obtained by bootstrapping the diver survey data set by re-sampling survey sites within subregion (Figure 1) and applying the weighted mean procedure described above to generate a distribution of $\overline{L}$.

Numerical density estimates (fish per 100 m^2) were obtained by dividing the fish counts in each survey by the area per survey (353 m^2 from two 15-m diameter survey cylinders) and multiplying by 100 (an individual survey consisted of the combined fish counts from the two divers deployed at a random site). We calculated selectivity for each observation using the observed length and Eq. (1), and multiplied each fish count by this value. The overall average numerical density was obtained by (1) averaging site-level density estimates within a coastline sector (see Figure 5 for sector map) and by (2) averaging all sector-level density estimates together, weighted by the amount of reef area in each sector. It is important to note here that we did not use the higher spatial resolution sectors for the $\overline{L}$ bootstrapping procedure due to the relatively low length observation sample sizes (we use the subregions instead). The standard deviations of overall mean density estimates were obtained by bootstrapping the diver survey data set by re-sampling survey sites within sector (Figure 5) and applying the weighted mean procedure described above to generate a distribution of mean numerical density. These density estimates are presented as time series graphs in the Species Report section. Finally, it is important to note that only instantaneous fish counts were kept for this calculation in order to get an abundance estimate close to "true" density. The implied assumption here is that the "catchability" (q) of an individual underwater survey is the fraction of the total hard-bottom population area (96,208 ha) covered by a single survey (353 m^2; q = 3.67e-7). We used hard-bottom area since all species in this report are heavily associated with this habitat type. Some species, like goatfishes, feed over soft-bottom areas but they are usually within range of hard-bottom areas which they rely on for refuge.

Biomass density estimates (kg per 100 m^2) were obtained by using the same approach as for numerical density, but by first converting each individual fish length into weight using published length-weight conversion parameters as provided in the Species Report section. Fish biomass density per sector was used to estimate fish biomass per sector by multiplying biomass density by the amount of hard-bottom area in each sector (obtained from CREP and bathymetric data compiled by the Hawaii Mapping Research Group). Total stock biomass was obtained by summing all sector biomass together. The standard deviations of biomass density and total fish biomass were obtained through bootstrapping in a similar fashion as for numerical density.

One limitation of this data set was the potential impact of fish behavior on the assumed catchability coefficient (3.66e-7) for population biomass calculations. Cryptic behavior and diver avoidance (or attraction) will have an effect on this assumed value and this will differ between species. Although the biomass calculations for all species were done assuming this value, we discuss potential biomass estimate biases for certain species in the Species Report section.

Another limitation of this data set is the potential mismatch between the survey domain (limited to 30-m depth) and the greater depth range of certain species. For species occurring at depths greater than 30 m, we did not attempt to assign a population abundance to the un-sampled

sea floor area, given our limited knowledge of the amount of suitable habitat at these depths. We do however discuss this potential bias and implications for the relevant species in the Species Report section.

Size composition and total catch from fishing report data

We used the commercial fishing report data from the State of Hawaii's Division of Aquatic Resources (DAR) to obtain an estimate of total commercial catch. Catch records for certain taxa that were not identified to the species level were not included in analyses that depended on this data set (all parrotfishes, the "kala" group of surgeonfishes composed of *Naso unicornis*, *N. annulatus*, and *N. brevirostris*, and the *Acanthurus blochii*/*A. xanthopterus* reporting group). We also used the Hawaii Marine Recreational Fishing Survey program (HMRFS) catch estimates provided by Williams and Ma (2013) to obtain an estimate of total recreational catch from 2004 to 2015. For the commercial data, we simply summed the reported catch by weight by year from 2003 to 2015 by species (for species reported at the species level). Given the uncertainty associated with both catch data sets, we assumed that annual total catch has been mostly stable from 2003 to 2015 and that the year to year variability is representative of the uncertainty around the total catch estimates. Thus it was not necessary that the time periods of commercial and recreational data sets matched perfectly. HMRFS data were not always available for every species in every year. Past reports (Williams & Ma, 2013) have shown that the nearshore fishery is dominated by recreational fishing, and there is no evidence that recreational fishing effort has been going dramatically up in recent years given that Hawaii's human population is increasing at a fairly low rate (~ 1% per year). Plotting the catch data by year for these species revealed mostly year-to-year variability, although these estimates were generally fairly variable (see Species Report section). In order to come up with a total catch estimate, we fitted a lognormal distribution to both the commercial and recreational yearly catch estimates and summed these together using a Monte Carlo procedure by randomly sampling both distributions, adding those values together, and fitting a new lognormal distribution to the resulting data set. Of note, when summing lognormal distributions, the median value of the final distribution will be different than the sum of the two median values of the original distribution (see Species Report section).

We also used the commercial fishing report data to obtain a second source of size composition data for species that have individual species codes (note: the HMRFS data set did not have sufficient length observation to be used consistently). As discussed in the Selectivity section, all 3 main fishing gears (hook-and-line, spearfishing, and nets) had a similar selectivity pattern, as inferred from the similar size composition of their catch (i.e. similar logistic shape with no indication of lower selectivity at larger sizes). We therefore combined catch records from all 3 fishing gears, providing close to 100,000 individual reports. Unfortunately, direct-length observations are not recorded in the commercial data set. However, each record report the total weight and the number of fish caught by species. It was possible to obtain an indirect measure of length by dividing the catch in weight by the number of fish caught to obtain average weight per individual report. Average weights per report were then converted to total lengths using published standard allometric weight (W)–length (L) relationships (see individual species tables in the Species Report section),

$$W = \alpha \cdot L^{\beta} \tag{2}$$

which can be inverted to obtain

$$L = \left(\frac{W}{\alpha}\right)^{\left(\frac{1}{\beta}\right)} \tag{3}$$

where α is a scaling and β is a volumetric model parameter. For each species, average length per report were combined across all years using numbers caught per report as a weighting variable, in a similar fashion as for diver-survey $\overline{L}$. Converting average weight per report to average length per report can theoretically lead to a biased estimate of average length (Jensen's inequality caused by the non-linear length-weight relationship; Ruel & Ayres, 1999). To test the degree to which this occurred, for each species, we compared the average length from catch records with only one recorded fish caught vs. the average calculated for all catch records regardless of how many fish per record were reported. We found minimal differences in average length between these two calculation methods. The resulting length observations for each report were checked and lengths that were greater than the maximum reported for each species were discarded. The standard deviations of the average length estimates derived from commercial report data were estimated by bootstrapping individual report data by subregion and running the above analyses.

Life history parameter sources

We reviewed the scientific literature for published life history parameters related to growth, longevity, and maturity. We did not restrict our search to local studies given the paucity of peer-reviewed literature on coral reef fish biology. If multiple growth or maturity studies were available for a species, we prioritized local studies, followed by the most recent, in-depth studies (even if from a different geographical area). If no life history study was available, for certain species, we used the data-poor life history estimation approach described in Nadon and Ault (2016). In short, this approach uses a local estimate of maximum length to provide family-specific probability distribution for all main life history parameters. The standard deviations of life history parameters were obtained by one of the following methods, presented in order of preference based on reliability: 1) bootstrapping the raw length, age, or maturity data, when available, 2) using the coefficient of variations at different sample sizes from Kritzer et al. (2001) for growth and Nadon (unpublished) for maturity (Table 4), or 3) from the stepwise approach itself, if it was used to generate life history parameters (Nadon and Ault, 2016). See Figure 4 for a summary of life history steps within this assessment framework.

Total and Natural Mortality Models

As mortality rates increase, the probability of a fish reaching larger sizes decreases, and thus the mean of the size frequency distribution ($\overline{L}$) decreases accordingly. Theoretically, the average length $\overline{L}$ in the catch can be expressed as

$$\overline{L} = \frac{\int_{a_c}^{a_\lambda} N_a L_a da}{\int_{a_c}^{a_\lambda} N_a da} \tag{4}$$

where the exploitable phase is integrated from a_c (age at first capture) to a_λ (oldest age), N_a is the abundance at age class a, and L_a is the expected length at age a.

A formula for estimating mortality rates using estimates of $\overline{L}$ was derived from Eq. (4) by Ehrhardt and Ault (1992). The first step in this derivation was to substitute L_a in Eq. (1) with the von Bertalanffy growth function and N_a with the exponential mortality model

$$\overline{N}_{a+\Delta a} = \overline{N}_a e^{-Z\Delta a} \tag{5}$$

where Z is the total instantaneous mortality rate and Δa is the age interval, normally one year. Step two was to integrate and algebraically solve for Z,

$$\left(\frac{L_\infty - L_\lambda}{L_\infty - L_{S95}}\right)^{Z/K} = \frac{Z\left(L_{S95} - \overline{L}\right) + K\left(L_\infty - \overline{L}\right)}{Z\left(L_\lambda - \overline{L}\right) + K\left(L_\infty - \overline{L}\right)} \tag{6}$$

where K and L_∞ are parameters of the von Bertalanffy growth equation (assumed to be constant over time), L_{S95} is the size at full selectivity (see Selectivity section), and L_λ is the expected size at oldest known age, respectively. We selected Eq. (6) instead of the Beverton-Holt model (Beverton & Holt 1956) due to a reported bias in this model associated with the assumption of infinite longevity (Ehrhardt & Ault, 1992). It is important to note that Eq. (4) and (6) are valid in equilibrium conditions where fishing mortality has been relatively constant for a sufficient amount of time for the population to be in a stable state. For each individual species, we looked at temporal trends in average lengths and estimated population abundance to verify that this was the case (see the Species Report section for further details). Fishing mortality was obtained from $F = Z - M$, where M is the instantaneous natural mortality rate which was derived from longevity in our study (see paragraph below for more details). Estimates of total instantaneous mortality rates Z were computed from Eq. (6) using a numerical procedure. Values of L_λ (expected length at maximum age a_λ) were estimated from the von Bertalanffy growth function using an observed maximum age.

To derive F from Z, as well as to parameterize our population simulation model, it is necessary to obtain an estimate of natural mortality (M). To do so, we used the procedure of Alagaraja (1984), similar to Hoenig (1983) and Hewitt and Hoenig (2005), which assumes that 4% of a cohort survives to the observed maximum age (a_λ):

$$M = \frac{-\ln(0.04)}{a_\lambda} \tag{7}$$

We used the 4% cohort survivorship value based on the analyses of Nadon et al. (2015) which showed that this is an appropriate survivorship value for coral reef fishes. We did not have independent estimates of *M per se* and had to rely on this longevity-based approach. Although there are other data-poor methods for estimating natural mortality, involving other parameters (e.g., K, L_{inf}, L_{mat}, water temperature), two recent scientific papers on the subject clearly suggest that longevity-only methods are better performing (Kenchington, 2014; Then et al., 2015). It is important to consider the potential difficulty in obtaining a representative longevity value in heavily exploited stocks. To reduce this concern as much as possible, we always selected the oldest recorded age, regardless of geographical location, as our measure of longevity. It was, unfortunately, impossible to only select longevity estimates from un-exploited stocks given that there are few life history studies on such stocks. The Species Report section provides details of parameters selected and their sources, and output parameter values and associated uncertainty.

Population Simulation Model

We built a population model in order to calculate various stock metrics (SPR, F_{30}, Lc_{30}). For exploited fish populations, a biological reference point for sustainability risks (spawning potential ratio, SPR) was computed using a numerical model to simulate exploited fish populations. The computations were based on the mortality rates derived from $\overline{L}$ estimates and life history parameters synthesized from the literature. Numerical abundance at age a was estimated through use of an exponential mortality function (Eq. 9). Length-at-age was estimated from the von Bertalanffy growth equation, and converted to weight-at-age using the allometric weight-length relationship (Eq. 1).

The numerical model was used to obtain spawning stock biomass per recruit (SSBR), at given levels of fishing mortality by summing over individuals in the population between the age of sexual maturity (a_m; age where 50% of individuals are mature, with knife-edge assumption) and 1.5 times the oldest recorded age (a_λ),

$$SSBR = \sum_{a_m}^{1.5a_\lambda} \overline{N}_a \overline{W}_a \qquad (8)$$

Where $\overline{N}_a$ is the mean abundance at age a and $\overline{W}_a$ is the mean weight of individuals at age a (derived from the von Bertalanffy equation combined with length-weight equation). The model was run using weekly time steps. Average abundance at age was modeled using the following equation:

$$\overline{N}_{a+\Delta a} = \overline{N}_a e^{-(S \cdot F + M)\Delta a} \qquad (9)$$

where F and M are fishing and natural mortality, respectively, and S is selectivity which was defined by a logistic curve with parameters L_{S50} and L_{S95} (see Selectivity section). SPR was computed as the ratio of the current SSB relative to that of an unexploited stock:

$$SPR = \frac{SSB_{\exp loited}}{SSB_{un\exp loited}} \quad (10)$$

Estimated *SPR*s were compared to the recommended 30% *SPR* threshold below which a stock is likely no longer sustainable (i.e., is experiencing recruitment overfishing), a standard recommended for less well-known stocks (Gabriel et al., 1989; Restrepo et al., 1998; Clark, 2002). Lc_{30}, the size at first capture required to obtain an SPR = 30% was also estimated using this model. To do so, we used an iterative procedure which calculated *SPR* at incrementing *Lc* values (keeping all other parameters fixed) until the SPR = 30% level was reached. An identical procedure was used to obtain F_{30}.

Calculated *SPR*, proportion of *SPR* iterations that resulted in $SPR < 0.30$, Lc_{30}, F_{30}, and F/F_{30} values are provided in the Species Report section.

Overfishing Limit Calculation

The sections above presented the data sources and models used to obtain various population parameters (mortality rates, *SPR*, F_{30}, Lc_{30}). To calculate an overfishing limit (*OFL*) estimate (i.e. the catch that results in a 50% chance of overfishing), we first needed to obtain an estimate of standing population biomass (*B*). This could be obtained in up to two ways depending on data reliability and availability for each species: 1) extrapolating total biomass from the diver-survey biomass density estimates, as explained earlier, and 2) by using the estimates of total catch (*C*), natural mortality, and length-derived fishing mortality in the Baranov catch equation:

$$B = C \div \frac{F}{F+M}\left(1-e^{-(F+M)}\right) \quad (11)$$

From one or both of these estimates of current population biomass, we derived the catch level corresponding to F_{30} (C_{30}) by using the Baranov equation and our estimates of sustainable fishing mortality rate (F_{30}):

$$C_{30} = B \cdot \frac{F_{30}}{F_{30}+M}\left(1-e^{-(F_{30}+M)}\right) \quad (12)$$

The final distribution of C_{30} estimates and other derived values (e.g., *SPR*) were obtained by incorporating all sources of uncertainty (data and parameters) using a Monte Carlo approach. In short, we drew a random value from the probability distributions of each data source ($\overline{L}$, life history parameters, diver-derived population biomass, and total catch) and ran all the steps to calculate C_{30} using these random values (Figure 4). The Monte Carlo draws for parameters that could not be negative (e.g. catch, $\overline{L}$) were bounded at zero (if they were drawn from probability distributions that allowed negative values). The Monte Carlo procedure was repeated 6,000 times to generate distributions of C_{30} and other derived values. The median of the C_{30} distribution represented the catch level with a 50% chance of overfishing (*OFL*).

It is important to note that randomly drawn combinations of life history parameters could lead to a biologically impossible scenario where an $\overline{L}$ was larger than the pristine average length predicted by these parameters. For these random draws, *F* will be negative and *SPR* will go above 1. This can be a fairly common situation for lightly fished stocks with $\overline{L}$ close to its pristine value and is not necessarily an indication of incorrect life history parameter distributions. Instead, it is the result of a lack of a proper *a priori* covariance structure between these parameters that should have limited certain parameter combinations. For example, a very high *M* value, combined with a low *K* and low L_{inf} values can lead to a pristine average length that is unrealistically low and below a randomly drawn $\overline{L}$. To correct this issue, for a randomly drawn $\overline{L}$, we rejected life history parameter combinations that led to this situation and re-drew life history parameters until a realistic combination was sampled.

Decision Process for Multiple Data Sources

Throughout the process used to generate *OFL* estimates (Figure 4), there were several steps where decisions had to be made regarding data sources. To reduce the subjectivity of these decisions, we created a decision table presented in Figure 4. In short, there were 4 main decision steps: 1) whether to combine the $\overline{L}$ estimates from diver and report data or keep only one source, 2) whether to use a local study, external study, or the Nadon and Ault (2016) approach as a source of life history parameters, 3) whether to use a bootstrap procedure on raw data or the meta-analysis of Kritzer et al. (2001) and Nadon (unpubl.) to generate uncertainty of life history parameters, and 4) whether to use C_{30} distribution generated from diver-survey biomass or from catch-based biomass to calculate an *OFL* (this final decision point is discussed for individual species in the Species Reports section but is ultimately left to managers).

Analyses Work Flow

The raw diver survey data were provided by CREP (file named “all_diver_rea.rdata”) and the raw commercial data were extracted directly from the PIFSC Oracle database where they are stored. Two R scripts were used to process these raw data sets (“process_uvc_data.r” and “process_dar_data.r”). Other R scripts were used to obtain various metrics and their associated distributions: average length (“get_lbar.r”), population biomass (“get_diver_biomass.r”), commercial and recreational catch (“get_catch.r”), and time series graphs (“get_abund_timeseries.r” and “get_lbar_timeseries.r”).

The overall approach to generate population status metrics (*F*, F_{30}, and *SPR*) and the C_{30} distributions (Figure 4) was implemented in a Java-language computer program developed specifically for this purpose. This tool requires inputs in the form of probability distribution parameters (e.g., mean, standard deviation) for 1) the life history parameters, 2) average length, 3) total catch (if available), and 4) population biomass from surveys (if available). In the case of the stepwise approach (Nadon and Ault, 2016), this tool also requires parameters for an L_{max} distribution and a species’ family-level taxonomic group. Other required parameters are entered as fixed values: selectivity (L_{S50} and L_{S95}), a_0, length-weight parameters (alpha and beta), number

of Monte Carlo iterations, the assumed survivorship at maximum age value (*S*), and the spawning schedule (when spawning occurs throughout the year, set to monthly by default).

Once launched, the program will draw random samples from the input distributions and run the calculations showed in Figure 4: 1) generate an estimate of Z from the length-mortality model, 2) calculate M from longevity (if necessary) and F, 3) calculate SPR and F_{30} using the population simulation model, and 4) calculate C_{30} from the diver surveys (if available) and from the catch data (if available). The program outputs a comma-separated data file (.CSV) containing parameter values for all Monte Carlo iterations. This CSV file is processed with an R script to generate the standard suite of figures and tables displayed in each species report ("process_mast.r").

RESULTS SUMMARY

It is beyond the scope of this summary section to discuss individual assessments of the 27 reef fish species in this report. In-depth results, comments, and specific concerns can be found in the Species Reports section at the end of this manuscript. Here, we provide a brief overview of the state of reef fishes in Hawaii, as can be inferred from the species analyzed in this report. Table 5 presents a summary of selected stock status metrics for each species.

Out of the 27 species in this report, 25 had depth ranges extending significantly (21 to 26%) into federal waters (i.e., beyond the 3 nautical mile limit of state waters). Two parrotfish species appeared to have limited presence in federal waters (*Chlorurus spilurus* and *Scarus psittacus*). A significant portion (~ 40%) of federal reef fish seafloor habitat above 250 m occurred at depths between 40 and 70 m, mainly on Penguin Bank, off Molokai (Figure 2).

We found local life history parameters for only 11 species and had to use parameters from studies conducted elsewhere in the Indo-Pacific region for 5 species. The remaining 11 species had either no (9) or inadequate (2) published life history studies and we used the data-poor approach presented in Nadon & Ault (2016) to obtain estimates (Table 5). As expected, the assessments conducted with these estimates were more variable than those conducted with life history parameters from actual studies.

Of the 27 assessed species, 11 had median *SPR* values below the minimum 0.30, which is the recommended limit we used as the default metric for overfishing in the current report (Restrepo et al., 1998). By this metric, *SPR* values lower than 0.30 indicate a stock may be experiencing overfishing (and due to the equilibrium assumption, may also be overfished). Two species had a median *SPR* values close to this limit (< 0.35; Table 5). Surgeonfishes had the most species with low *SPR* values, while goatfishes generally had higher *SPR* values. Typically, species with low *SPR*s were the ones with long lifespan (i.e., surgeonfishes, large parrotfishes, *A. virescens*) or highly targeted (i.e., jacks). Species with shorter lifespans (i.e., goatfishes) fared generally better.

To generate C_{30} from estimates of F_{30} (fishing mortality at $SPR = 0.3$), we had to obtain estimates of current stock biomass, either directly from diver surveys or indirectly from dividing total catch by an estimate of current F. Biomass estimates derived from diver-survey biomass were usually much more precise than those obtained through the catch. Consequently, C_{30} distributions derived from diver-biomass were generally more precise as well. Table 5 presents both estimates of population biomass by species. For species where both biomass estimates were available, 6 out of 12 species had biomass estimates within an order of magnitude of each other (Table 5). Almost all biomass estimates derived from the catch were lower than those derived from diver surveys, suggesting some measure of under-reporting in the commercial catch and/or some bias from the HMRFS recreational fishing survey. The only 2 species with greater catch-derived biomass than diver-survey biomass were goatfish species, with a potential bias associated with an important fishery for juveniles (see Species Reports section).

DISCUSSION

The assessment approach used in this report focused on fisheries-independent diver-survey data and recent estimates of both commercial and recreational catch. It used mortality and population models that are relatively simple, but well-tested and appropriate for the data-poor situation that characterize coral-reef fisheries (Ehrhardt & Ault, 1992; Ault et al., 2005; Hordyk et al., 2015; Nadon et al., 2015). Several assumptions and caveats apply to these models.

First, we assumed the stocks analyzed in the current study were at equilibrium in terms of both mortality rates and recruitment (i.e., relatively constant over the last decade or so). Ault et al. (2005) showed that mortality rates derived from average length are fairly robust to even moderate levels of recruitment variation. In the case of an extreme recruitment event (e.g., an annual ten-fold increase in the background recruitment level), we would have expected average lengths to decrease dramatically for a few years followed by a quick upward rebound before a return to the long-term equilibrium. In the case of a long-term increasing trend in fishing mortality, we would have expected a slow, constant decline in average length. We did not observe such patterns in average length over time in our study and this suggests that potential fluctuations in recruitment levels over time were not significant enough to affect our average length estimates and that fishing mortality was more or less constant. Furthermore, the fish abundance time series from diver surveys did not reveal major trends, although these observations were fairly variable and only started in 2005. Despite these issues, these time series observations also support the general equilibrium assumption. It is worth noting again that because we assumed the populations were at equilibrium, a finding that a stock may be experiencing overfishing also meant that the stock may be overfished (and vice versa).

A second key assumption was that size composition, abundance, and catch data were representative of the true population around the MHI. Both the underwater visual survey and commercial report data sets had strengths and weaknesses. The underwater surveys by scuba divers did not reach depths beyond 30 m due to safety and time constraints, thus underestimating total population size for species with depth range extending beyond this depth. However, diver surveys were able to sample remote and exposed areas of the MHI that are likely visited less frequently by fishers. The size composition and abundance data for the visual survey data set was thus more representative of nearshore (< 30-m deep) communities but encompassed the entire nearshore waters in the MHI, including remote, lightly-populated, and relatively inaccessible sections of coastlines. On the other hand, size composition data from commercial reports included information on deeper fish communities, but were less likely to be representative of inaccessible coastlines. Despite these potential biases, the size composition information from these two disparate data sets have been shown to be similar suggesting that the average lengths used in the current report were likely representative of the real values (Nadon et al., 2015). It is also important to note that the population abundance estimate from the diver surveys assumed a catchability coefficient equal to the area of a single survey divided by the total hard-bottom habitat area above 30 m. In other words, we did not assume any detectability bias which could have an impact on population biomass estimates for certain, more mobile species (jacks, snappers, larger parrotfishes). However, for more mobile species we did not use diver survey

abundance estimates for C_{30} and *OFL* estimation because of this potential bias, and instead used catch based abundance estimates.

The total catch estimates used in this report came from the commercial reports and the HMRFS program for recreational catches (which are the vast majority of the total catch), both of which have issues. The commercial reports may under-estimate the catch given that it is self-reported. The HMRFS catches are based on an interpolation of total fishing effort from telephone surveys, combined with creel surveys, and suffer from low sampling effort. These issues reduced our confidence in catch-derived C_{30}. However, for most species, diver-survey based C_{30} were also available, which helped verify catch-derived metrics.

Third, it is highly likely that segments of fish stocks located around more heavily populated islands (i.e., Oahu, Maui) face considerably higher fishing pressure than more isolated parts of the MHI. However, it is not entirely clear to what level reef fish populations are connected between islands, in terms of larval exchange and/or adult movement. For example, a tagging study failed to detect inter-island movements for tagged *Caranx ignobilis*, a large and highly mobile predator (Meyer et al., 2007). Conversely, a State of Hawaii tagging program did record a kahala jack (*Seriola dumerili*, amberjack) swimming hundreds of kilometers from the NWHI to the MHI in a 3-year timespan (Tagawa & Clayward, 2006). Genetic connectivity studies indicate that most reef fish species have no genetic structuring across the Hawaiian archipelago (Rivera et al., 2004; Craig et al., 2007; Gaither et al., 2010). However, the absence of genetic structure does not necessarily imply that stocks are well-connected at time scales relevant to population dynamic processes. More informatively, recent genetic parentage analyses of two coral reef fish species in Australia have found parent-offspring pairs at distances up to 250 km, with a median dispersal distance of 110 km and 190 km (Williamson et al., 2016). As shown in Table 2, the longest distance between islands in the MHI is 116 km (Oahu – Kauai), with most islands separate by much shorter distances. Another parentage study conducted on Hawaii Island found yellow tang surgeonfish parent-offspring pairs separated by up to 184 km, although they did not attempt to find cross-channel pairs (Christie et al., 2010). Furthermore, a recent study of passive pelagic particle connectivity in the MHI, based on a pelagic larval duration of 45 days found a median distance for successful settlements around 100 km (Wren et al., 2016) and that cross-channel dispersal can be common. Population connectivity within the MHI is still an open question and will require further research attention, however, based on current research, it appears that our MHI-scale analyses are appropriate. As a side note, it is generally well-accepted that the MHI and NWHI reef fishes form different stocks, and that little larval or adult exchange exists between these two regions given the dominant current direction and the large distances involved, with the exception of the kahala example mentioned above (Toonen et al., 2011; Wren et al., 2016).

Fourth, for many species, we had to use life history parameters from other Pacific areas. It is possible that these values change geographically and with environmental conditions (Choat & Robertson, 2002; Gust et al., 2002, although see Donovan et al., 2013). The availability of an extensive underwater visual survey data set for the relatively pristine NWHI allowed Nadon et al. (2015) to evaluate the validity of the length-based mortality model used in the current report, as well as the validity of our life history information. Nadon et al. (2015) used independent

estimates of M from the NWHI (where Z derived from average length is assumed to be equal to M) to derive an estimate of average cohort survivorship (S) to maximum age (a_{λ}). They obtained a value close to 0.04. The exact survivorship value is linked to the sampling effort in the data set from which a_{λ} is obtained (i.e., the larger the number of aged individuals, the greater the chance of finding extremely old individuals that are not representative of a 5% or even 1% cohort survivorship value; Kenchington, 2014). Since the a_{λ} value for reef fishes generally comes from life history studies with less than 100 aged individuals, it is possible that these values represent cohort survivorship higher than 1.5%, which is what our analysis suggests. For species with no published life history parameters, we used the approach presented in Nadon & Ault (2016) to provide first-step estimates. This approach uses a local estimate of L_{max} which may be biased downward in heavily fished stocks (and thus result in biased life history parameters). This is less of an issue in the current report given that length data in the pristine NWHI were available to generate L_{max} estimates.

Future directions

The Pacific Islands Fisheries Science Center is conducting research on a wide variety of subjects that will help address some of the concerns mentioned above. The Coral Reef Ecosystem Program, with assistance from the Stock Assessment Program, will continue collecting fisheries-independent diver data. This data set, in conjunction with longer HMRFS and DAR catch data sets, will eventually have a time-series of sufficient length to run more advanced, non-equilibrium models. The continuing efforts in deep-water surveys using underwater cameras will also provide abundance and size composition data for a section of the reef fish populations that is not accessible by diver survey and may be significantly different. These camera system deployments are also generating deep-water habitat information. The Life History Program at PIFSC is continuing their work on growth, maturity, and longevity of local stocks in the U.S. Pacific which will lead to more appropriate life history parameters and will allow further assessment for data-less species. Finally, new population genetic work, mainly at the University of Hawaii, can provide further information regarding the scale of reef fish population connectivity across the MHI and depending on the results may lead to future assessments being conducted at a different scale (e.g., island or smaller island group).

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TABLES AND FIGURES

Table 1.--List of parameters used in the document.

Parameter	Definition
α, β	Parameters of the length-weight relationship
a_{λ}	Oldest recorded age (i.e., longevity)
a_0	Theoretical age at which length equals zero from the von Bertalanffy growth curve
B	Total population biomass
C_{30}	Catch limit resulting in SPR = 0.3
F	Instantaneous annual fishing mortality rate
F_{30}	Instantaneous annual fishing mortality rate resulting in SPR = 0.3
K	Brody growth coefficient of the von Bertalanffy growth curve
L_{bar} or $\overline{L}$	Average length in the exploited phase of a stock
Lc_{30}	Size at first capture limit resulting in SPR = 0.3
L_{inf} or L_{∞}	Expected length at infinite age from the von Bertalanffy growth curve
L_{λ}	Expected length at the oldest recorded age
L_{mat}	Length at which 50% of females reach maturity
$L_{\max}$	Longest length in a growth study or 99$^{\mathrm{th}}$ percentile of lengths in a population survey
L_{S50}	Length at 50% selectivity
L_{S95}	Length at 95% selectivity
M	Instantaneous annual natural mortality rate
OFL	Overfishing limit, defined as the median of the C_{30} distribution
S	Survivorship at maximum recorded age
SPR	Spawning potential ratio
Z	Instantaneous annual total mortality rate

Table 2.-- Information summary of the two principal regions of the Hawaiian Islands, including the four subregions of the main Hawaiian Islands. Reef area is to 30-m depth and excludes soft bottom habitat. Source: CREP and Hawaii Mapping Research Group bathymetric synthesis data set.

Region	Human population (2010)	Reef area (km^2)	Prop. of total reef in region	Pop. per reef area (# km^{-2})	Channel width (km)[a]
Main Hawaiian Is.					
Hawaii	185,079	168	0.18	1099	48
Maui Nui	154,950	269	0.28	577	48-42
Oahu	953,000	251	0.26	3794	42-116
Kauai-Niihau	65,819	274	0.28	240	116-220

[a] Channel widths from east to west.

Table 3.-- Area of sea floor in the MHI by depth zones, in state and federal waters (soft and hard bottom). Depth range extends to 250 m which is close to the maximum recorded depths for the species included in this report. Source: CREP and Hawaii Mapping Research Group bathymetric synthesis data set.

Depth (m)		Hectares of sea floor			Cumulative percent in fed. Waters
Min	Max	State waters	Federal waters	Total	
0	30	126,930	0	126,930	0
30	40	37,670	57	37,727	< 1
40	50	32,960	23,097	56,057	10
50	60	32,770	27,893	60,663	18
60	70	31,725	19,711	51,436	21
70	80	31,667	9,151	40,818	21
80	90	27,698	6,343	34,041	21
90	100	25,343	7,560	32,903	21
100	150	88,823	32,365	121,188	22
150	200	44,440	24,036	68,476	24
200	250	39,120	32,261	71,381	26

Table 4.--Coefficient of variation of 4 life history parameters at various sample sizes. L_{inf}, K, and a_{max} from Kritzer et al. (2001), and L_{mat} from Nadon (unpubl.).

Sample size	CV L_{inf}	CV K	CV L_{mat}	CV a_{max}
25	0.167	0.568	0.070	0.190
50	0.111	0.299	0.048	0.168
75	0.078	0.250	0.036	0.147
100	0.060	0.222	0.031	0.129
125	0.050	0.190	0.027	0.118
150	0.045	0.172	0.025	0.113
200	0.040	0.142	0.021	0.092
300	0.030	0.120	0.017	0.074
500	0.021	0.095	0.013	0.056

Table 5.--Species summary of selected stock metrics. Bold text indicates stocks considered overfished /overfishing according to the *SPR* = 30% based biological reference point. Overfishing is defined as F/F_{30} > 1 and overfished is defined as *SPR* < 0.30.

Species	Man. unit	Group	LH source	Max depth (m)	Percent in fed. waters	F/F_{30}	*SPR*	Pop. from catch (kg)	Pop. from survey (kg)
Acanthuridae									
Acanthurus blochii	C	Ac	E	80	21	**2.3**	**0.12**	-	365,000
Acanthurus dussumieri	C	Ac	E	131	22	0.8	0.36	356,000	719,000
Naso brevirostris	C	Ac	E	122	22	**1.9**	**0.14**	-	132,000
Naso hexacanthus	C	Ac	E	124	22	**2.0**	**0.13**	30,000	-
Naso lituratus	C	Ac	E	93	21	**1.3**	**0.25**	30,000	452,000
Naso unicornis	C	Ac	L	120	22	**6.0**	**0.03**	-	364,000
Carangidae									
Carangoides orthogrammus	C	Ca	S	235	26	0.7	0.41	123,000	-
Caranx ignobilis	B	ND7	L	228	26	**1.1**	**0.28**	1,070,000	-
Caranx melampygus	C	Ca	L	230	26	0.7	0.40	811,000	-
Lutjanidae									
Aprion virescens	B	ND7	L	203	24	0.9	0.33	758,000	434,000
Lutjanus fulvus	C	Lu	S	128	22	0.9	0.33	48,000	180,000
Lutjanus kasmira	B	ND7	L	265	26	0.3	0.62	181,000	496,000
Mullidae									
Mulloidichthys flavolineatus	C	Mu	L	97	21	0.5	0.49	307,000	42,000
Mulloidichthys pflueregi	C	Mu	S	242	26	0.7	0.41	21,000	-
Mulloidichthys vanicolensis	C	Mu	L	132	22	0.4	0.55	139,000	35,000
Parupeneus cyclostomus	C	Mu	S	113	21	**1.3**	**0.24**	12,000	77,000
Parupeneus insularis	C	Mu	S	90	21	0.4	0.57	5,000	42,000
Parupeneus porphyreus	C	Mu	L	140	22	**1.9**	**0.15**	15,000	14,000
Scaridae									
Calotomus carolinus	C	Sc	S	71	21	**2.2**	**0.13**	-	38,000
Chlorurus perspicillatus	C	Sc	S	80	21	0.5	0.54	-	79,000
Chlorurus spilurus	C	Sc	S	34	0	**1.4**	**0.23**	-	139,000
Scarus dubius	C	Sc	S	80	21	0.6	0.45	-	33,000
Scarus psittacus	C	Sc	S	48	10	0.7	0.41	-	130,000
Scarus rubroviolaceus	C	Sc	L	68	21	**1.2**	**0.26**	-	624,000
Other families									
Cephalopholis argus	C	Se	L	80	21	0.1	0.80	232,000	777,000
Monotaxis grandoculis	C	Le	S	101	22	0.8	0.38	29,000	232,000
Myripristis berndti	C	Ho	L	159	22	0.4	0.59	-	260,000

Management units: C = Coral Reef Management Unit Species (CREMUS), B = Bottomfish Management Unit Species (BMUS)
Grouping: Ac = Acanthuridae, Ca = Carangidae, Ho = Holocentridae, Le = Lethrinidae, Lu = Lutjanidae, Mu = Mullidae, ND7 = Non-deep 7 bottomfish, Se = Serranidae, Sc = Scaridae.
Life history source: E = external (different geographic location), L = local (from Hawaii), S = stepwise approach (Nadon & Ault, 2016).

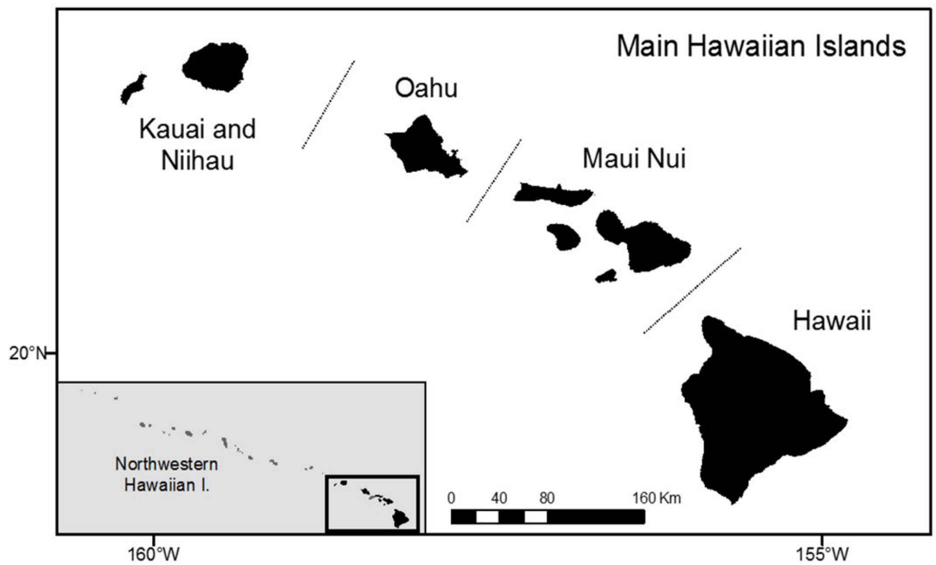


Figure 1.--Map of the Hawaiian Islands (including Northwestern Hawaiian Islands in inset), with the four subregions. Figure from Nadon et al. (2015).

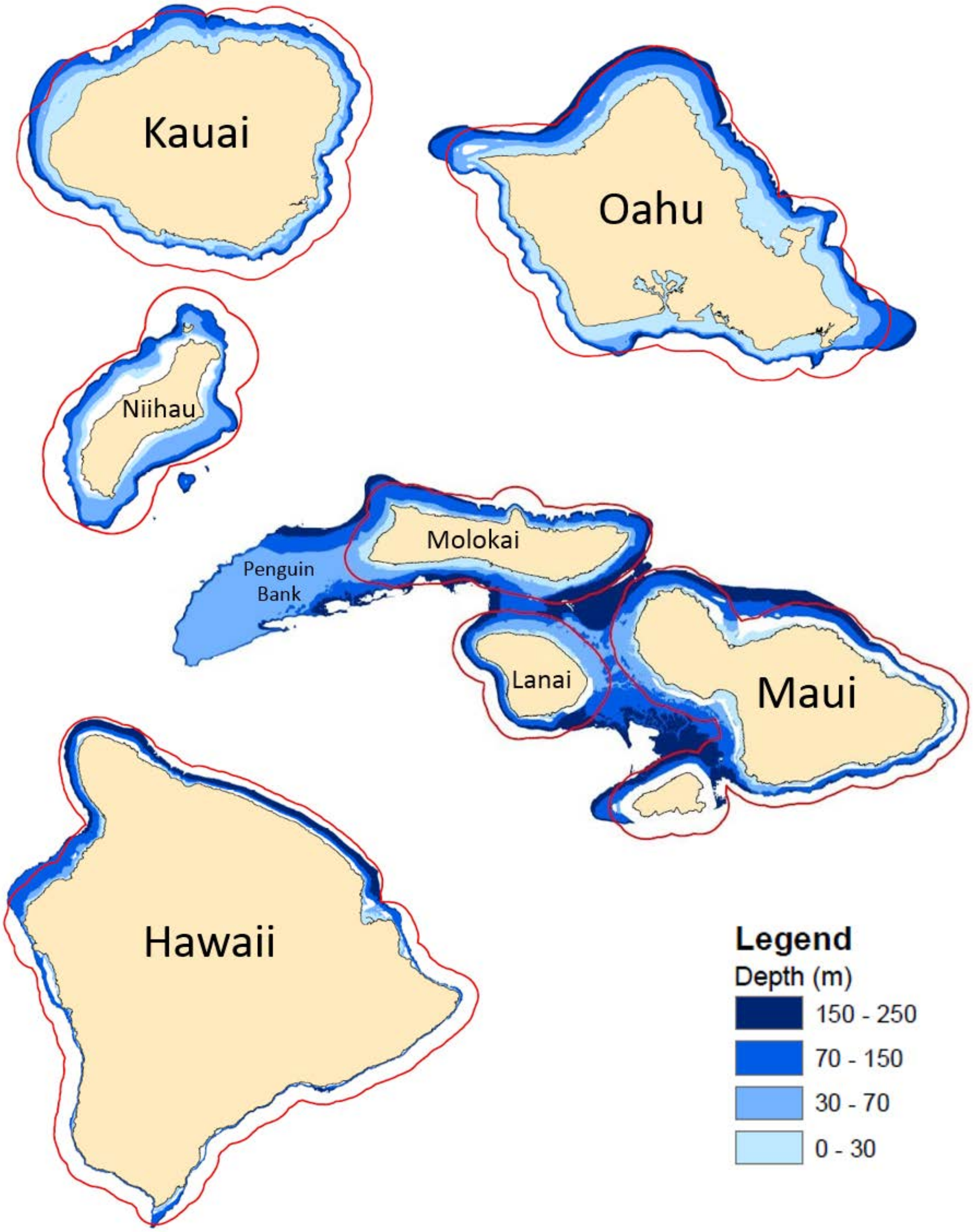


Figure 2.--Map of the 8 main Hawaiian Islands with deep water depth zones (0-m to 250-m depths). Black contour lines represent the 3 nautical mile State waters limit. Islands are not to scale. Data source: CREP and Hawaii Mapping Research Group.

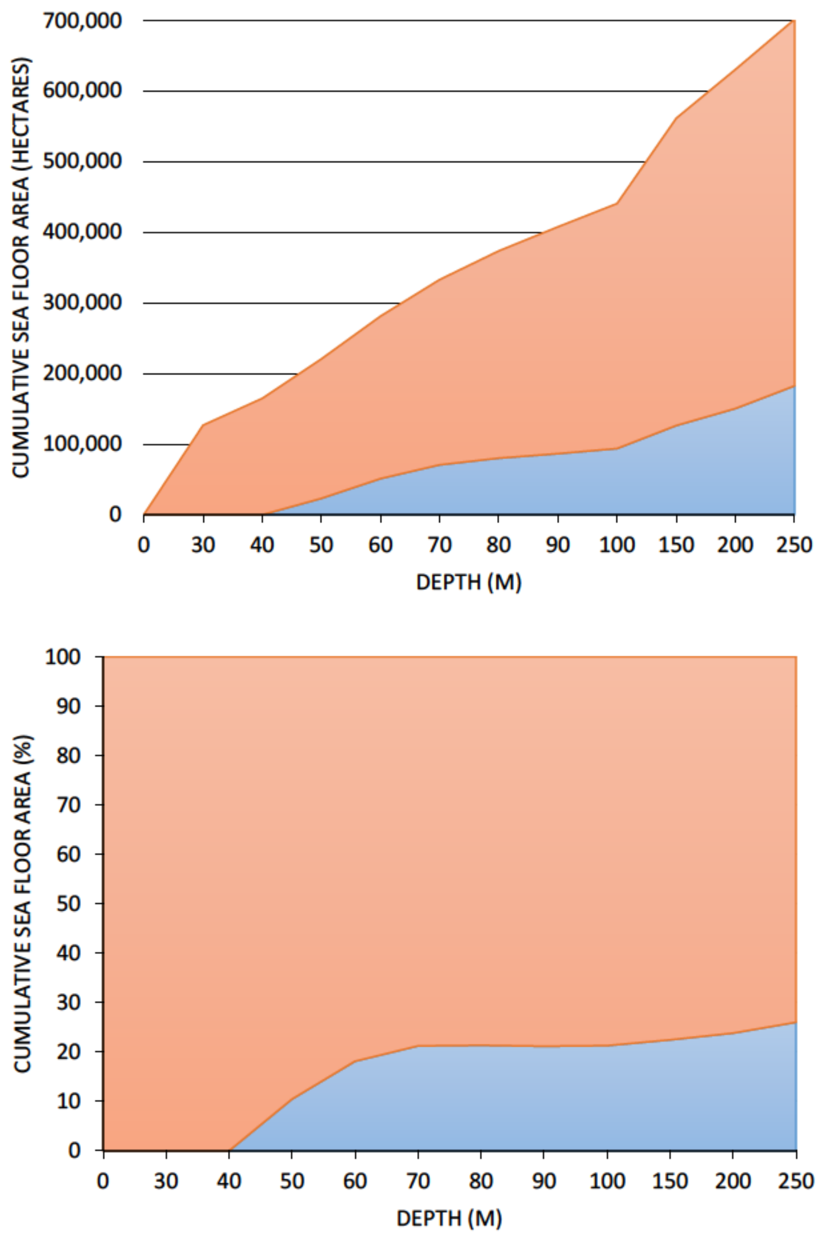


Figure 3.--Cumulative sea floor area in hectares (top panel) and percentage of total (bottom panel) from 0 m to 250 m. Blue area is federal waters and red area is state waters. Soft and hard bottom included.

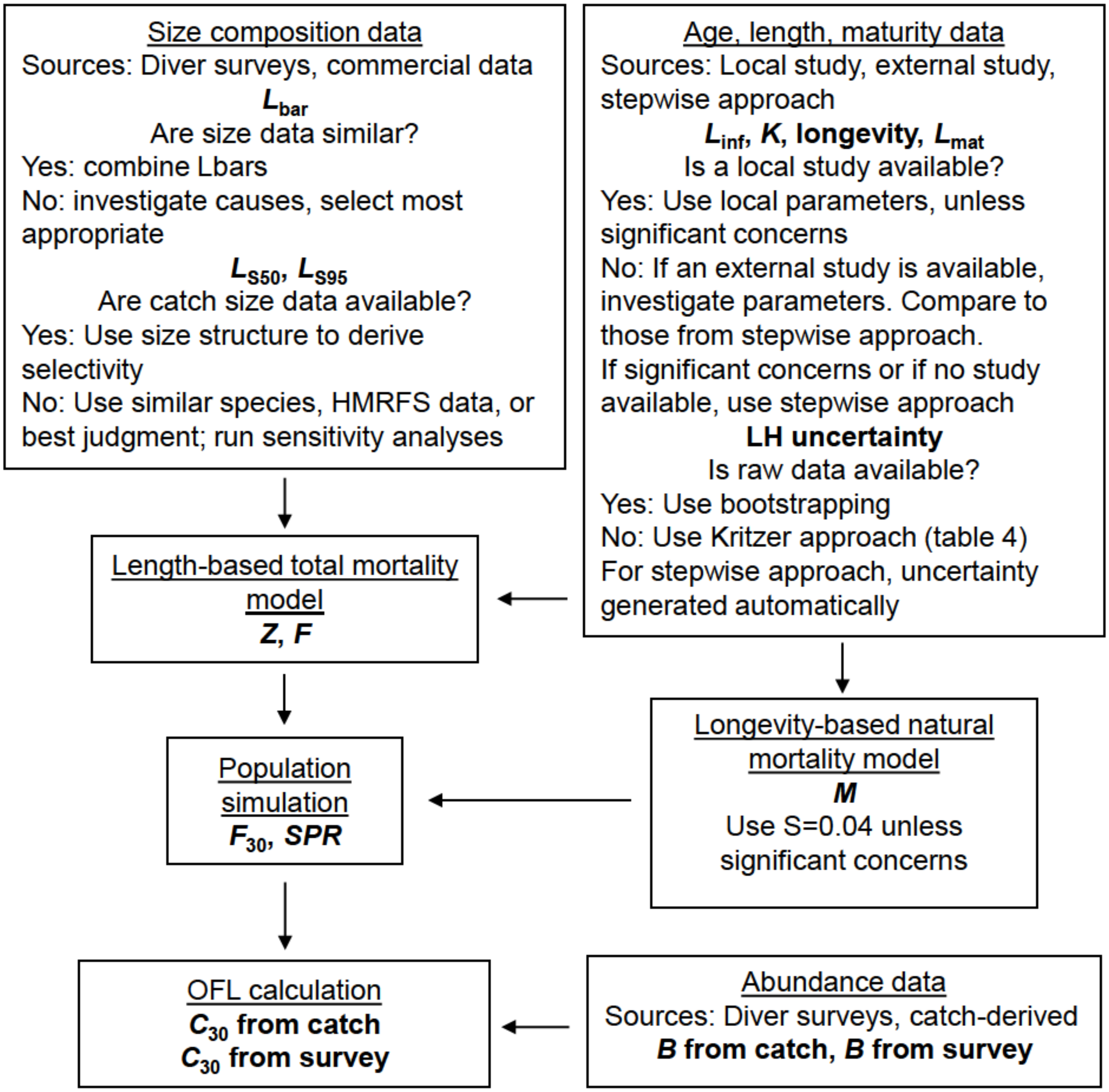


Figure 4.--Overall approach and decision points used to calculate stock status and obtain overfishing limits (*OFL*).

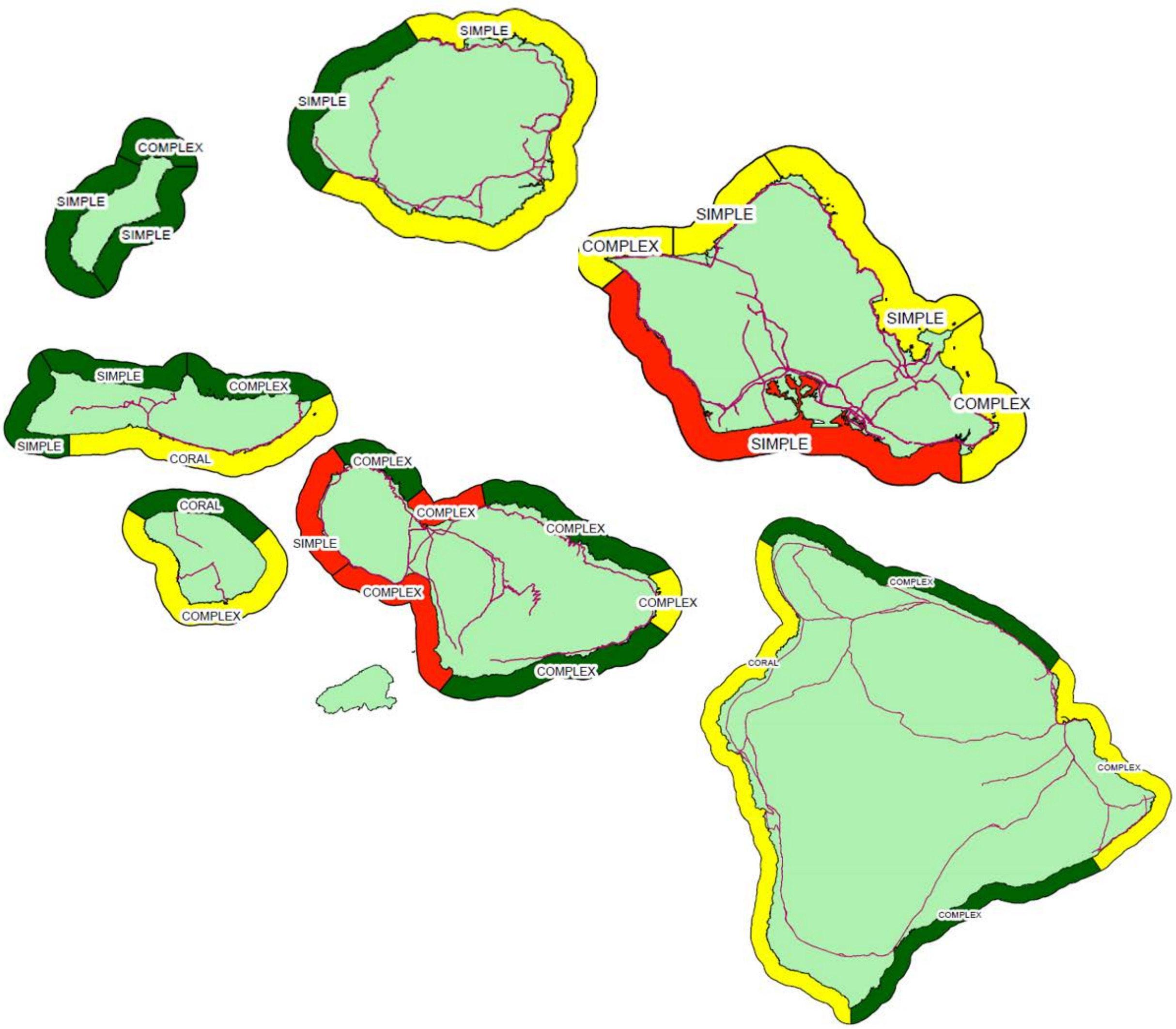


Figure 5.--Survey sectors of the MHI (islands at different scales). These sectors were used when running bootstrap analyses for biomass density data from diver surveys. There are 3 habitat categories (simple, complex, and coral-dominated) and 3 fishing intensity category (green = low, yellow = moderate, and red = high). Habitat categories were derived from CREP habitat survey data and the fishing categories are based on accessibility and human population density.

SPECIES REPORTS

Acanthurus blochii

Ringtail surgeonfish, *pualu*
Acanthuridae (surgeonfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	363	61	mm	24	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
K	0.25	0.14	yr^{-1}		
a_0	-0.38	-	yr		
L_{mat}	276	19	mm	24	Mean: 76% of L_{inf}, SD: Nadon (unpublished)
Longevity	35	6.7	yr	24	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
L-W α	1.87e-5	-	-	-	Kulbicki (2005)
L-W β	3.03				
L_{S50}	225	-	mm	-	Estimated.
L_{S95}	250				
$\bar{L}$ diver survey	299	3	mm	672	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	-
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	80	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.09	0.02	yr^{-1}
F	0.27	0.21	yr^{-1}
F_{30}	0.12	0.03	yr^{-1}
F/F_{30}	2.3	1.7	-
SPR	0.12	0.17	-
SPR < 0.30 iterations	84	-	%
Lc_{30}	290	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	-
B from survey	365,392	48,886	kg
Commercial catch	3,604	1,362	kg
Recreational catch	1,394	4,005	kg
Total catch	5,668	3,042	kg
C_{30} from catch	-	-	-
C_{30} from survey	38,300	9,000	kg

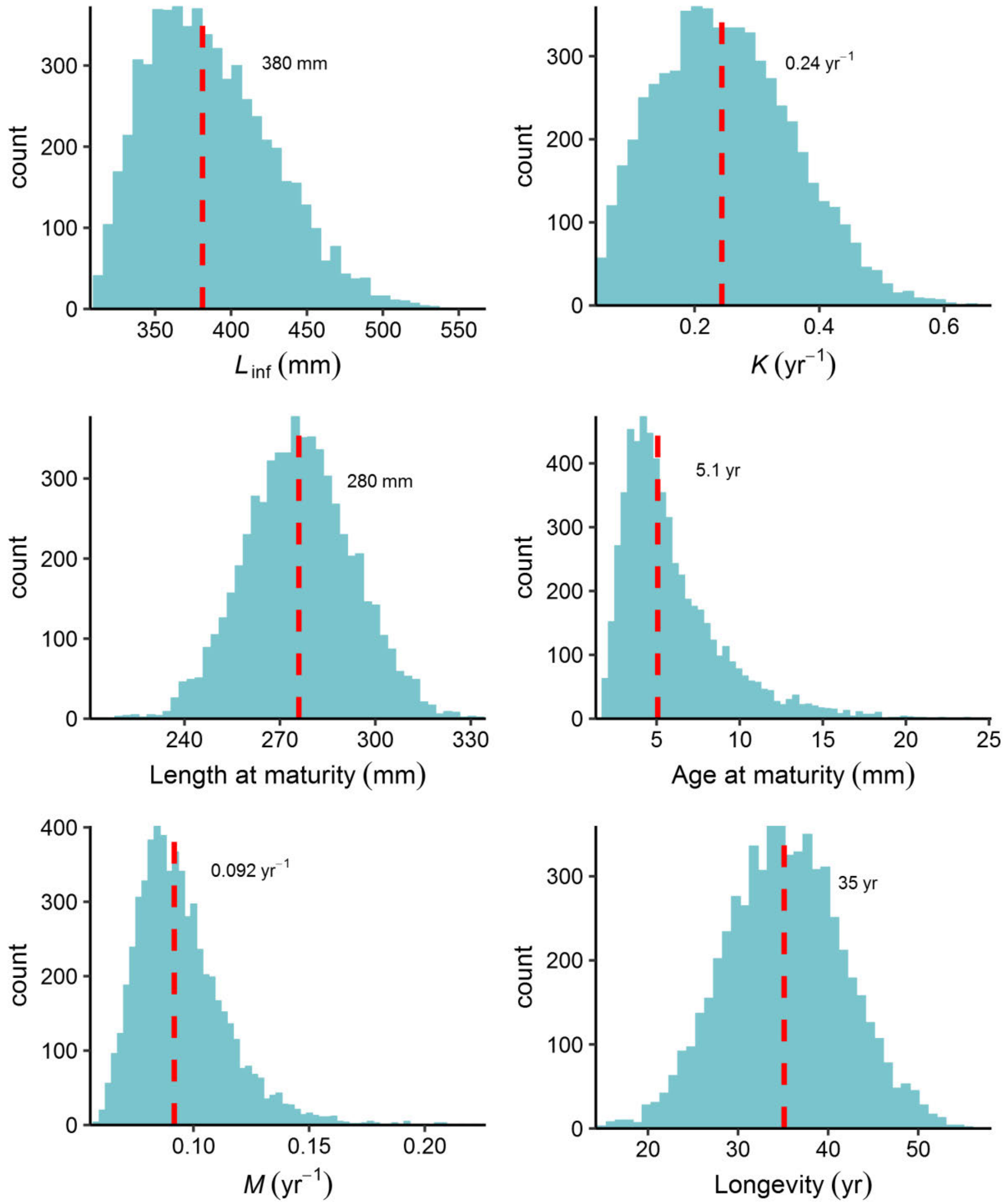
General comments

The DAR commercial reporting system combines *A. xanthopterus* with this species. The commercial catch for these two species is listed above, but as a reference only. In the HMRFS data set, the *A. xanthopterus* catch is 4× larger than *A. blochii*.

Population abundance has been slowly rising since 2007 while L_{bar} has remained fairly stable at around 30cm, suggesting a population near equilibrium. Selectivity had to be estimated from *A. dussumieri*, a similar species, given the absence of fishery data. A sensitivity run with L_{S50} at 250 and L_{S95} at 280 had little impact on the results (F: 0.28, *SPR*: 0.11). There were some concerns with the LH parameters, which came from an Australian study with a low sample size and we therefore ran extra analyses using the stepwise approach (L_{max}: 420 mm gave L_{inf}: 390 mm, K:0.42, M: 0.1). The higher L_{inf} value resulted in a much higher F (0.61) and lower *SPR* (0.03). However, the C_{30} was mostly unchanged (40,300 kg).

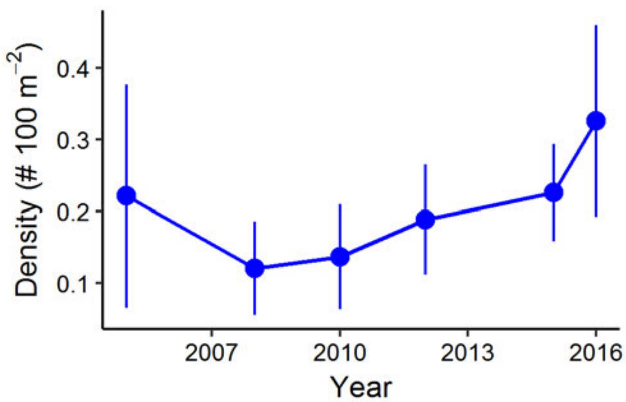
The annual total catch estimate (5,668 kg) is fairly small compared to the *OFL* estimate (38,300 kg), even though it includes *A. xanthopterus* catches. This amount of catch is too small to explain the level of fishing mortality estimated from L_{bar}. However, the diver survey data for this species is fairly reliable (i.e., easily identifiable, common species, non-cryptic) and therefore the C_{30} estimates from these surveys should be reliable.

Acanthurus blochii

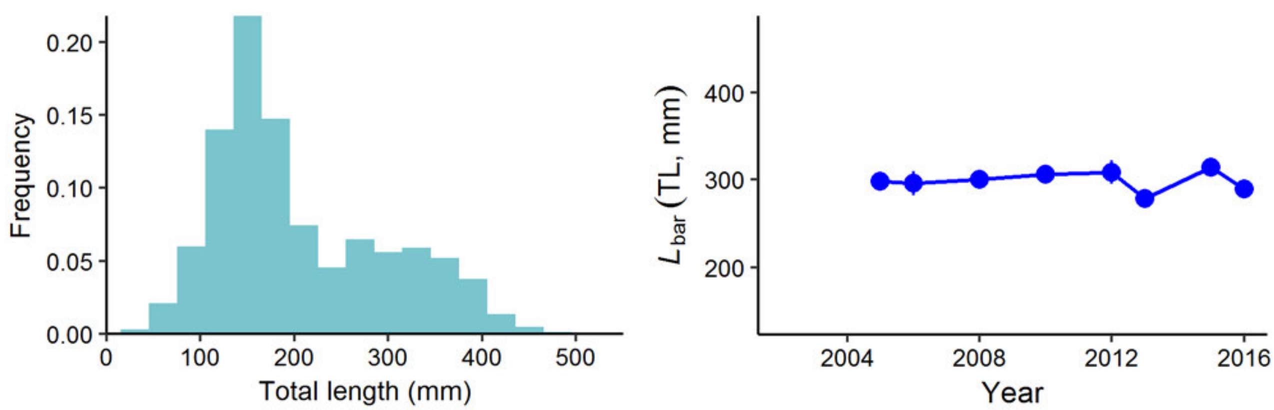


Life history parameter distributions.

Acanthurus blochii

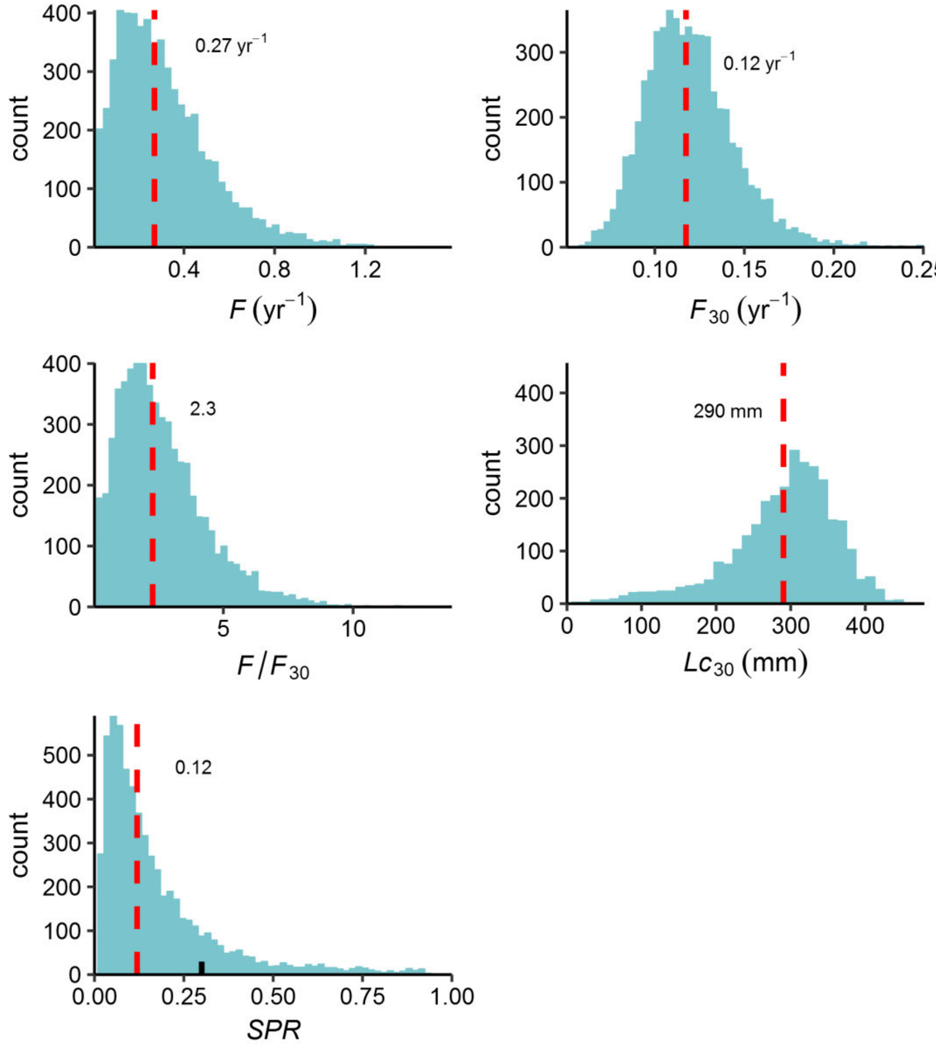


Abundance index from UVS (blue circles, ±SE).

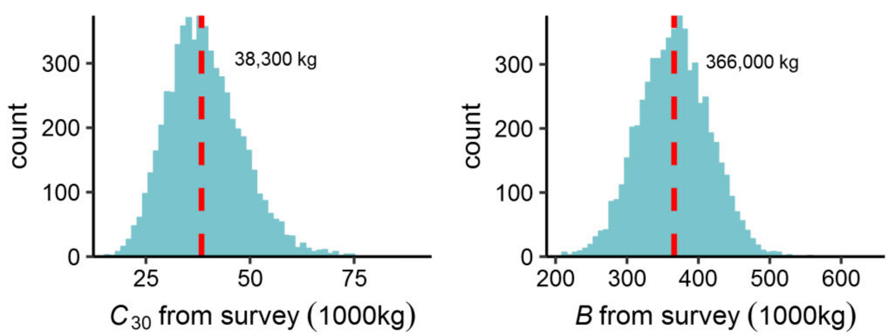


Size structure and average length time series from UVS (±SE).

Acanthurus blochii

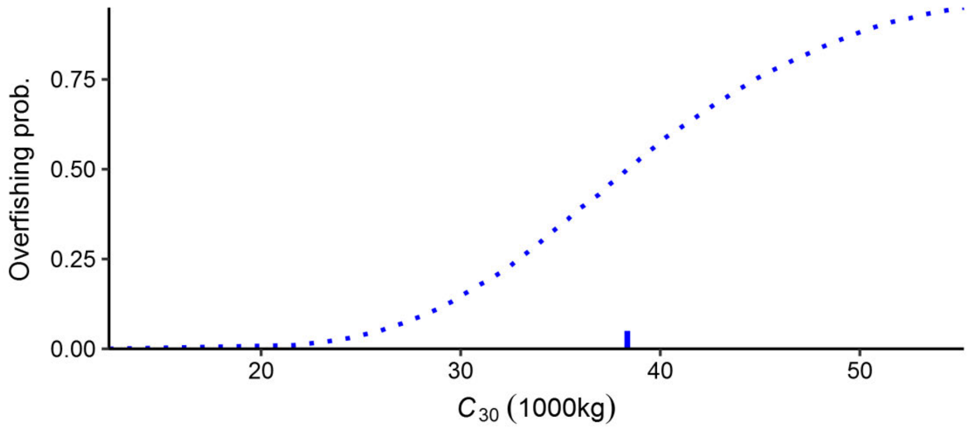


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Acanthurus blochii



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	28.4	0.31	34.2
0.11	28.8	0.32	34.4
0.12	29.1	0.33	34.7
0.13	29.5	0.34	34.9
0.14	29.8	0.35	35.1
0.15	30.1	0.36	35.4
0.16	30.4	0.37	35.5
0.17	30.7	0.38	35.7
0.18	31.0	0.39	35.9
0.19	31.4	0.40	36.2
0.20	31.6	0.41	36.4
0.21	31.9	0.42	36.7
0.22	32.2	0.43	36.9
0.23	32.5	0.44	37.1
0.24	32.7	0.45	37.3
0.25	32.9	0.46	37.5
0.26	33.1	0.47	37.8
0.27	33.4	0.48	38.0
0.28	33.6	0.49	38.2
0.29	33.9	0.50	38.3
0.30	34.0		

Acanthurus blochii

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	364	0.31	324
0.11	362	0.32	322
0.12	358	0.33	320
0.13	356	0.34	317
0.14	353	0.35	315
0.15	351	0.36	315
0.16	349	0.37	313
0.17	349	0.38	310
0.18	346	0.39	308
0.19	344	0.40	306
0.20	342	0.41	306
0.21	340	0.42	304
0.22	338	0.43	302
0.23	335	0.44	299
0.24	335	0.45	299
0.25	333	0.46	297
0.26	331	0.47	295
0.27	331	0.48	295
0.28	328	0.49	292
0.29	326	0.50	290
0.30	324		

Acanthurus dussumieri

Eyestripe surgeonfish, *palani*
Acanthuridae (surgeonfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	371	41	mm	43	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
K	0.296	0.089	yr^{-1}		
a_0	-0.29	-	yr		
L_{mat}	282	14	mm	50	Mean: Choat & Robertson (2002), SD: Nadon (unpublish.)
Longevity	28	4.7	yr	43	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
L-W α	2.33e-5	-	-	-	Kulbicki (2005)
L-W β	3.03				
L_{S50}	230	-	mm	-	DAR commercial data
L_{S95}	260				
$\bar{L}$ diver survey	323	3	mm	1198	NOAA-CREP diver survey
$\bar{L}$ commercial	334	1	mm	6403	DAR commercial data
$\bar{L}$ combined	333	2	mm	-	-
Max. depth	131	-	m	-	Pyle et al. (2016)
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.11	0.02	yr^{-1}
F	0.12	0.08	yr^{-1}
F_{30}	0.14	0.02	yr^{-1}
F/F_{30}	0.8	0.6	-
SPR	0.36	0.21	-
SPR < 0.30 iterations	37	-	%
Lc_{30}	129	-	mm

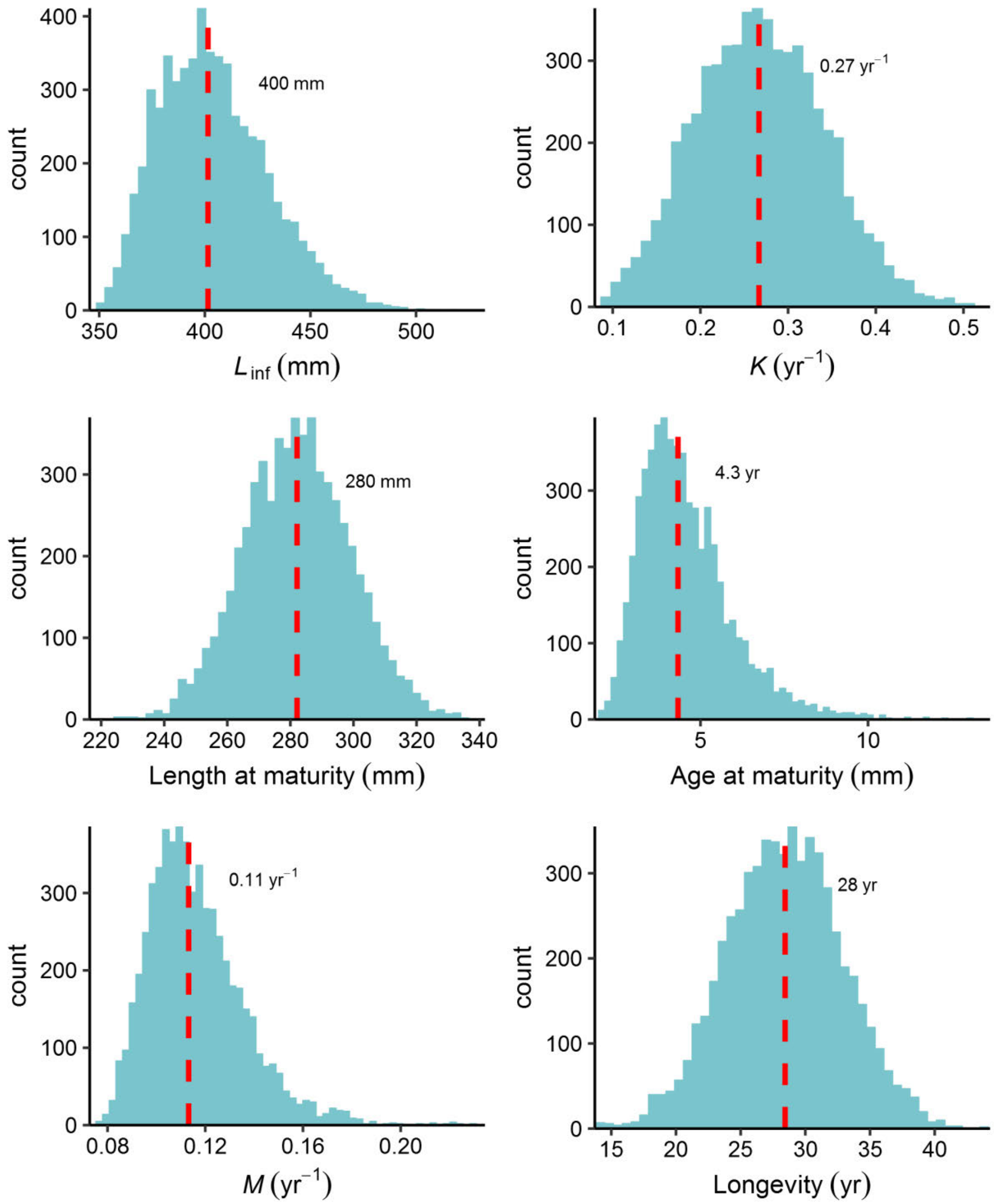
Parameter	Median	SD	Unit
B from catch	356,000	938,000	kg
B from survey	718,622	106,385	kg
Commercial catch	13,370	2,294	kg
Recreational catch	21,529	12,334	kg
Total catch	35,959	11,712	kg
C_{30} from catch	44,900	121,000	kg
C_{30} from survey	90,100	18,600	kg

General comments

Both population abundance and L_{bar} (UVS and commercial) time series were relatively stable suggesting a population mostly at equilibrium. Recreational catch did seem to be increasing, but the yearly estimates are fairly variable and this trend may have been spurious. L_{bar} estimates from the UVS and commercial data sets were almost identical. The LH parameters were obtained from an Australian study with a limited sample size. A sensitivity run using the stepwise approach gave the following results: L_{max}: 428 mm, L_{inf}: 399 mm, K: 0.40, M: 0.1, F_{30}: 0.13. The higher L_{inf} value resulted in a higher F (0.25) and lower *SPR* (0.14). The diver-survey *C*30 was mostly unchanged (81,000 kg), but the C_{30} from catch was reduced to 24,000 kg due to the higher F.

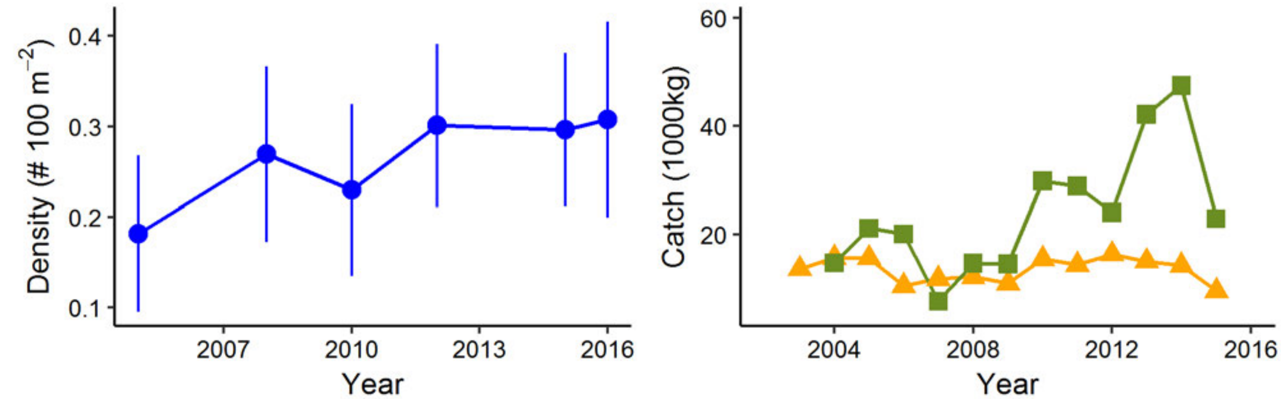
The population estimates derived from the catch was about half the size from the diver surveys. The lower population estimate from the catch data results in a lower catch-derived *OFL* estimate (44,900 kg vs. 90,100 kg). Given the quality of the diver data (i.e., high observation count, appropriate sampling design) and the similarity in F_{30} estimates between the external LH parameters and the stepwise-derived LH parameters, the survey-derived C_{30} is likely more reliable. The true population size may be even larger than the diver estimate (718,622 kg) given that this species' habitat extends far beyond diver survey depth (131 m vs. 30 m).

Acanthurus dussumieri

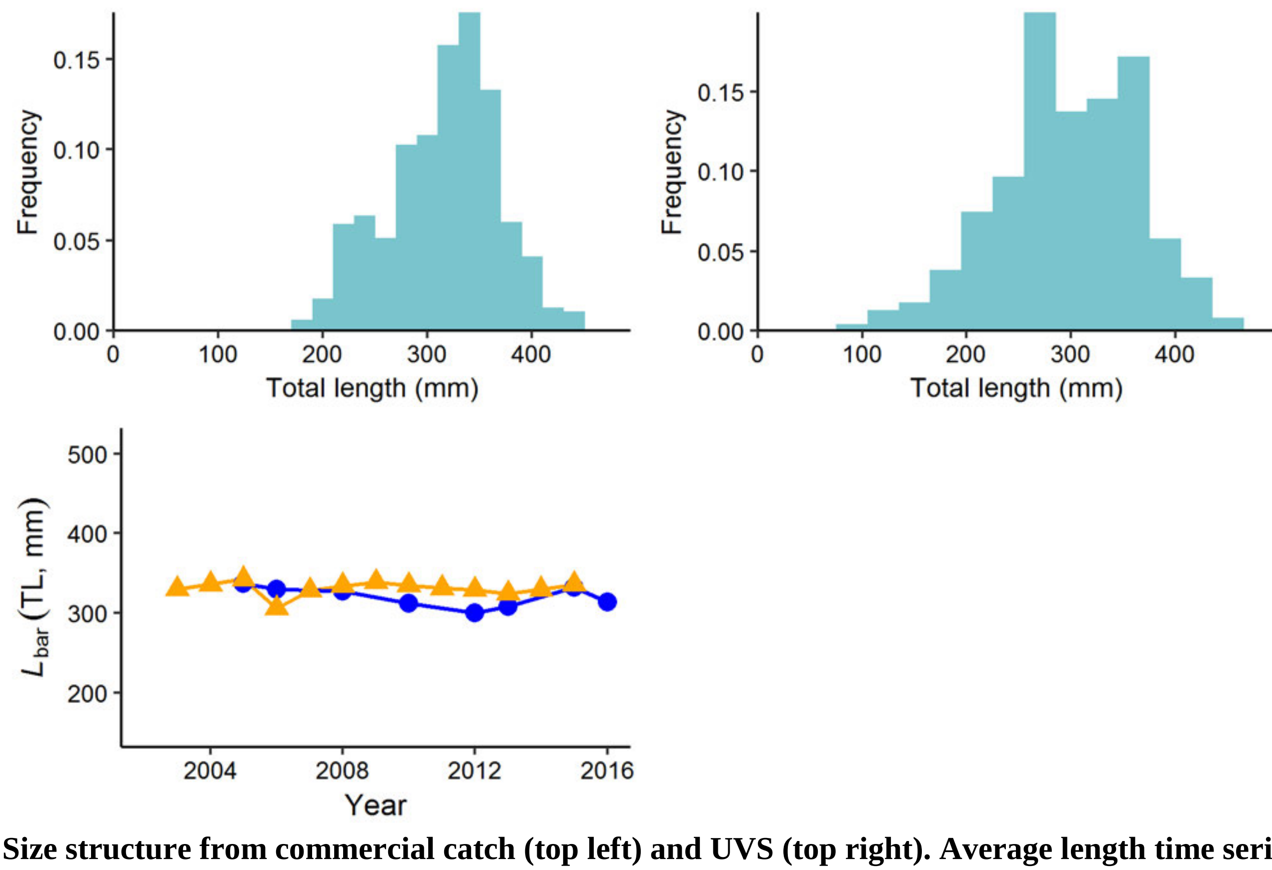


Life history parameter distributions.

Acanthurus dussumieri

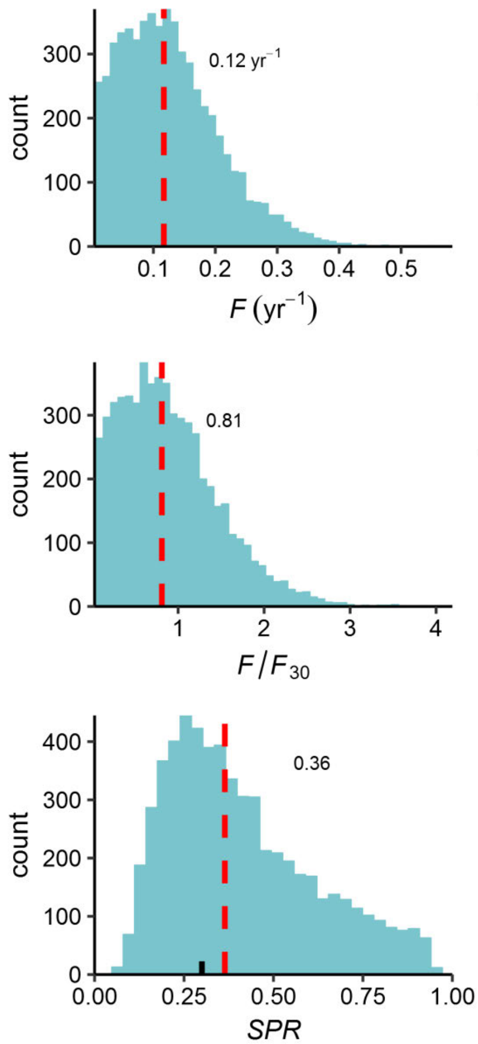


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



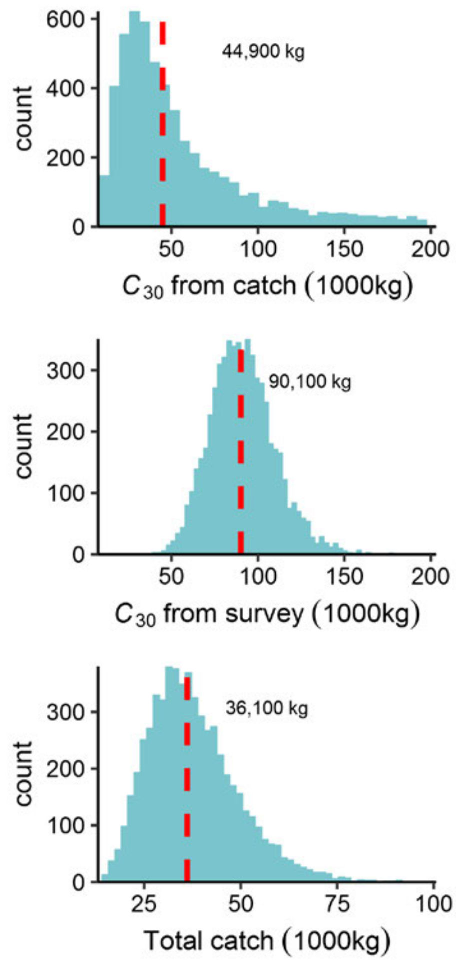
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Acanthurus dussumieri



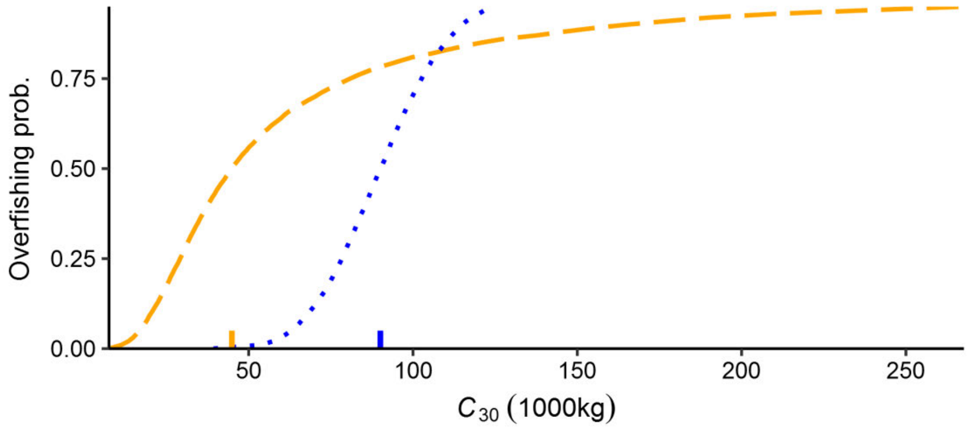
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Acanthurus dussumieri



C_{30} and current total catch (left) and population size (right) distributions.

Acanthurus dussumieri



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	20.4	68.4	0.31	32.2	81.2
0.11	21.1	69.2	0.32	32.8	81.7
0.12	21.8	70.1	0.33	33.4	82.3
0.13	22.4	71.0	0.34	33.9	82.7
0.14	23.0	71.7	0.35	34.6	83.1
0.15	23.6	72.4	0.36	35.1	83.6
0.16	24.2	73.2	0.37	35.7	84.0
0.17	24.8	73.9	0.38	36.3	84.6
0.18	25.3	74.5	0.39	36.9	85.1
0.19	25.8	75.0	0.40	37.6	85.6
0.20	26.3	75.6	0.41	38.3	86.0
0.21	26.9	76.1	0.42	38.9	86.5
0.22	27.4	76.7	0.43	39.7	86.9
0.23	28.0	77.3	0.44	40.2	87.3
0.24	28.6	77.8	0.45	41.0	87.7
0.25	29.1	78.4	0.46	41.7	88.2
0.26	29.7	78.9	0.47	42.6	88.7
0.27	30.2	79.3	0.48	43.3	89.1
0.28	30.7	79.7	0.49	44.1	89.6
0.29	31.2	80.3	0.50	44.9	90.1
0.30	31.7	80.8			

Acanthurus dussumieri

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	315	0.31	246
0.11	310	0.32	242
0.12	308	0.33	237
0.13	304	0.34	232
0.14	301	0.35	230
0.15	299	0.36	225
0.16	294	0.37	218
0.17	292	0.38	214
0.18	287	0.39	207
0.19	285	0.40	202
0.20	283	0.41	196
0.21	278	0.42	191
0.22	276	0.43	186
0.23	274	0.44	177
0.24	271	0.45	170
0.25	267	0.46	163
0.26	264	0.47	156
0.27	260	0.48	147
0.28	255	0.49	138
0.29	253	0.50	129
0.30	248		

Naso brevirostris

Paletail unicornfish, *kala lolo*
Acanthuridae (surgeonfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	327	16	mm	120	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
K	0.402	0.076	yr^{-1}		
a_0	-0.21	-	yr		
L_{mat}	269	7	mm	120	Mean: Choat & Robertson (2002), SD: Nadon (unpublish.)
Longevity	25	3.0	yr	120	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
L-W α	6.09e-6	-	-	-	Kulbicki (2005)
L-W β	3.24				
L_{S50}	200	-	mm	-	Best estimate based on similar surgeonfishes.
L_{S95}	220				
$\bar{L}$ diver survey	271	7	mm	561	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	No species-specific catch data.
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	122	-	m	-	Pyle et al. (2016)
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.13	0.02	yr^{-1}
F	0.30	0.16	yr^{-1}
F_{30}	0.16	0.02	yr^{-1}
F/F_{30}	1.9	1.0	-
SPR	0.14	0.12	-
SPR < 0.30 iterations	88	-	%
Lc_{30}	264	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	132,456	31,857	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	17,800	4,680	kg

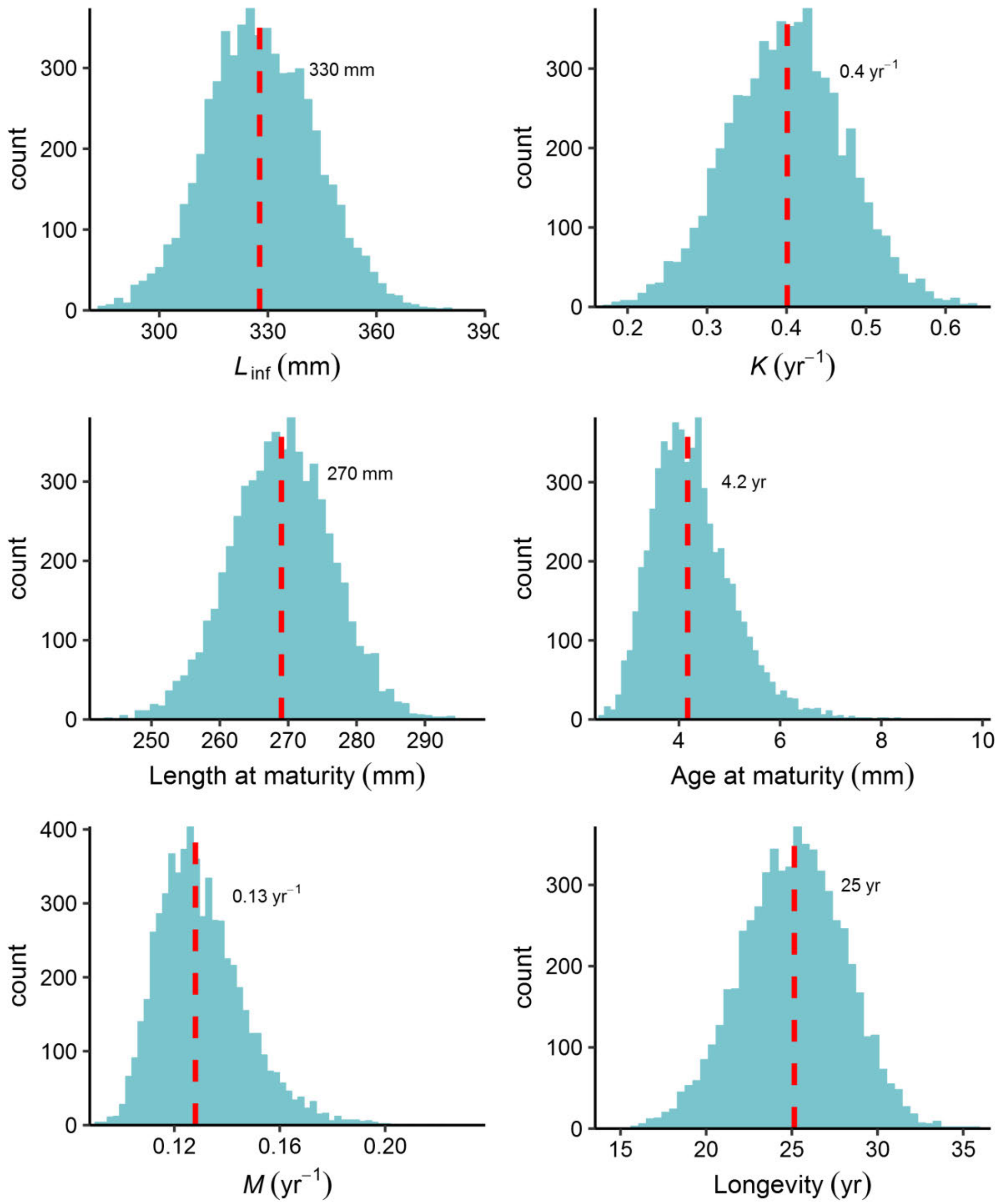
General comments

The commercial catch data set for this species includes both *N. unicornis* and *N. annulatus*, and therefore could not be used to estimate L_{bar}. The HMRFS data was also fairly unreliable given that this species only had 1 year with a recreational catch estimate.

Population abundance and L_{bar} appeared fairly stable, suggesting a population near equilibrium. Size selectivity had to be estimated, based on other surgeonfishes. A sensitivity run with L_{S50} at 225 and L_{S95} at 250 had some moderate impact on the results (F = 0.23, SPR = 0.22), but did not change overall conclusions. The life history parameters are from a study in Australia, with a decent sample size. Using the stepwise approach to generate LH parameters, we obtained the following estimates: L_{max}: 416 mm, L_{inf}: 388 mm, K: 0.39, M: 0.10, F_{30}: 0.12. Similarly to previous surgeonfishes, the L_{inf} was much higher than the Australian study value. This led to a higher F (0.71) and lower SPR (0.02). F_{30} (0.12) and C_{30} (13,745 kg) where only slightly lower given the similarity in M estimates.

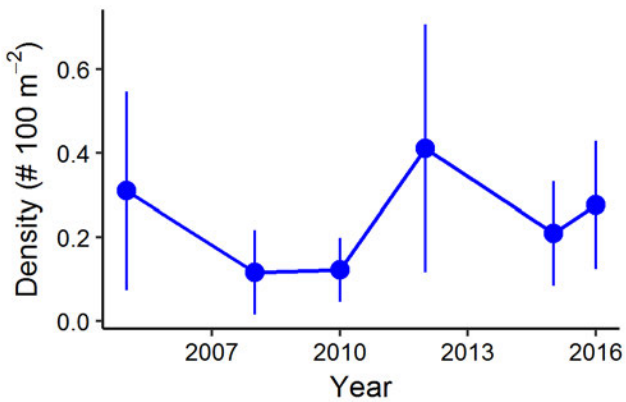
Given the quality of the diver data (i.e., high observation count, appropriate sampling design) and the similarity in F_{30} estimates between the external LH parameters and the stepwise-derived LH parameters, the survey-derived C_{30} is likely reasonable. The true population size may be even larger than the diver estimate (132,456 kg) given that this species' habitat extends beyond diver survey depth (122 m vs. 30 m).

Naso brevirostris

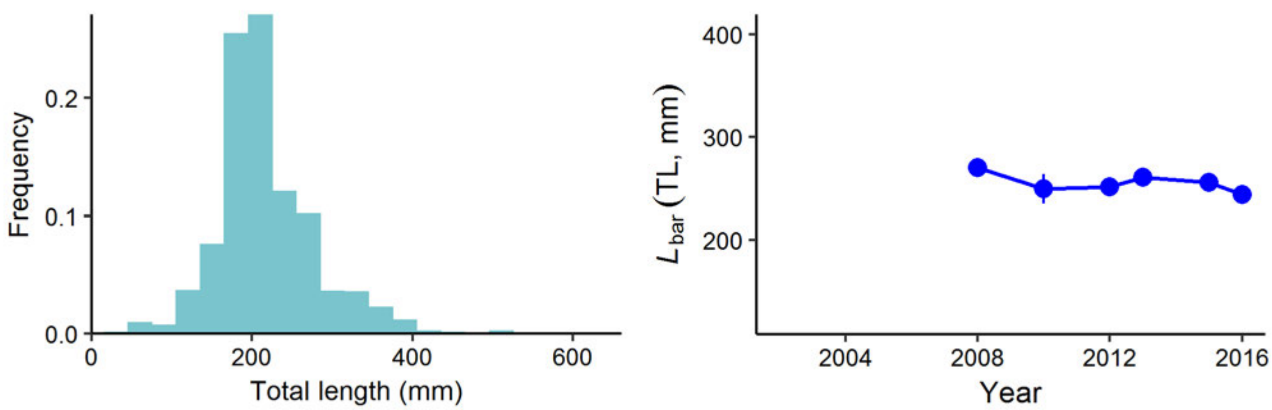


Life history parameter distributions.

Naso brevirostris

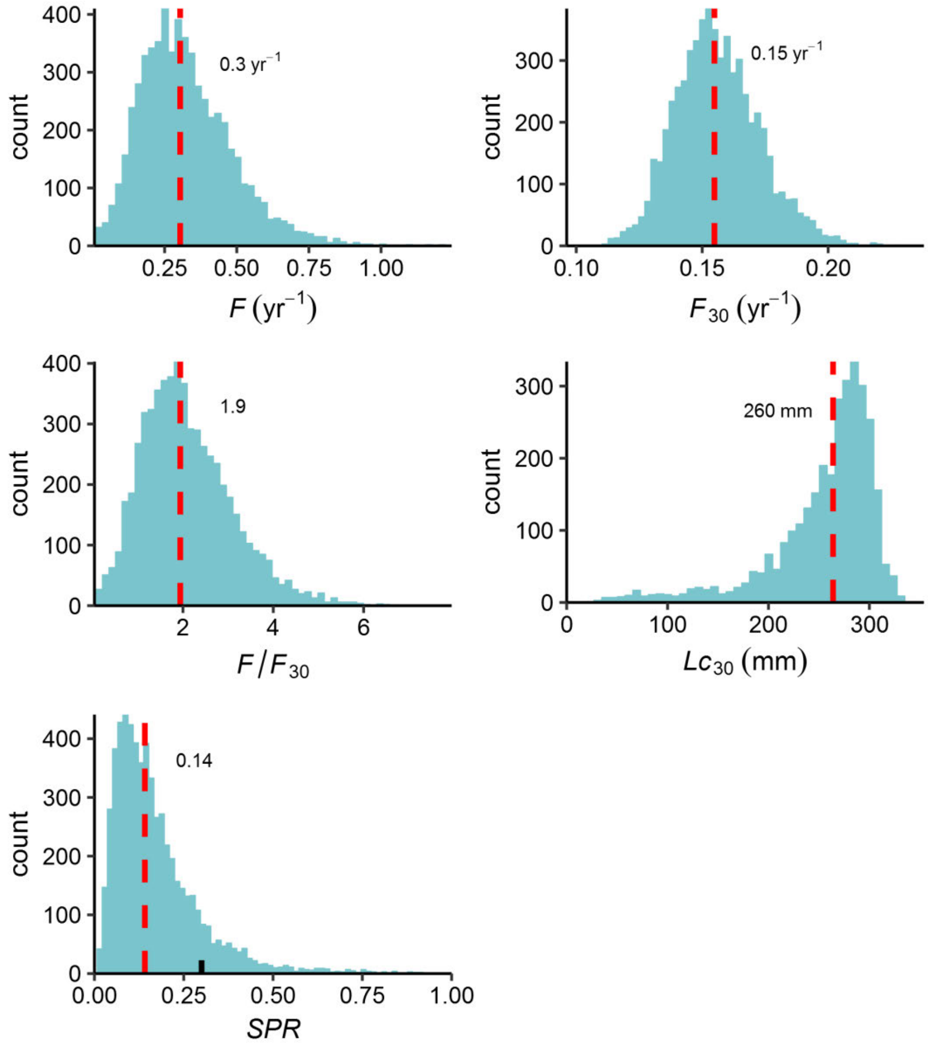


Abundance index from UVS (blue circles, ±SE).

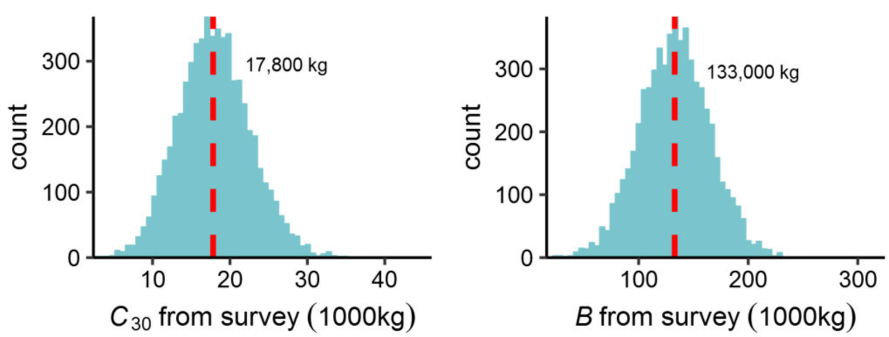


Size structure and average length time series from UVS (±SE).

Naso brevirostris

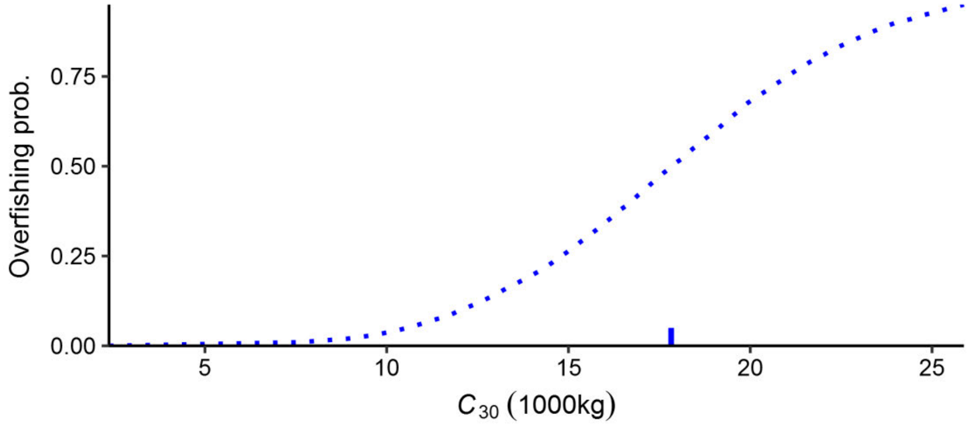


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Naso brevirostris



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	12.0	0.31	15.6
0.11	12.3	0.32	15.7
0.12	12.5	0.33	15.9
0.13	12.7	0.34	16.0
0.14	12.9	0.35	16.1
0.15	13.1	0.36	16.2
0.16	13.3	0.37	16.3
0.17	13.5	0.38	16.4
0.18	13.7	0.39	16.6
0.19	13.9	0.40	16.7
0.20	14.1	0.41	16.8
0.21	14.2	0.42	16.9
0.22	14.4	0.43	17.0
0.23	14.5	0.44	17.2
0.24	14.7	0.45	17.3
0.25	14.8	0.46	17.4
0.26	14.9	0.47	17.5
0.27	15.1	0.48	17.6
0.28	15.2	0.49	17.7
0.29	15.3	0.50	17.8
0.30	15.5		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	302	0.31	282
0.11	300	0.32	282
0.12	300	0.33	280
0.13	300	0.34	280
0.14	298	0.35	280
0.15	296	0.36	278
0.16	296	0.37	278
0.17	294	0.38	276
0.18	294	0.39	276
0.19	292	0.40	274
0.20	292	0.41	274
0.21	292	0.42	272
0.22	290	0.43	272
0.23	290	0.44	270
0.24	288	0.45	270
0.25	288	0.46	268
0.26	286	0.47	268
0.27	286	0.48	266
0.28	286	0.49	266
0.29	284	0.50	264
0.30	284		

Naso hexacanthus

Sleek unicornfish, *kala lolo*
Acanthuridae (surgeonfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	599	57	mm	59	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
K	0.221	0.061	yr^{-1}		
a_0	-0.22	-	yr		
L_{mat}	511	22	mm	59	Mean: Choat & Robertson (2002), SD: Nadon (unpub.)
Longevity	44	6.9	yr	59	Mean: Choat & Robertson (2002), SD: Kritzer (2001)
L-W α	4.12e-5	-	-	-	Choat and Axe (1996)
L-W β	2.85				
L_{S50}	350	-	mm	-	DAR commercial data
L_{S95}	410				
$\bar{L}$ diver survey	-	-	mm	-	NOAA-CREP diver survey
$\bar{L}$ commercial	507	2	mm	1249	DAR commercial data
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	124	-	m	-	BRFA BotCam project
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.07	0.01	yr^{-1}
F	0.16	0.08	yr^{-1}
$F30$	0.08	0.01	yr^{-1}
$F/F30$	2.0	0.9	-
SPR	0.13	0.14	-
SPR < 0.30 iterations	88	-	%
Lc_{30}	497	-	mm

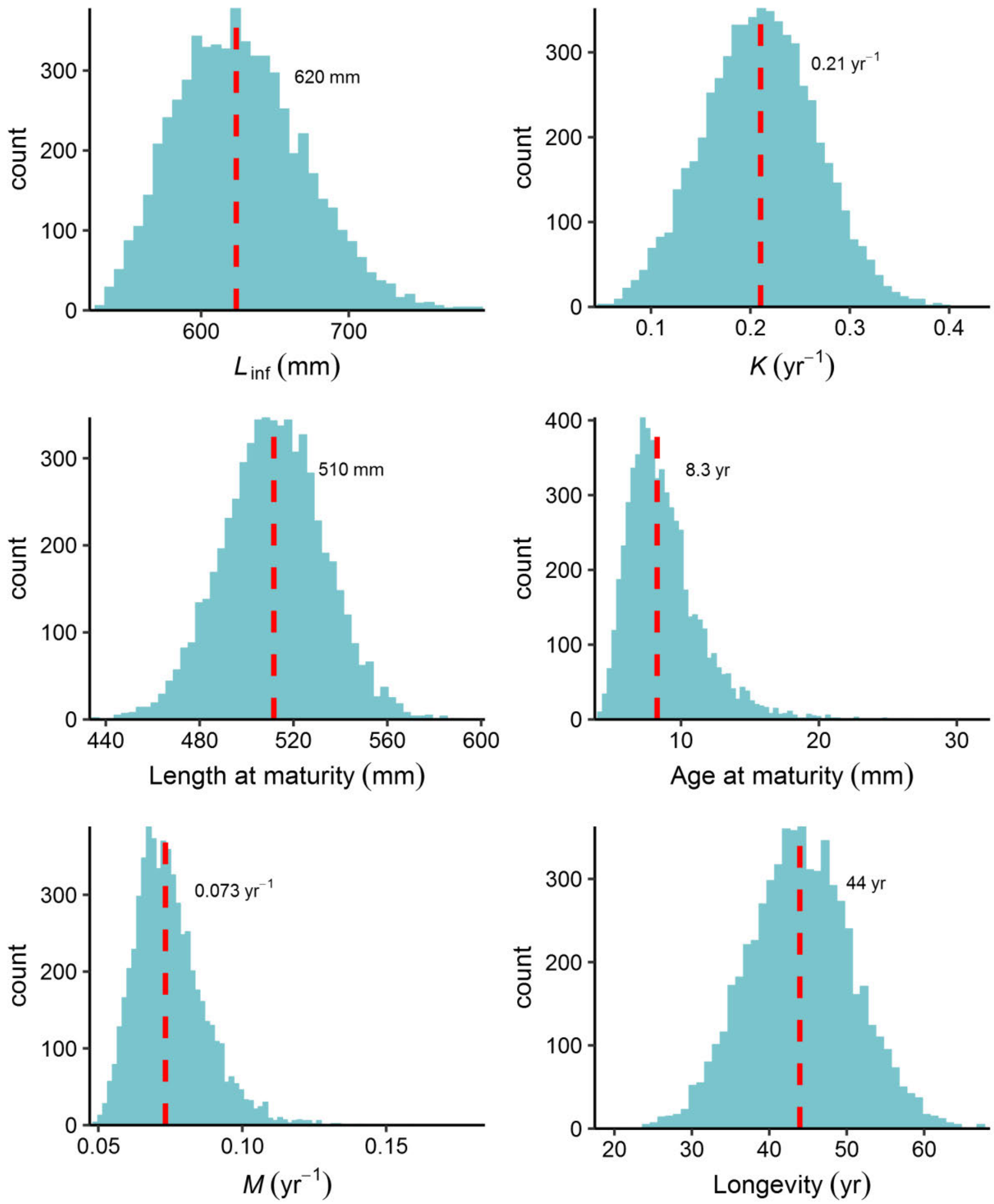
Parameter	Median	SD	Unit
B from catch	29,900	75,600	kg
B from survey	-	-	kg
Commercial catch	1,361	1,434	kg
Recreational catch	2,279	3,884	kg
Total catch	4,185	3,664	kg
C_{30} from catch	2,260	5,170	kg
C_{30} from survey	-	-	kg

General comments

The number of diver survey observations for this species was insufficient to generate reliable L_{bar} or population biomass estimates. The commercial catch increased from 2007 to 2013, but dropped back down to 2003-2006 levels in the last few years. The recreational catch estimates were fairly variable, making it hard to discern any patterns. L_{bar} have been stable since 2003, which indicated a population near equilibrium.

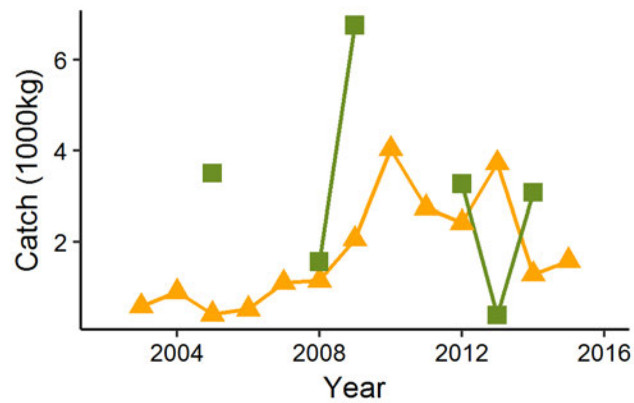
The life history parameters came from an Australian study with low sample size. We obtained the following parameters from the stepwise approach, which are fairly similar: L_{max}: 642 mm, L_{inf}: 614 mm, K: 0.28, M: 0.10, F_{30}: 0.11. F (0.20), *SPR* (0.15), and C_{30} (2,578 kg) were also close to the original results. We also tried reducing the survivorship estimate for the M calculation from 0.04 to 0.01. This increased M from 0.07 to 0.10 and did not change the results significantly (F: 0.21, *SPR*: 0.15).

Naso hexacanthus

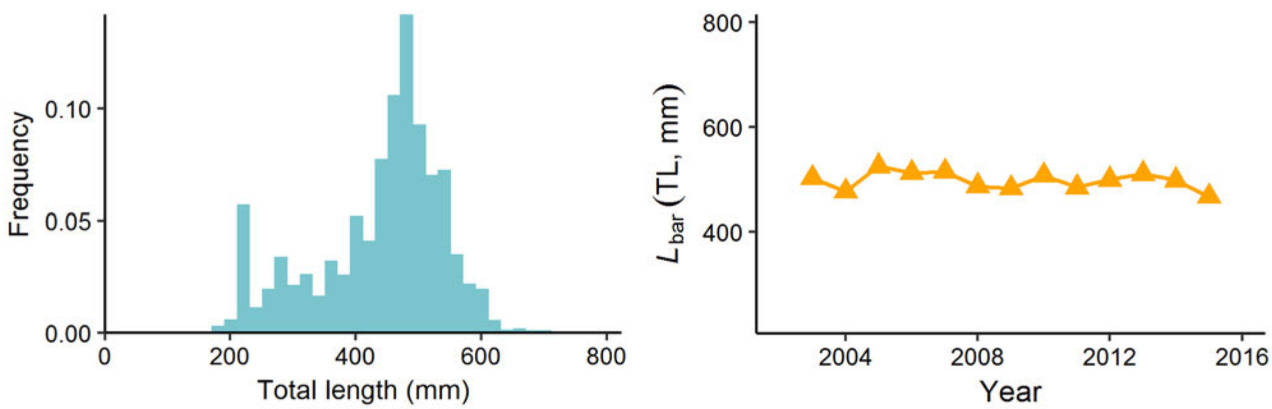


Life history parameter distributions.

Naso hexacanthus

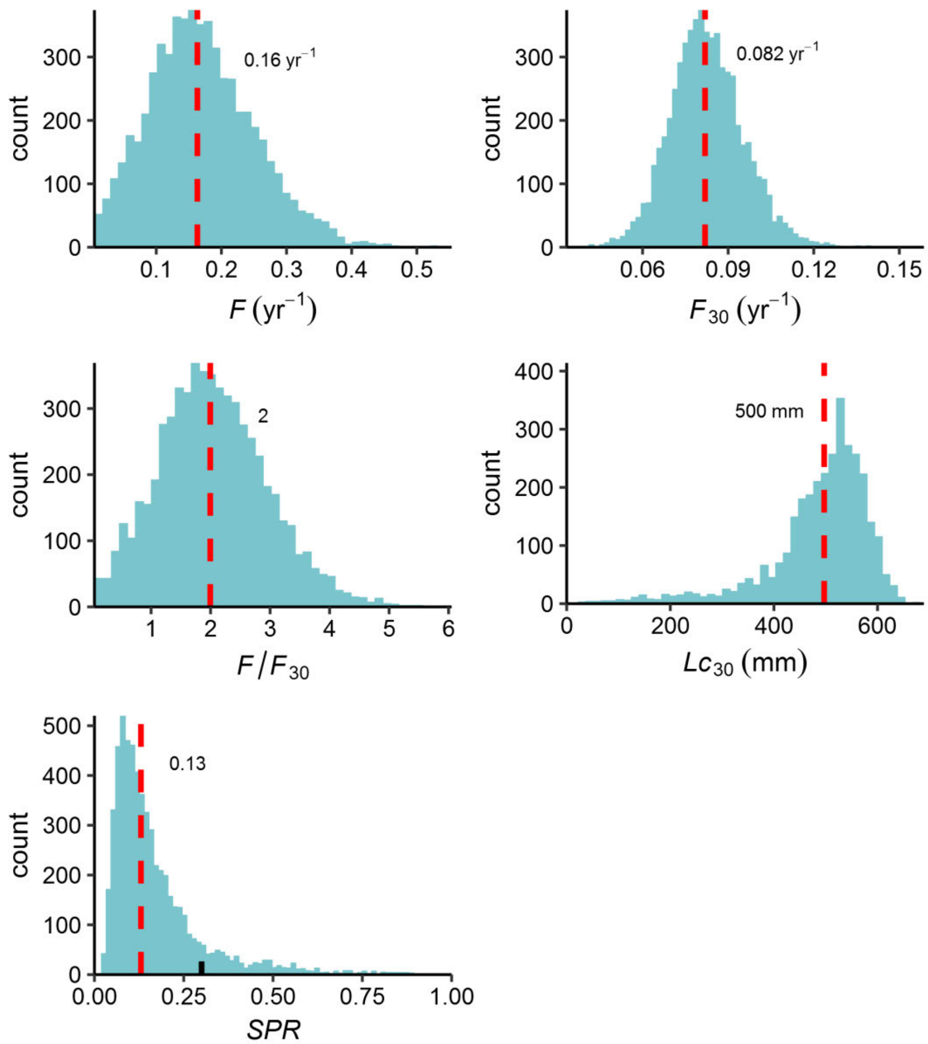


Total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



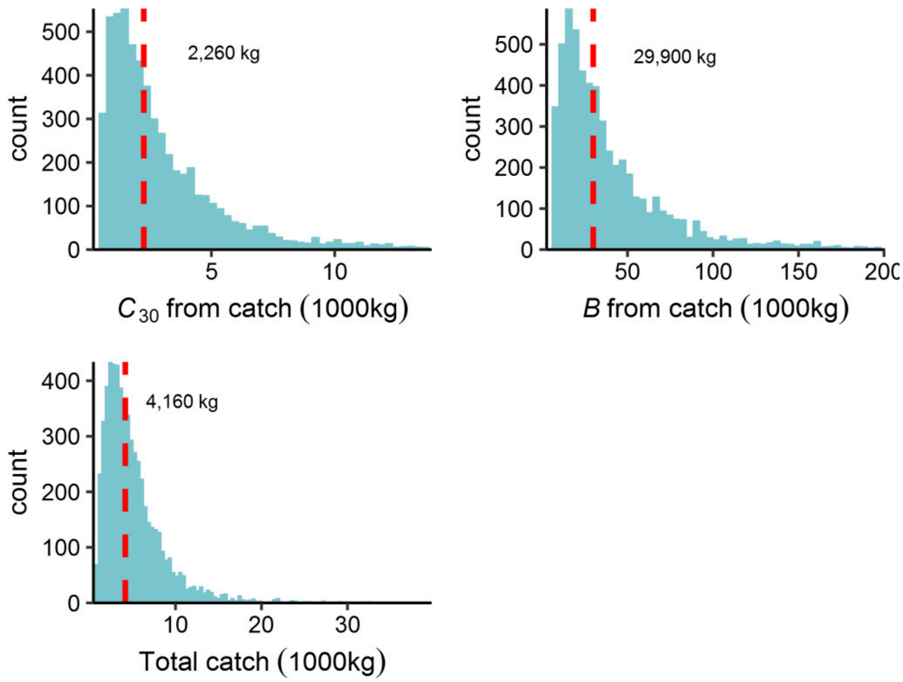
Size structure and average length time series from commercial data (±SE)

Naso hexacanthus



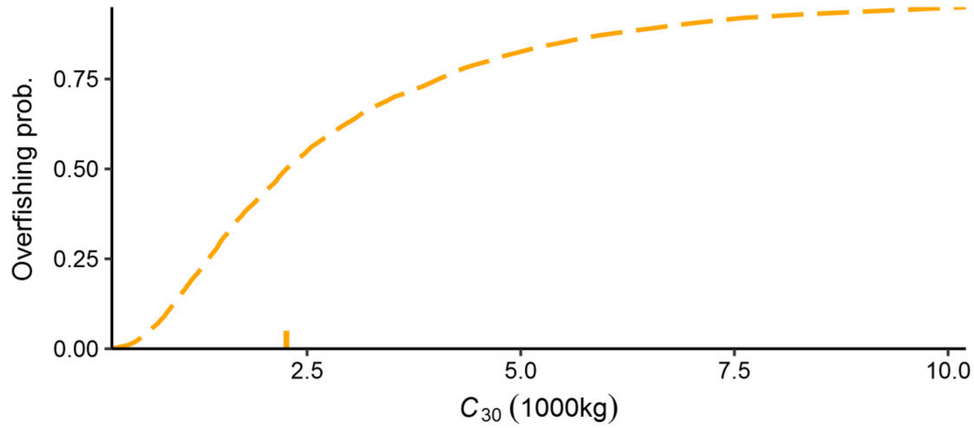
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Naso hexacanthus



C_{30} and current total catch (left) and population size (right) distributions.

Naso hexacanthus



Overfishing probability for a range of C_{30} levels (commercial data – orange dashed line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from catch (1000 kg)	Overfishing probability	C_{30} from catch (1000 kg)
0.10	0.86	0.31	1.53
0.11	0.89	0.32	1.57
0.12	0.93	0.33	1.60
0.13	0.96	0.34	1.63
0.14	1.00	0.35	1.66
0.15	1.02	0.36	1.70
0.16	1.05	0.37	1.74
0.17	1.09	0.38	1.77
0.18	1.12	0.39	1.81
0.19	1.14	0.40	1.86
0.20	1.18	0.41	1.90
0.21	1.22	0.42	1.93
0.22	1.25	0.43	1.98
0.23	1.27	0.44	2.02
0.24	1.30	0.45	2.07
0.25	1.34	0.46	2.11
0.26	1.38	0.47	2.15
0.27	1.41	0.48	2.18
0.28	1.45	0.49	2.22
0.29	1.47	0.50	2.26
0.30	1.49		

Naso hexacanthus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	578	0.31	536
0.11	574	0.32	532
0.12	572	0.33	532
0.13	570	0.34	528
0.14	567	0.35	528
0.15	567	0.36	525
0.16	564	0.37	525
0.17	564	0.38	522
0.18	560	0.39	522
0.19	556	0.40	518
0.20	556	0.41	514
0.21	556	0.42	514
0.22	553	0.43	511
0.23	550	0.44	511
0.24	550	0.45	508
0.25	546	0.46	508
0.26	546	0.47	504
0.27	542	0.48	500
0.28	539	0.49	500
0.29	539	0.50	497
0.30	536		

Naso lituratus

Orangespine unicornfish, *umaumalei*
Acanthuridae (surgeonfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	322	36	mm	58	Mean: Nadon (unpublished), SD: Kritzer (2001)
K	0.341	0.10	yr^{-1}		
a_0	-0.66	-	yr		
L_{mat}	250	37	mm	66	Mean: Nadon (unpublished) , SD: Nadon (unpublished)
Longevity	25	4.2	yr	58	Mean: Nadon (unpublished), SD: Kritzer (2001)
L-W α	7.20e-5	-	-	-	Smith and Dalzell (1993)
L-W β	2.84				
L_{S50}	215	-	mm	-	DAR commercial data
L_{S95}	230				
$\bar{L}$ diver survey	276	1	mm	1563	NOAA-CREP diver-survey data set
$\bar{L}$ commercial	287	2	mm	1098	DAR commercial data set
$\bar{L}$ combined	280	2	mm	-	-
Max. depth	93	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.13	0.02	yr^{-1}
F	0.21	0.13	yr^{-1}
F_{30}	0.17	0.04	yr^{-1}
F/F_{30}	1.3	0.9	-
SPR	0.25	0.20	-
SPR < 0.30 iterations	62	-	%
Lc_{30}	215	-	mm

Parameter	Median	SD	Unit
B from catch	30,000	205,000	kg
B from survey	451,619	37,121	kg
Commercial catch	544	1,934	kg
Recreational catch	3,730	7,888	kg
Total catch	4,924	7,317	kg
C_{30} from catch	4,390	27,000	kg
C_{30} from survey	66,200	15,400	kg

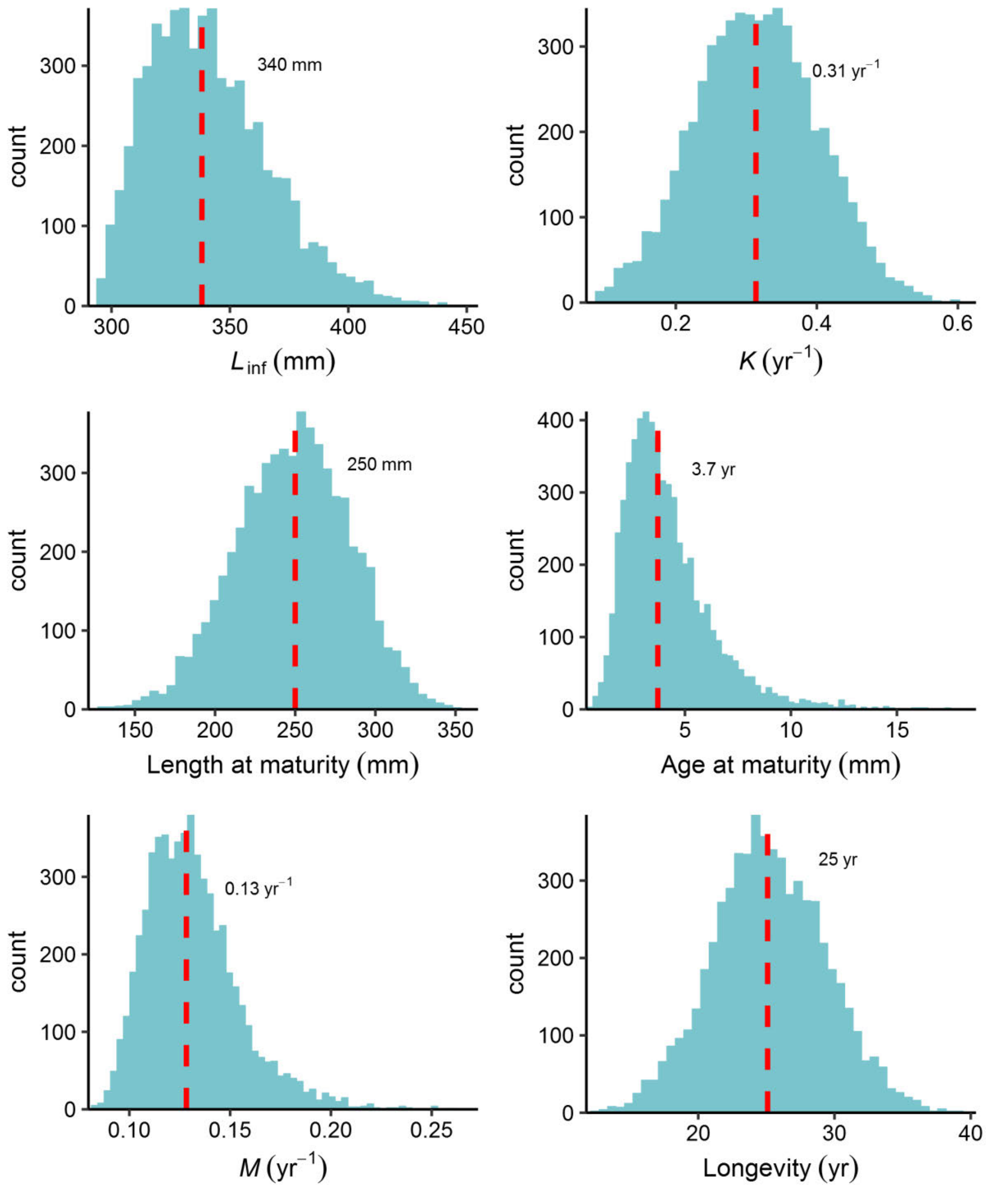
General comments

Population abundance appeared to be relatively stable, with a sharp increase in 2016 which may be spurious. L_{bar} from both data sets were similar and stable from 2003 to 2016, suggesting a population near equilibrium. The commercial catch increased slightly from 2008 to 2012, but appear to be declining in recent years. The recreational catch was too variable to infer on any temporal patterns.

The life history parameters for this species came from specimens collected in the Mariana islands by PIFSC, but they appeared appropriate for the Hawaii population. A sensitivity run using the stepwise approach gave nearly identical parameters: L_{max}: 350 mm, L_{inf}: 321 mm, K: 0.44, M: 0.1, F_{30}: 0.15, and F: 0.25.

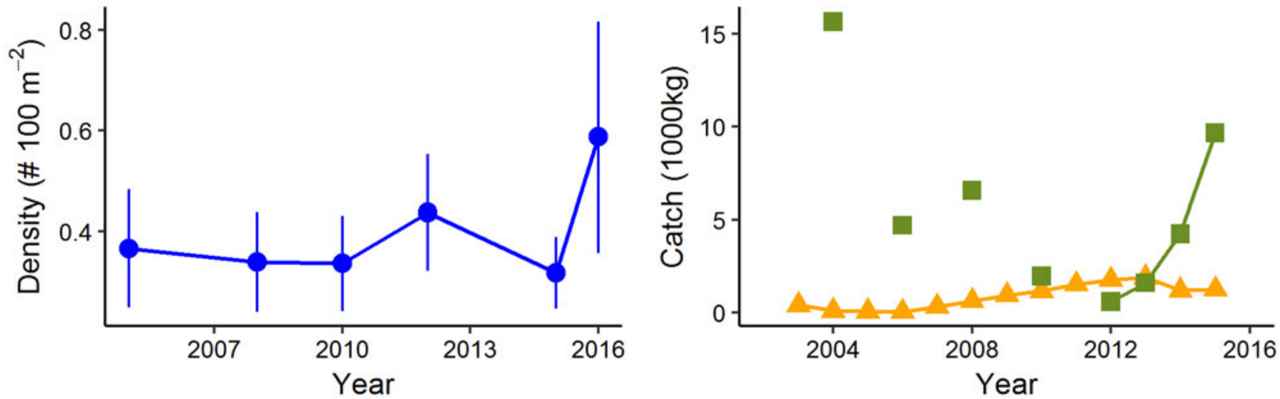
There was a strong discrepancy between the population size estimates from the catch vs. those from diver surveys (30,000 kg vs. 451,619 kg). The catch estimates from both the HMRFS and commercial data sets seemed unrealistically low. The diver-derived population estimate should be fairly reliable given that this is a commonly encountered species that is easily identifiable and is not particularly afraid of divers. Therefore, the C_{30} from the survey data is likely more reliable than the C_{30} derived from the catch. The population estimate was likely negatively biased given that the population extends to 93 m, which is beyond the diver survey depth (30 m) from which the population size is derived.

Naso lituratus

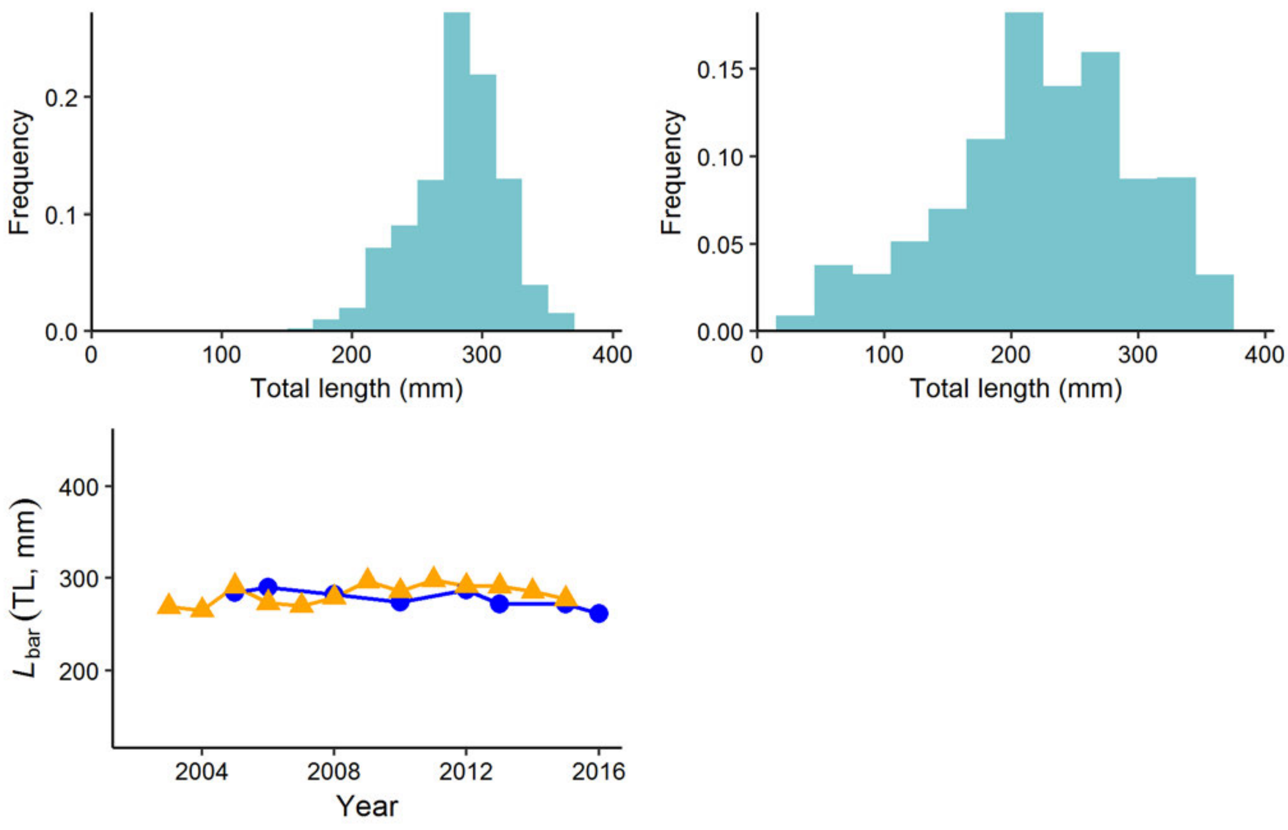


Life history parameter distributions.

Naso lituratus

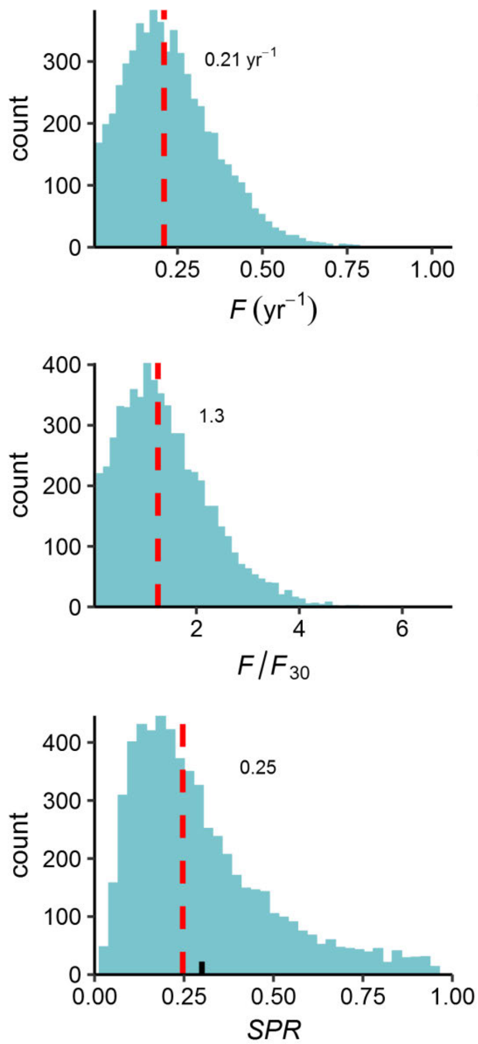


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



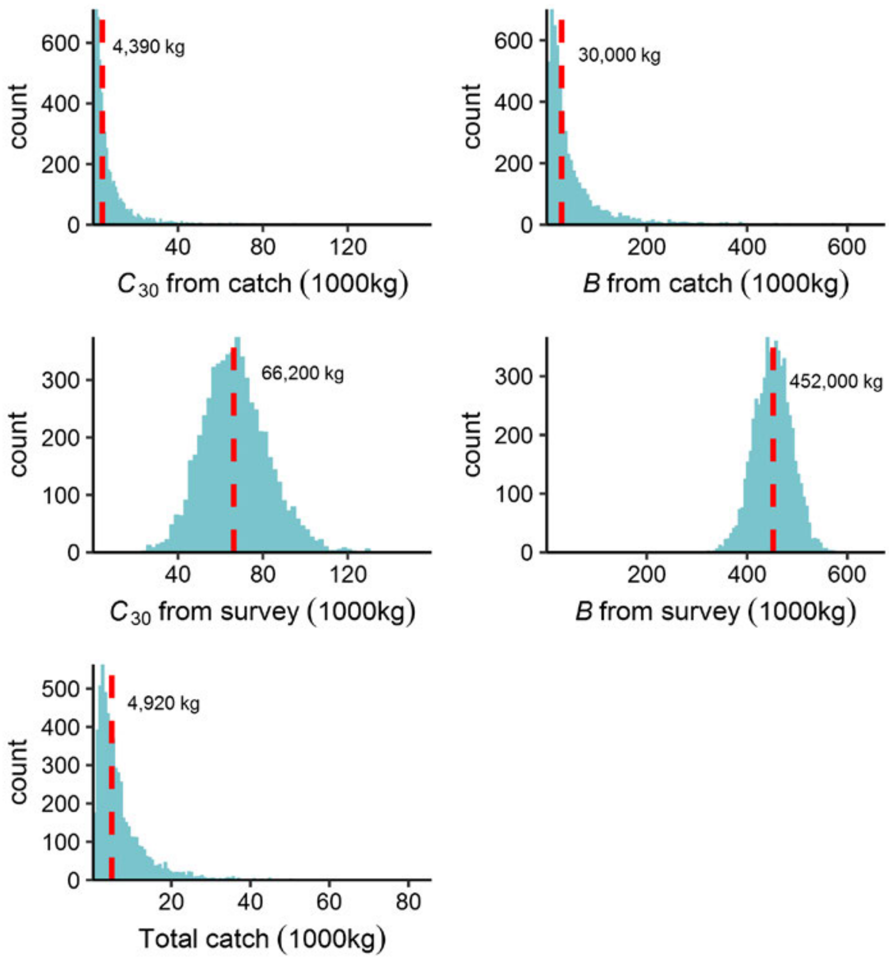
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Naso lituratus



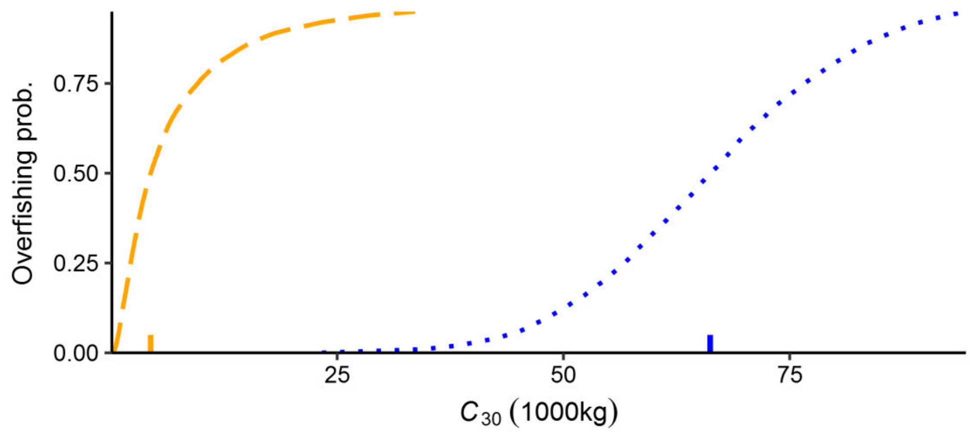
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Naso lituratus



***C*$_{30}$ and current total catch (left) and population size (right) distributions.**

Naso lituratus



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	1.18	48.4	0.31	2.62	59.1
0.11	1.24	49.1	0.32	2.70	59.4
0.12	1.30	49.8	0.33	2.78	59.8
0.13	1.36	50.4	0.34	2.85	60.2
0.14	1.43	51.0	0.35	2.92	60.6
0.15	1.50	51.7	0.36	3.01	61.0
0.16	1.58	52.3	0.37	3.08	61.4
0.17	1.65	52.8	0.38	3.17	61.7
0.18	1.72	53.4	0.39	3.25	62.2
0.19	1.78	53.9	0.40	3.35	62.6
0.20	1.86	54.5	0.41	3.44	62.9
0.21	1.93	54.9	0.42	3.51	63.4
0.22	1.99	55.4	0.43	3.63	63.7
0.23	2.06	55.8	0.44	3.73	64.1
0.24	2.13	56.3	0.45	3.82	64.5
0.25	2.19	56.8	0.46	3.92	64.8
0.26	2.26	57.1	0.47	4.02	65.1
0.27	2.32	57.5	0.48	4.14	65.5
0.28	2.40	57.9	0.49	4.27	65.9
0.29	2.48	58.2	0.50	4.39	66.2
0.30	2.55	58.7			

Naso lituratus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	295	0.31	254
0.11	292	0.32	254
0.12	290	0.33	252
0.13	288	0.34	247
0.14	286	0.35	247
0.15	284	0.36	245
0.16	282	0.37	243
0.17	279	0.38	241
0.18	277	0.39	239
0.19	275	0.40	236
0.20	275	0.41	234
0.21	273	0.42	232
0.22	271	0.43	230
0.23	269	0.44	228
0.24	267	0.45	226
0.25	264	0.46	224
0.26	264	0.47	221
0.27	262	0.48	219
0.28	260	0.49	217
0.29	258	0.50	215
0.30	256		

Naso unicornis

Bluespine unicornfish, *kala*
Acanthuridae (surgeonfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	480	4	mm	534	Mean and SD: Andrews et al. (2016)
K	0.44	0.02	yr^{-1}		
a_0	-0.12	-	yr		
L_{mat}	355	10	mm	295	Mean and SD: Eble (2009)
Longevity	50	5.4	yr	534	Mean and SD: Andrews et al. (2016)
L-W α	1.65e-5	-	-	-	Kulbicki (2005)
L-W β	3.035				
L_{S50}	230	-	mm	-	Estimated from HMRFS data and other surgeonfishes.
L_{S95}	260				
$\bar{L}$ diver survey	348	5	mm	522	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	DAR commercial data
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	120	-	m	-	BRFA BotCam project
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.06	0.01	yr^{-1}
F	0.60	0.07	yr^{-1}
F_{30}	0.10	0.01	yr^{-1}
F/F_{30}	6.0	0.9	-
SPR	0.03	0.01	-
SPR < 0.30 iterations	100	-	%
Lc_{30}	467	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	364,114	74,939	kg
Commercial catch	11,282	3,350	kg
Recreational catch	8,169	4,829	kg
Total catch	20,197	5,743	kg
C_{30} from catch	-	-	kg
C_{30} from survey	33,200	7,270	kg

General comments

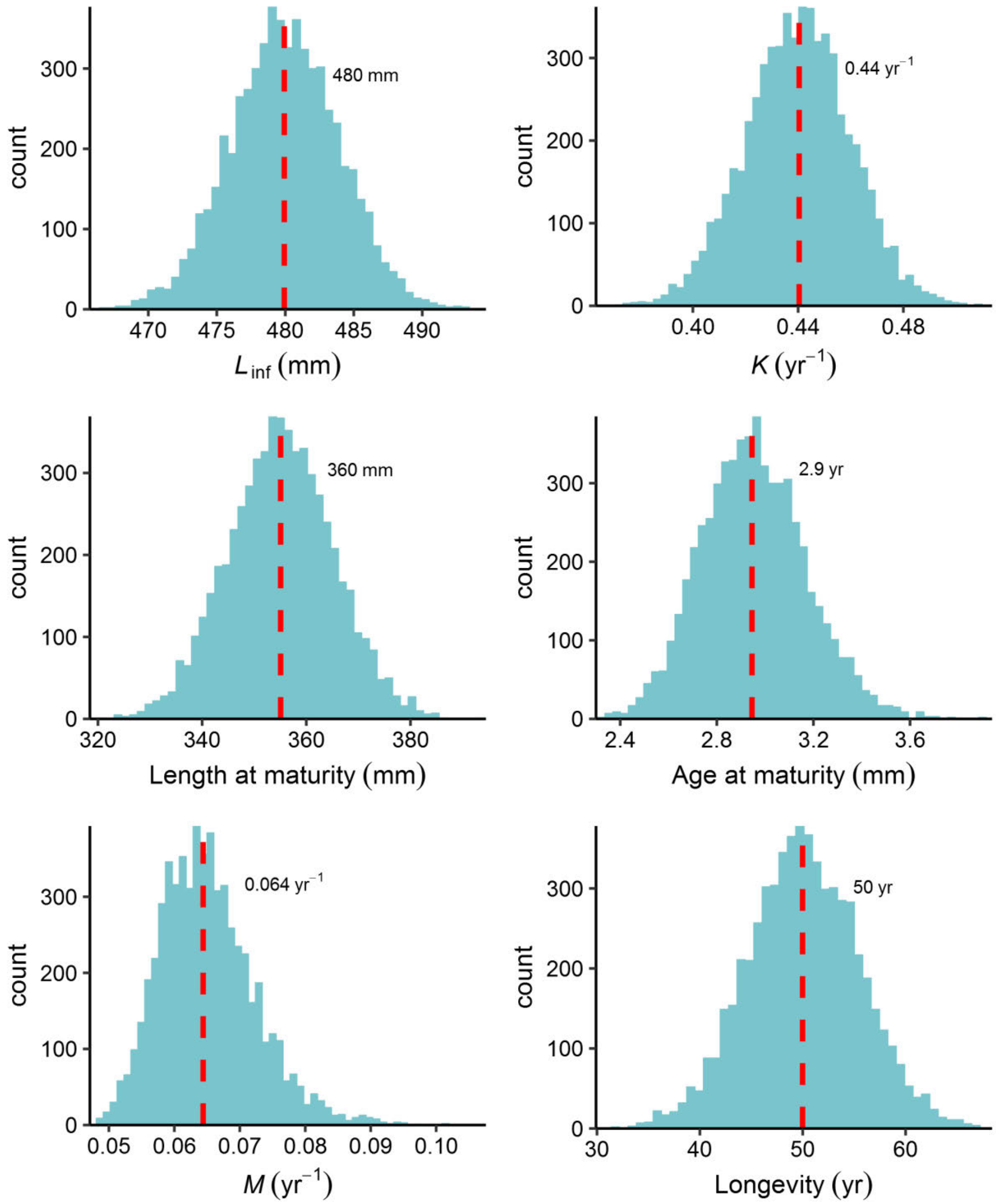
The commercial data set could not be used to generate L_{bar} estimates given that *N. annulatus* and *N. brevirostris* are included with *N. unicornis* in the reporting system. The commercial catch for these 3 species is reported in the table above and in the graph further below as reference only.

Population abundance and L_{bar} were stable from 2005 to 2016, likely indicating a population near equilibrium. The recreational catch was fairly variable, but overall appeared stable as well. The LH parameters came from an in-depth study conducted locally and is likely highly reliable. There was some HMRFS data (n = 18) that could be used to help infer the selectivity parameters. A sensitivity run with L_{S50} at 200 and L_{S95} at 230 had little impact on the results (M: 0.11, F = 0.54, SPR = 0.05).

The elevated F/F_{30} ratio and correspondingly low SPR estimate could not be explained by the relatively modest catch estimate, which was below the C_{30} estimate (20,197 kg vs. 33,100 kg). The reason for this may be the unusually high maximum age recorded for this species (50 year, from a bomb radio-carbon validated aged Oahu specimen). This high longevity leads to an extremely low M estimate, which in turn leads to a high F estimate and low SPR. The 50-year max age could be from an outlier individual, not representative of a 4% cohort survival rate (see equation 7). To test this scenario, we also ran the analyses using S = 1% and longevity at 40 years and obtained the following estimates: F: 0.54, SPR: 0.05.

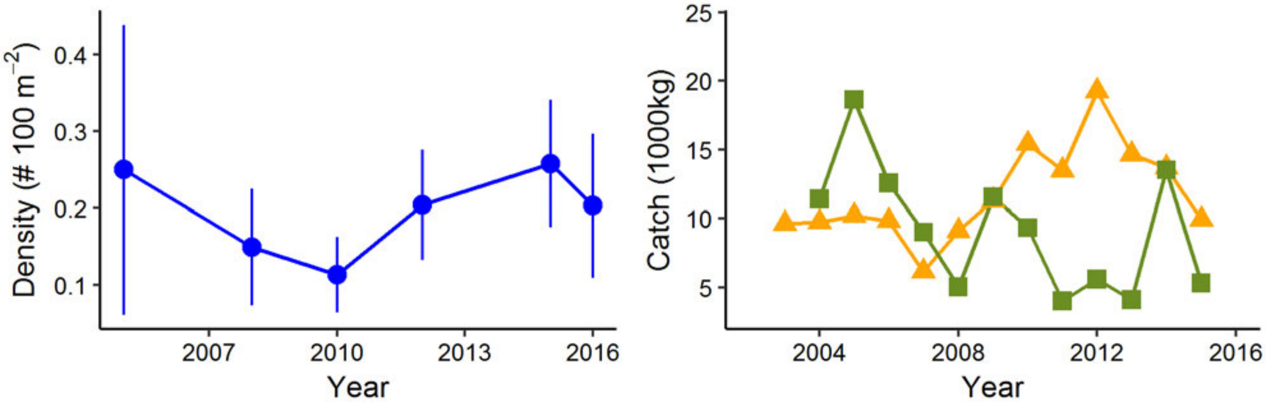
Despite this discrepancy, the population estimate from diver surveys should be reliable given that this is a common species that is easily identifiable. The population estimate is likely biased downward given that this species has been recorded to 120-m depths and diver surveys only reach 30-m depths.

Naso unicornis

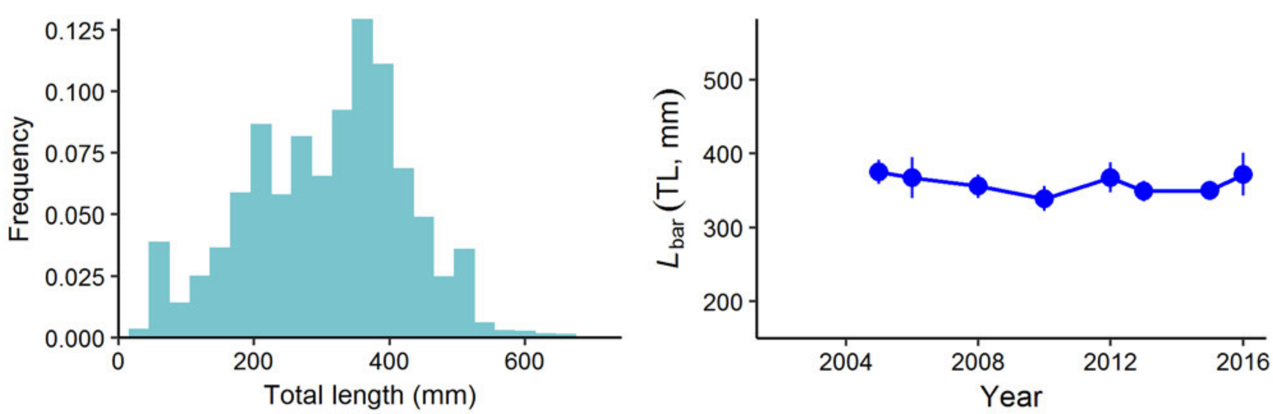


Life history parameter distributions.

Naso unicornis

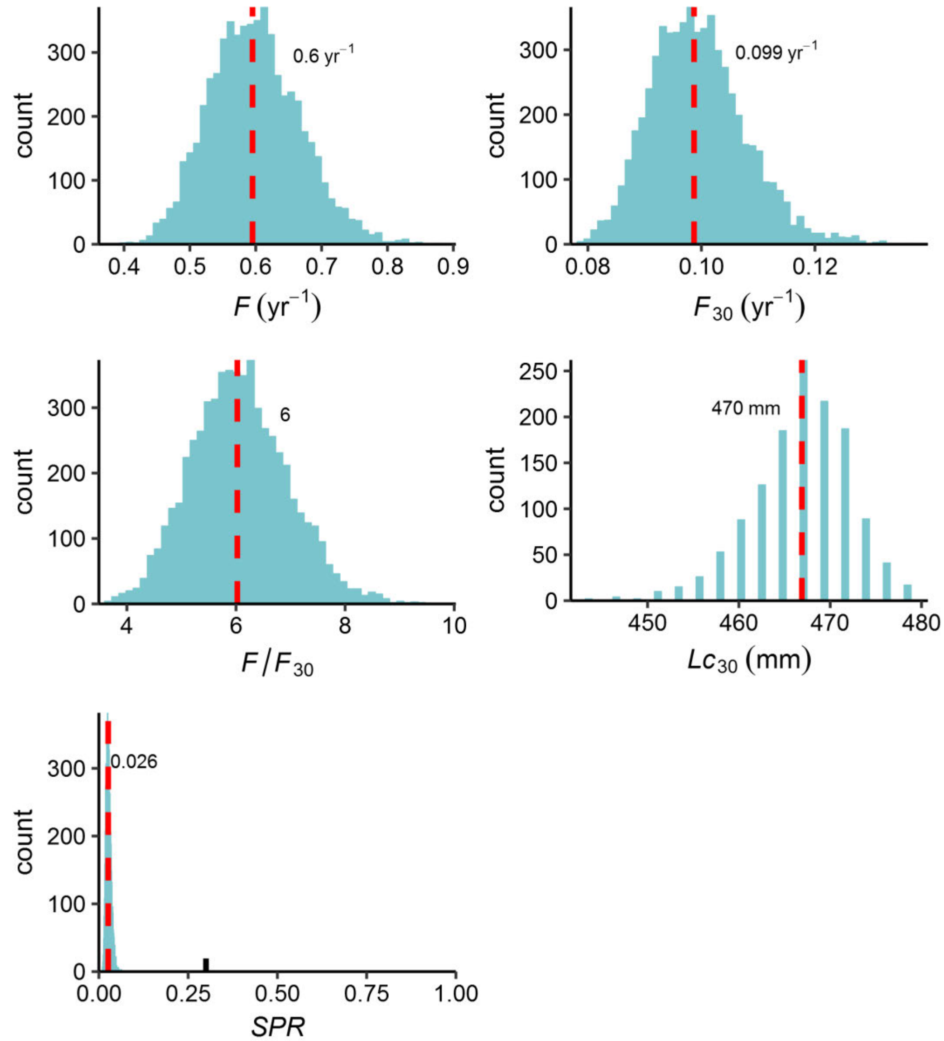


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors (presented as a reference, see comments section).

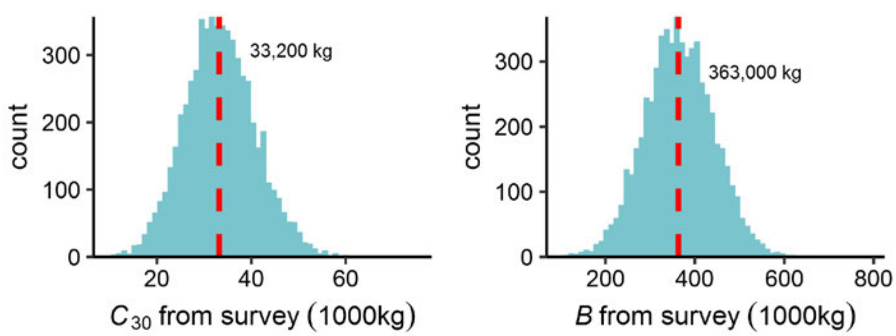


Size structure and average length time series from UVS (±SE).

Naso unicornis

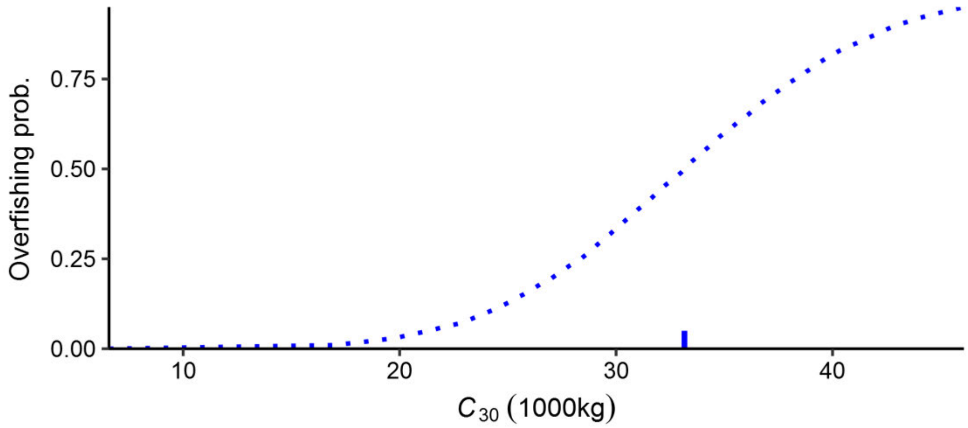


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Naso unicornis



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). ***OFL*** **is represented by a small vertical bar.**

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	24.2	0.31	29.6
0.11	24.5	0.32	29.8
0.12	24.9	0.33	29.9
0.13	25.2	0.34	30.2
0.14	25.5	0.35	30.3
0.15	25.8	0.36	30.5
0.16	26.1	0.37	30.7
0.17	26.4	0.38	30.9
0.18	26.6	0.39	31.1
0.19	26.8	0.40	31.3
0.20	27.1	0.41	31.4
0.21	27.4	0.42	31.7
0.22	27.7	0.43	31.8
0.23	27.9	0.44	32.0
0.24	28.1	0.45	32.2
0.25	28.3	0.46	32.4
0.26	28.5	0.47	32.6
0.27	28.7	0.48	32.8
0.28	28.9	0.49	32.9
0.29	29.1	0.50	33.2
0.30	29.4		

Naso unicornis

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	474	0.31	469
0.11	474	0.32	469
0.12	474	0.33	469
0.13	474	0.34	469
0.14	471	0.35	469
0.15	471	0.36	469
0.16	471	0.37	469
0.17	471	0.38	469
0.18	471	0.39	469
0.19	471	0.40	469
0.20	471	0.41	469
0.21	471	0.42	469
0.22	471	0.43	467
0.23	471	0.44	467
0.24	471	0.45	467
0.25	471	0.46	467
0.26	471	0.47	467
0.27	469	0.48	467
0.28	469	0.49	467
0.29	469	0.50	467
0.30	469		

Carangoides orthogrammus

Island jack, *ulua*
Carangidae (jacks)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	773	81	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 685 (3) from DAR commercial data
K	0.290	0.101	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	454	58	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	11	3.4	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	1.29e-5	-	-	-	Kulbicki (2005)
L-W β	2.994				
L_{S50}	325	-	mm	-	DAR commercial data
L_{S95}	350				
$\bar{L}$ diver survey	-	-	mm	-	NOAA-CREP diver survey
$\bar{L}$ commercial	502	3	mm	3128	DAR commercial data
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	235	-	m	-	BRFA BotCam project
Federal waters	26	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.27	0.08	yr^{-1}
F	0.18	0.19	yr^{-1}
F_{30}	0.26	0.07	yr^{-1}
F/F_{30}	0.7	0.8	-
SPR	0.41	0.25	-
SPR < 0.30 iterations	36	-	%
Lc_{30}	0	-	mm

Parameter	Median	SD	Unit
B from catch	123,000	609,000	kg
B from survey	-	-	kg
Commercial catch	2,686	1,098	kg
Recreational catch	13,162	16,036	kg
Total catch	16,714	14,139	kg
C_{30} from catch	24,300	134,000	kg
C_{30} from survey	-	-	kg

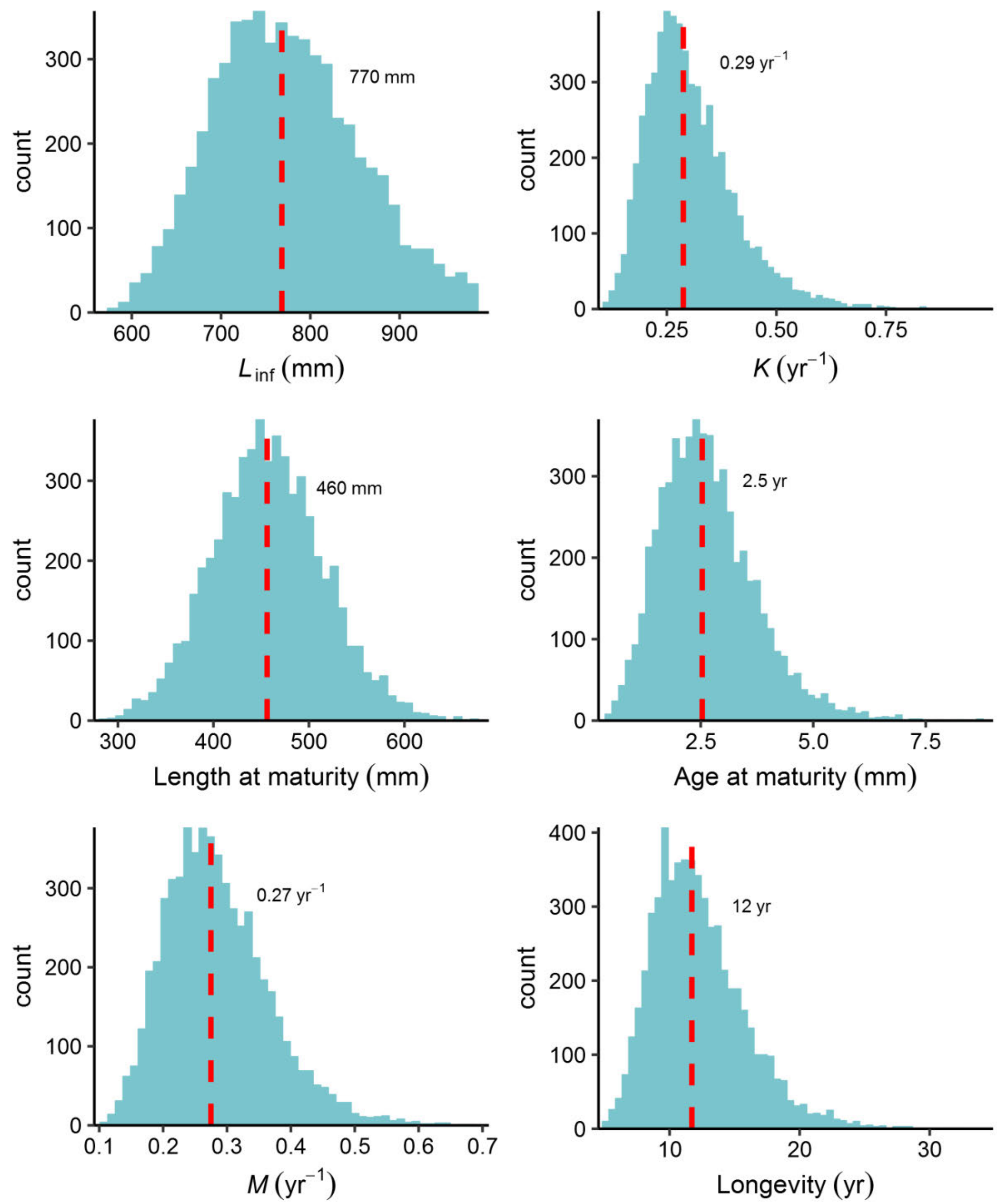
General comments

There were insufficient UVS observations to generate population or L_{bar} estimates for this species. Commercial and recreational catches appeared relatively stable from 2003 to 2016, although the recreational catch estimates were highly variable. L_{bar} estimates from the commercial data set appeared to be slowly rising in the early year of the time series before slowly declining in recent years.

No life history parameters exist for this species and we therefore used the stepwise approach to generate estimates. We used the L_{max} estimate from the commercial data since the diver estimate was deemed unreliable due to a low observation number. The estimate of L_{max} for the NWHI from diver surveys was 700 mm (from 95 UVS observations). A sensitivity run using an even larger L_{max} (720 mm) generated the following LH parameters estimates: L_{inf}: 798 mm, K: 0.27, M: 0.27, F: 0.18, F_{30}: 0.25, *SPR*: 0.38, C_{30}: 22,358 kg). These results were fairly similar to the original ones.

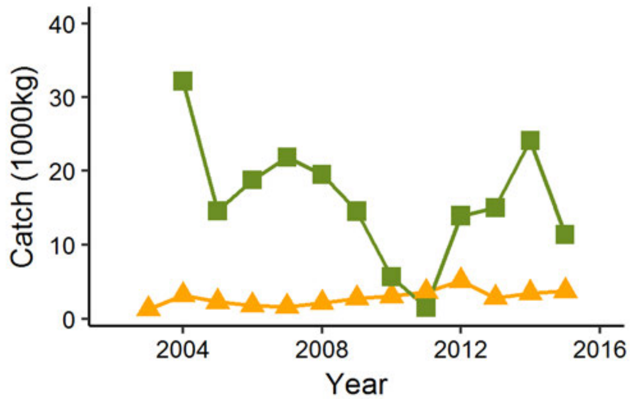
Note that the estimated L_{inf} parameter is higher than the L_{max} due to the indeterminate growth curve typical of jacks (high M/K ratio).

Carangoides orthogrammus

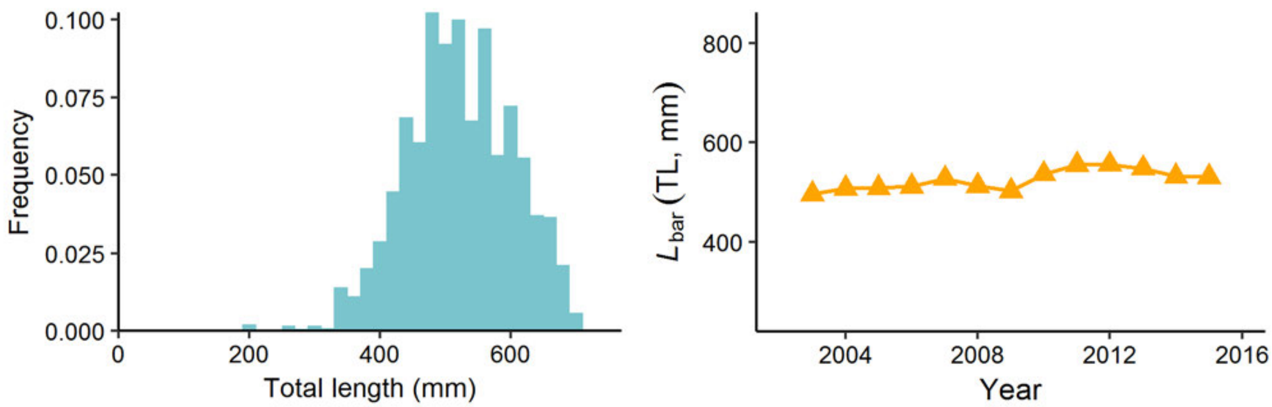


Life history parameter distributions.

Carangoides orthogrammus

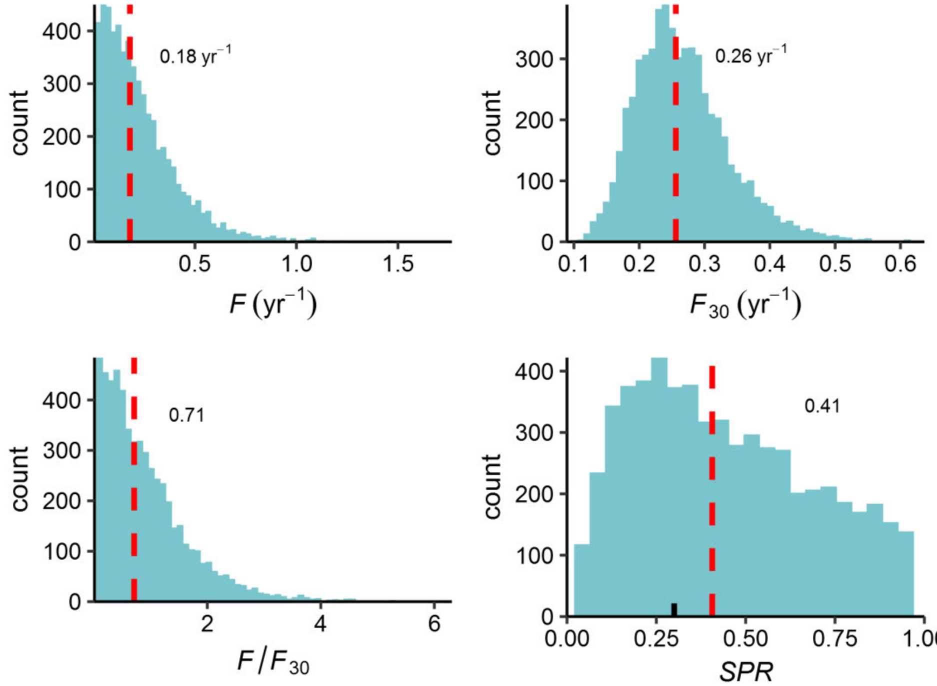


Total catch time series from recreational (green squares) and commercial (orange triangles) sectors.

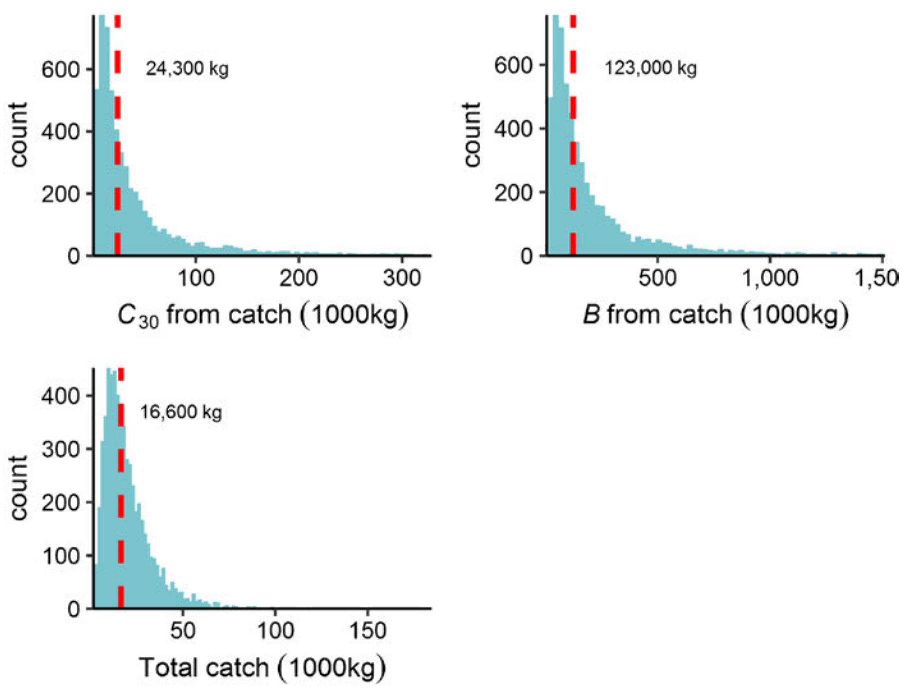


Size structure and average length time series from commercial data (±SE)

Carangoides orthogrammus

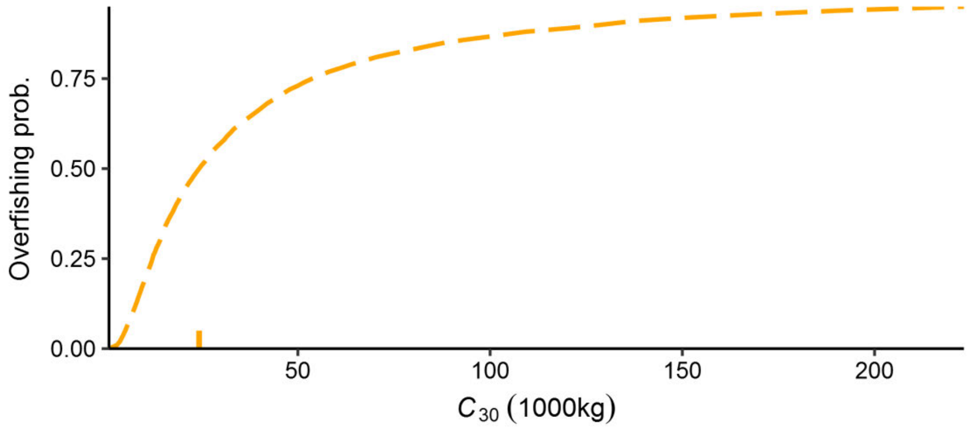


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} and current total catch (left) and population size (right) distributions.

Carangoides orthogrammus



Overfishing probability for a range of C_{30} levels (commercial data – orange dashed line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from catch (1000 kg)	Overfishing probability	C_{30} from catch (1000 kg)
0.10	7.0	0.31	14.5
0.11	7.4	0.32	14.8
0.12	7.8	0.33	15.1
0.13	8.1	0.34	15.5
0.14	8.4	0.35	16.0
0.15	8.8	0.36	16.4
0.16	9.1	0.37	16.9
0.17	9.4	0.38	17.5
0.18	9.8	0.39	17.9
0.19	10.2	0.40	18.3
0.20	10.5	0.41	18.9
0.21	10.9	0.42	19.3
0.22	11.2	0.43	19.9
0.23	11.6	0.44	20.4
0.24	11.9	0.45	21.0
0.25	12.2	0.46	21.6
0.26	12.4	0.47	22.3
0.27	12.9	0.48	22.9
0.28	13.2	0.49	23.6
0.29	13.7	0.50	24.3
0.30	14.1		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	539	0.31	358
0.11	530	0.32	348
0.12	520	0.33	338
0.13	510	0.34	325
0.14	500	0.35	318
0.15	494	0.36	306
0.16	484	0.37	292
0.17	478	0.38	276
0.18	471	0.39	266
0.19	462	0.40	250
0.20	452	0.41	240
0.21	442	0.42	224
0.22	436	0.43	205
0.23	426	0.44	188
0.24	419	0.45	169
0.25	413	0.46	150
0.26	406	0.47	118
0.27	393	0.48	0
0.28	387	0.49	0
0.29	377	0.50	0
0.30	367		

Caranx ignobilis

Giant trevally, *ulua aukea*
Carangidae (jacks)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	2170	310	mm	10	Mean and SD: Sudekum (1991)
K	0.111	0.02	yr^{-1}		
a_0	0.097	-	yr		
L_{mat}	839	31	mm	10	Mean and SD: Sudekum (1991)
Longevity	11	3	yr	10	Mean and SD: Sudekum (1991)
L-W α	2.22e-5	-	-	-	Seki (1986)
L-W β	2.913				
L_{S50}	350	-	mm	-	DAR commercial data
L_{S95}	430				
$\bar{L}$ diver survey	-	-	mm	-	-
$\bar{L}$ commercial	761	6	mm	5372	DAR commercial data
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	228	-	m	-	BRFA BotCam project
Federal waters	26	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.26	0.05	yr^{-1}
F	0.18	0.10	yr^{-1}
F_{30}	0.17	0.03	yr^{-1}
F/F_{30}	1.1	0.7	-
SPR	0.28	0.22	-
SPR < 0.30 iterations	54	-	%
Lc_{30}	430	-	mm

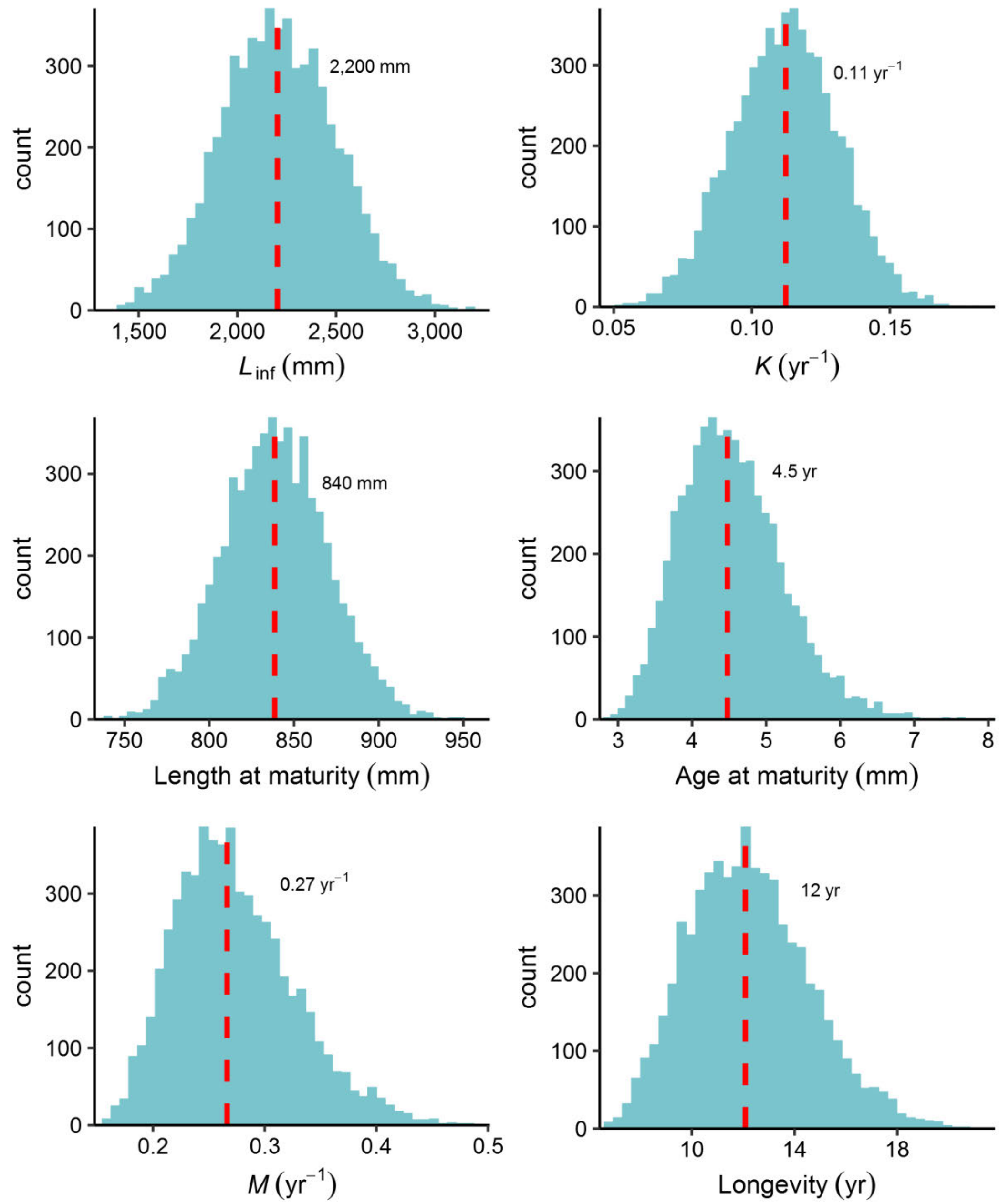
Parameter	Median	SD	Unit
B from catch	1,070,000	3,930,000	kg
B from survey	-	-	kg
Commercial catch	6,689	2,079	kg
Recreational catch	133,921	117,016	kg
Total catch	142,429	113,530	kg
C_{30} from catch	147,000	564,000	kg
C_{30} from survey	-	-	kg

General comments

There were insufficient diver observations in the MHI to generate a reliable L_{bar} estimate. The catch was dominated by the recreational sector and, although fairly variable from year to year, it appear to be mostly constant. L_{bar} from the commercial catch were also stable throughout the period under consideration, suggesting equilibrium conditions.

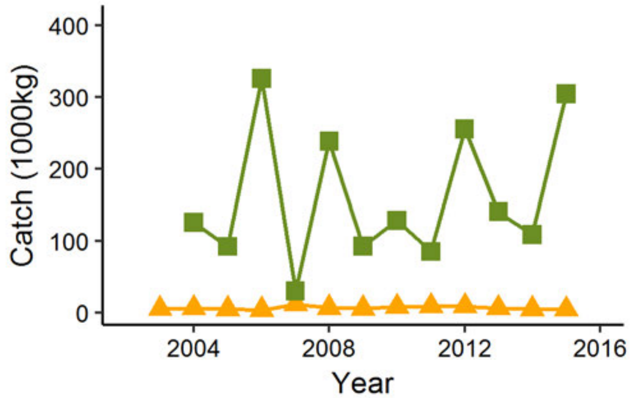
The life history parameters for this species came from a local study with a very limited sample size. We also ran the analyses using the stepwise approach and generated the following values: L_{max}: 1351 mm, L_{inf}: 1679 mm, K: 0.17, M: 0.21, F_{30}: 0.15, F: 0.21, *SPR*: 0.19. These are fairly similar to the original analyses and did not change the conclusions.

Caranx ignobilis

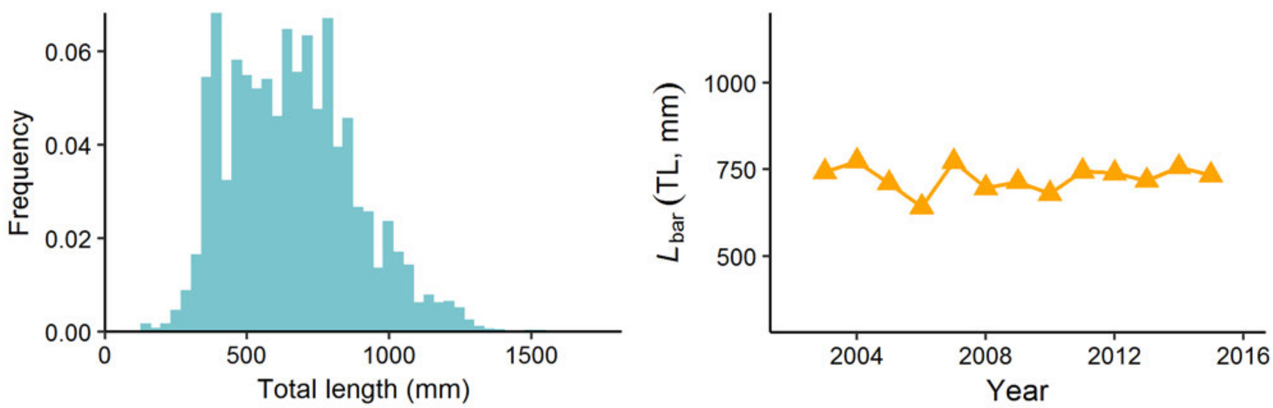


Life history parameter distributions.

Caranx ignobilis

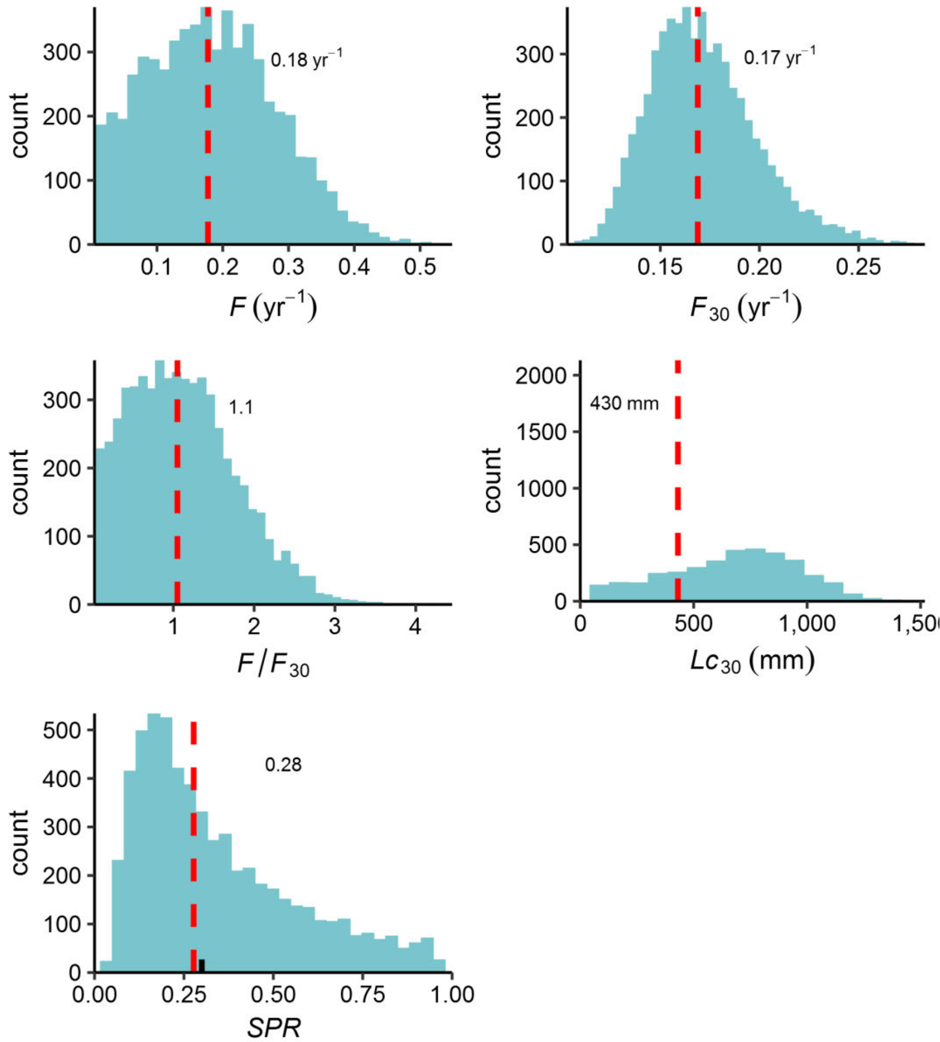


Total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



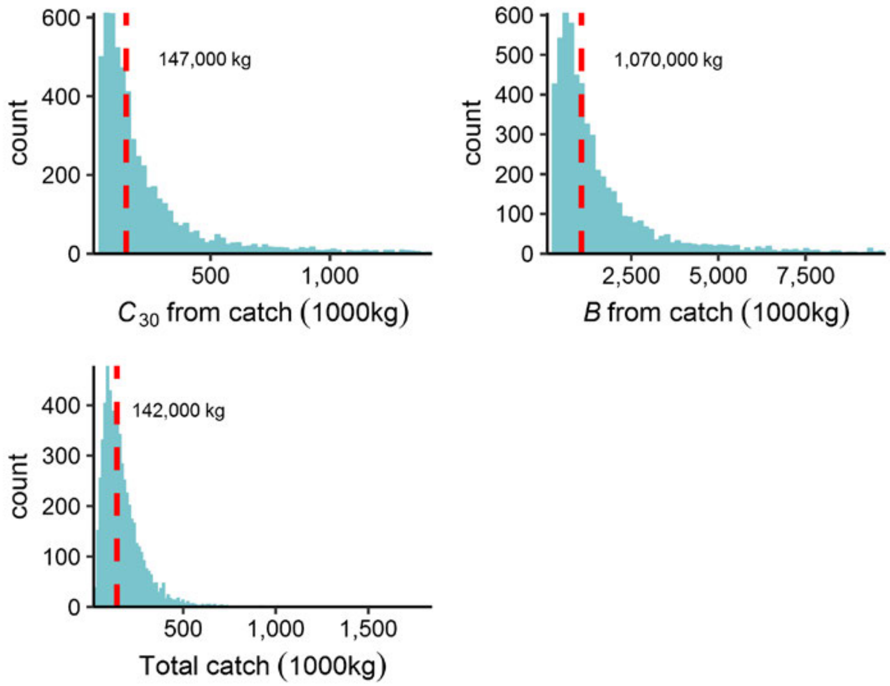
Size structure and average length time series from commercial data (±SE)

Caranx ignobilis



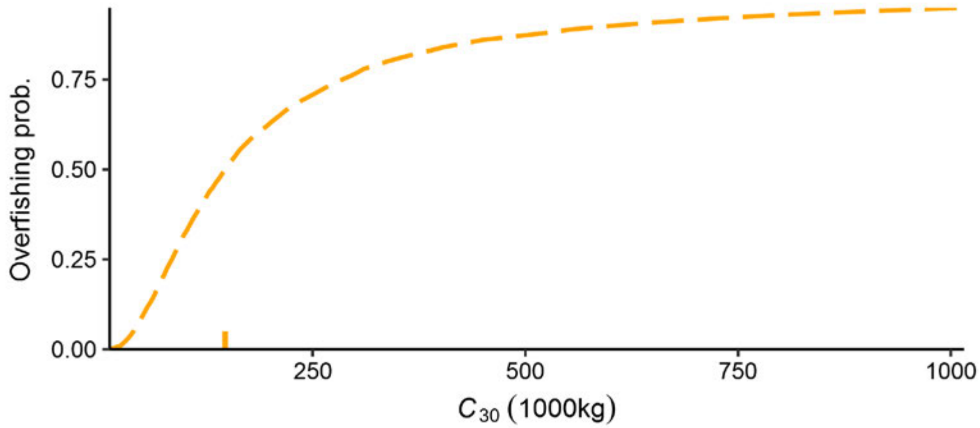
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Caranx ignobilis



C_{30} and current total catch (left) and population size (right) distributions.

Caranx ignobilis



Overfishing probability for a range of C_{30} levels (commercial data – orange dashed line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from catch (1000 kg)	Overfishing probability	C_{30} from catch (1000 kg)
0.10	51.8	0.31	96.9
0.11	54.0	0.32	99.2
0.12	56.3	0.33	102.0
0.13	59.3	0.34	104.1
0.14	61.6	0.35	106.4
0.15	63.8	0.36	108.8
0.16	65.7	0.37	111.3
0.17	67.8	0.38	113.9
0.18	70.2	0.39	116.6
0.19	71.8	0.40	119.4
0.20	73.9	0.41	121.9
0.21	76.2	0.42	124.2
0.22	77.8	0.43	126.5
0.23	80.0	0.44	129.1
0.24	82.3	0.45	132.7
0.25	84.6	0.46	135.2
0.26	86.6	0.47	138.4
0.27	88.7	0.48	141.5
0.28	90.4	0.49	144.1
0.29	92.6	0.50	147.0
0.30	94.9		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	959	0.31	710
0.11	945	0.32	696
0.12	931	0.33	686
0.13	917	0.34	679
0.14	906	0.35	668
0.15	892	0.36	654
0.16	878	0.37	640
0.17	864	0.38	626
0.18	858	0.39	616
0.19	844	0.40	602
0.20	833	0.41	584
0.21	819	0.42	570
0.22	808	0.43	556
0.23	798	0.44	536
0.24	788	0.45	518
0.25	777	0.46	504
0.26	763	0.47	486
0.27	752	0.48	466
0.28	742	0.49	452
0.29	732	0.50	430
0.30	721		

Caranx melampygus

Bluefin trevally, *'omilu*
Carangidae (jacks)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	1041	174	mm	14	Mean: Sudekum (1991), SD: Kritzer (2001)
K	0.233	0.13	yr^{-1}		
a_0	-0.044	-	yr		
L_{mat}	476	33	mm	14	Mean: Sudekum (1991), SD: Nadon (unpublished)
Longevity	7	1.3	yr	14	Mean: Sudekum (1991), SD: Kritzer (2001)
L-W α	2.38e-5	-	-	-	Seki (1986)
L-W β	2.94				
L_{S50}	325	-	mm	-	DAR commercial data
L_{S95}	370				
$\bar{L}$ diver survey	465	9	mm	169	NOAA-CREP diver survey
$\bar{L}$ commercial	557	3	mm	4501	DAR commercial data
$\bar{L}$ combined	550	3	mm	-	-
Max. depth	230	-	m	-	Pyle et al. (2016)
Federal waters	26	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.44	0.07	yr^{-1}
F	0.27	0.21	yr^{-1}
F_{30}	0.37	0.06	yr^{-1}
F/F_{30}	0.7	0.6	-
SPR	0.40	0.23	-
SPR < 0.30 iterations	34	-	%
Lc_{30}	88	-	mm

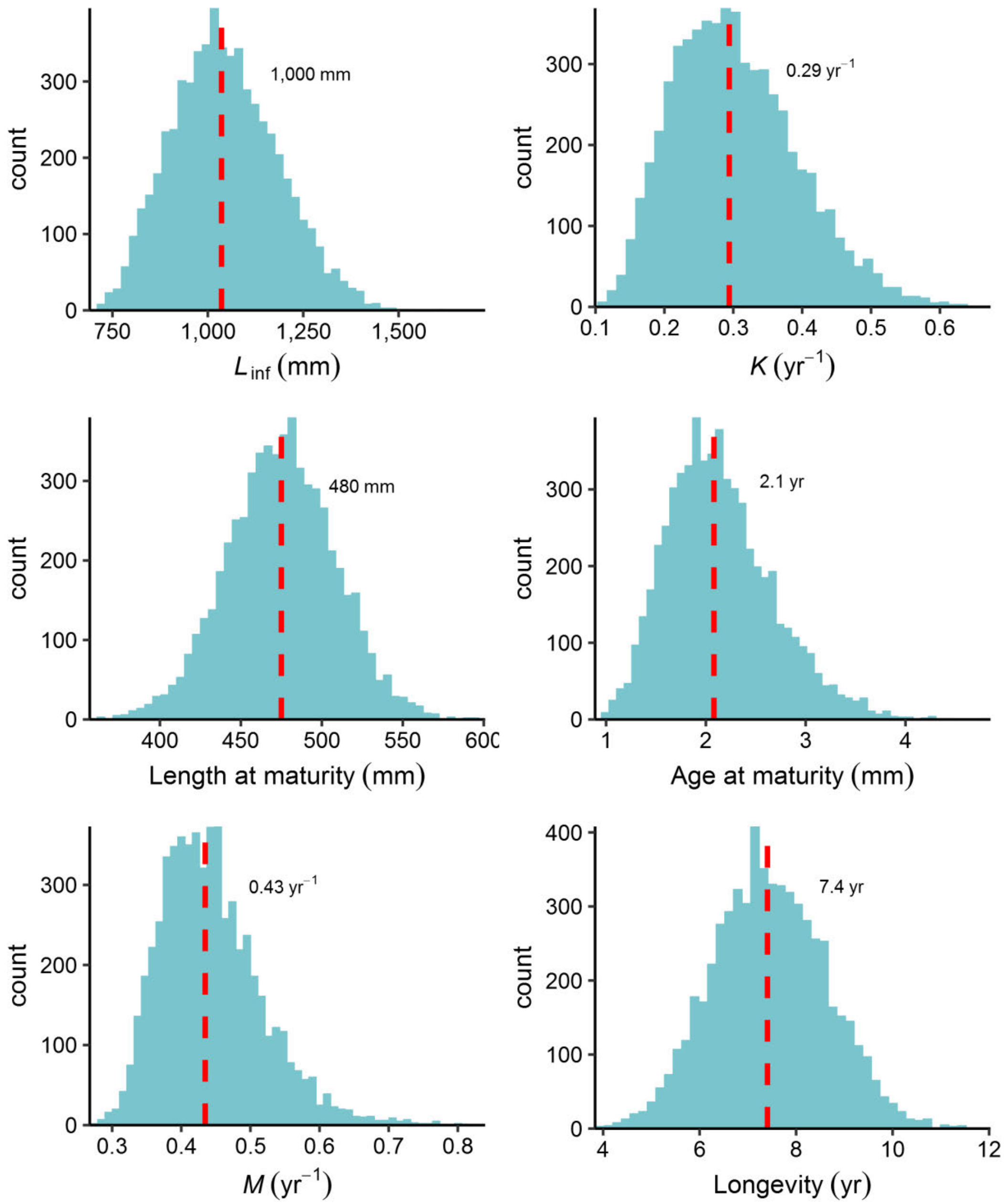
Parameter	Median	SD	Unit
B from catch	811,000	3,500,000	kg
B from survey	-	-	kg
Commercial catch	3,147	718	kg
Recreational catch	144,775	50,248	kg
Total catch	148,127	50,035	kg
C_{30} from catch	205,000	911,000	kg
C_{30} from survey	-	-	kg

General comments

Population abundance appeared to be slowly increasing in recent years. There were enough diver observations to obtain an L_{bar} estimate, but the fast swimming behavior of this species made estimating population size unreliable. L_{bar} from the UVS were not abundant enough on a yearly basis to generate a long term pattern. L_{bar} from the commercial data appeared fairly stable, which suggested that the population was mostly at equilibrium. The recreational sector dominated the catch and appeared fairly constant, although variable from year to year.

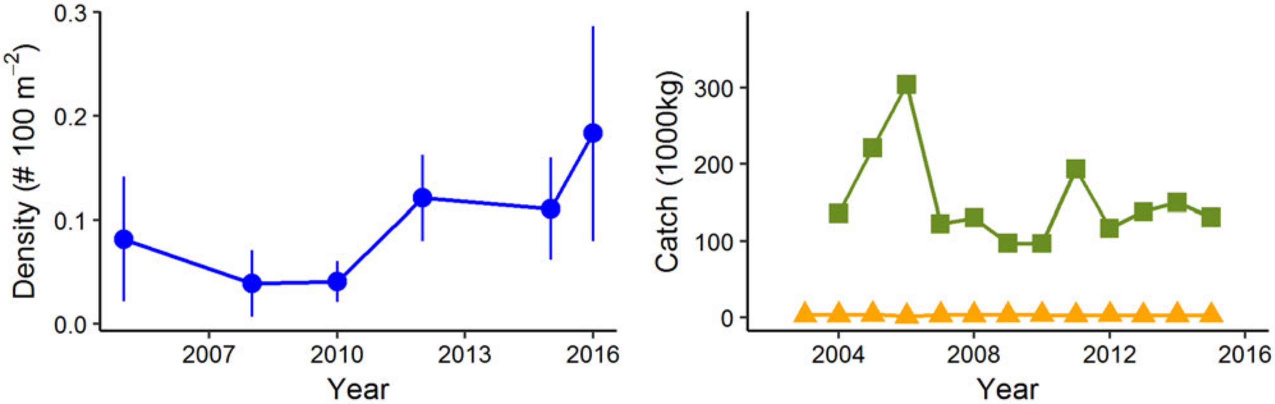
As for *C. ignobilis*, the life history parameters for this species came from a local study with a limited sample size. We also ran the analyses using the stepwise approach and generated the following values: L_{max}: 843 mm, L_{inf}: 921 mm, K: 0.25, M: 0.26, F_{30}: 0.22, F: 0.22, *SPR*: 0.32, C_{30}: 141,420 kg. These were reasonably similar to the original analyses and did not change the conclusions.

Caranx melampygus

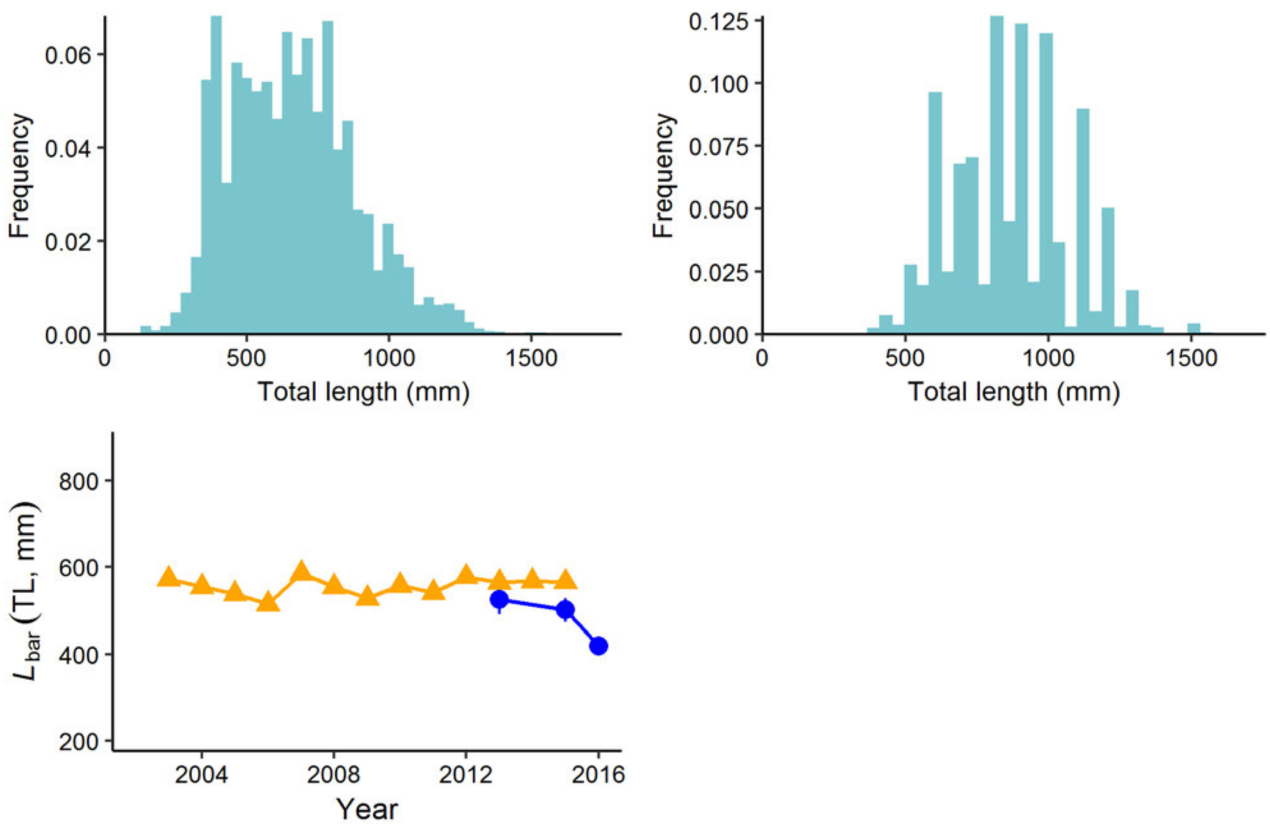


Life history parameter distributions.

Caranx melampygus

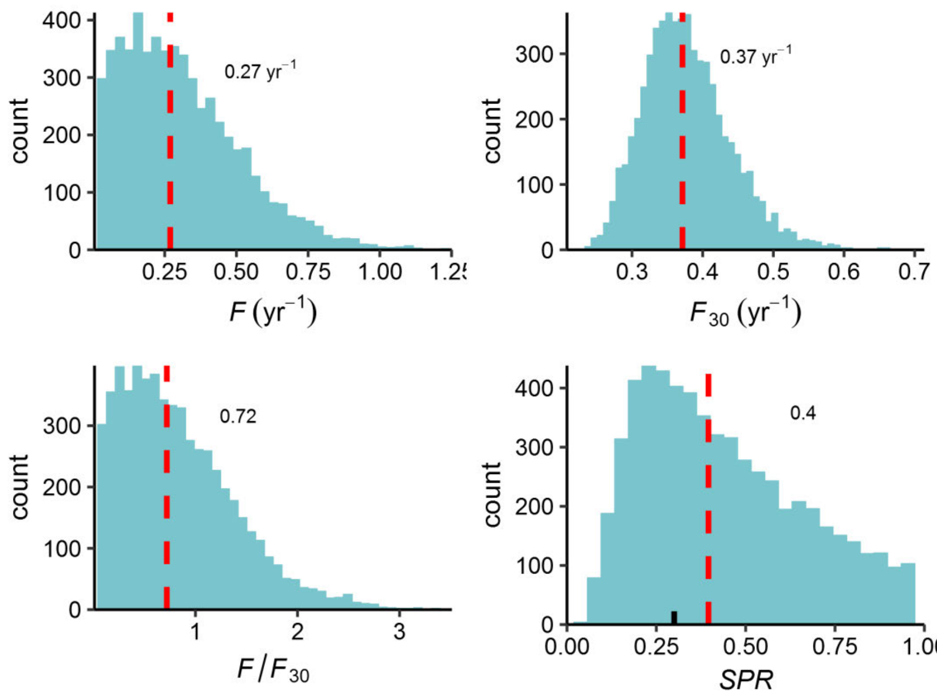


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



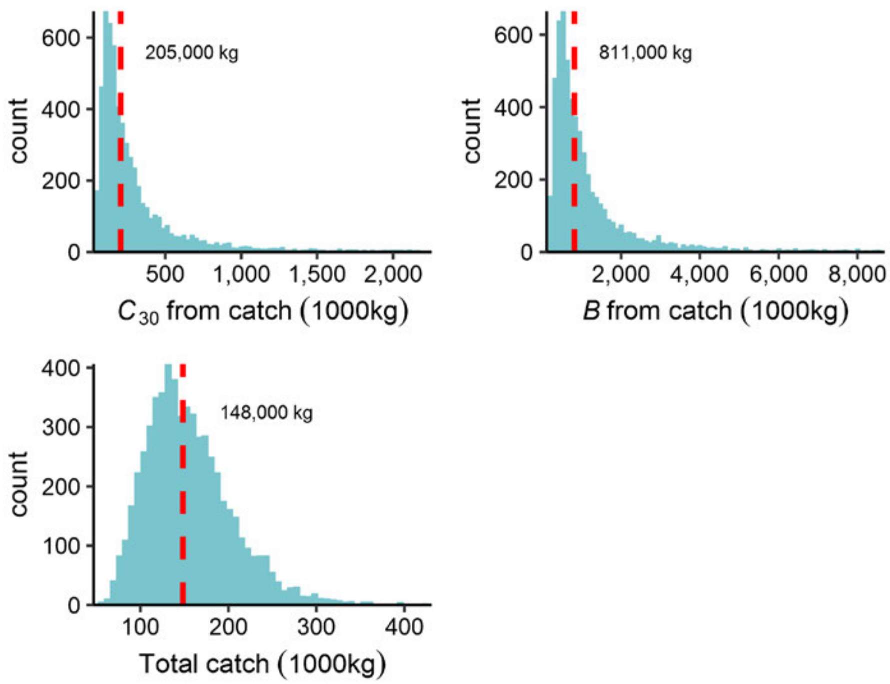
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Caranx melampygus



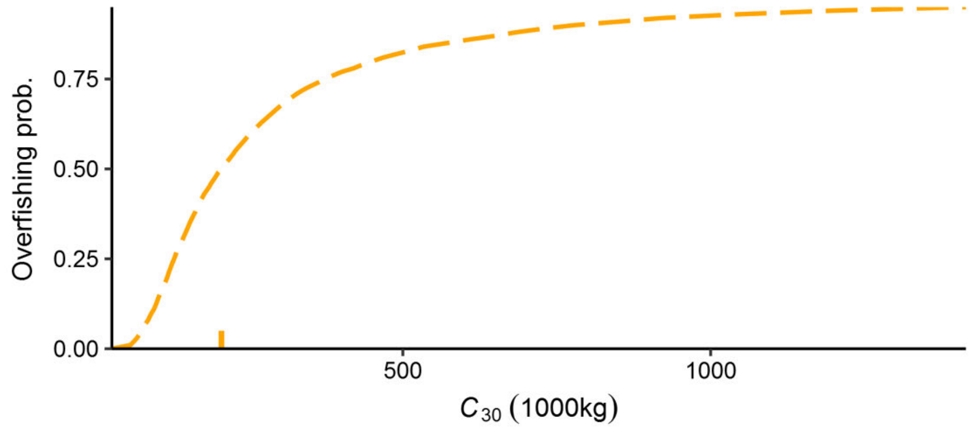
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Caranx melampygus



C_{30} and current total catch (left) and population size (right) distributions.

Caranx melampygus



Overfishing probability for a range of C_{30} levels (commercial data – orange dashed line). *OFL* is represented by a small vertical bar.

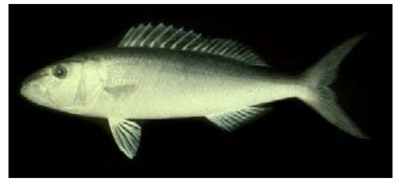
Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from catch (1000 kg)	Overfishing probability	C_{30} from catch (1000 kg)
0.10	92.1	0.31	143.7
0.11	95.6	0.32	146.4
0.12	98.2	0.33	149.0
0.13	100.4	0.34	151.5
0.14	102.5	0.35	153.8
0.15	104.9	0.36	156.7
0.16	107.5	0.37	159.6
0.17	110.4	0.38	162.7
0.18	112.7	0.39	165.0
0.19	115.4	0.40	167.7
0.20	117.5	0.41	170.9
0.21	119.4	0.42	174.2
0.22	121.6	0.43	177.2
0.23	123.6	0.44	181.3
0.24	126.0	0.45	185.4
0.25	128.4	0.46	188.6
0.26	130.7	0.47	192.7
0.27	132.7	0.48	196.5
0.28	135.6	0.49	200.0
0.29	138.1	0.50	205.3
0.30	141.4		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	536	0.31	354
0.11	526	0.32	344
0.12	517	0.33	332
0.13	507	0.34	325
0.14	500	0.35	315
0.15	491	0.36	302
0.16	484	0.37	292
0.17	474	0.38	280
0.18	465	0.39	267
0.19	458	0.40	254
0.20	452	0.41	240
0.21	445	0.42	224
0.22	436	0.43	211
0.23	426	0.44	198
0.24	416	0.45	182
0.25	410	0.46	166
0.26	400	0.47	146
0.27	393	0.48	130
0.28	384	0.49	107
0.29	374	0.50	88
0.30	364		

Aprion virescens



Green jobfish, *uku*
Lutjanidae (snappers)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	771	50	mm	379	Mean and SD: O'Malley (unpubl.)
K	0.372	0.021	yr^{-1}		
a_0	-0.51	-	yr		
L_{mat}	489	16	mm	103	Mean: Everson (1989), SD: Nadon (unpublished)
Longevity	31	2.3	yr	379	Mean and SD: O'Malley (unpubl.)
L-W α	6.44e-4	-	-	-	HMFRS data
L-W β	2.404				
L_{S50}	425	-	mm	-	DAR commercial data
L_{S95}	475				
$\bar{L}$ diver survey	613	10	mm	278	NOAA-CREP diver survey
$\bar{L}$ commercial	665	1	mm	17634	DAR commercial data
$\bar{L}$ combined	664	1	mm	-	-
Max. depth	203	-	m	-	BRFA BotCam project
Federal waters	24	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.10	0.01	yr^{-1}
F	0.15	0.07	yr^{-1}
F_{30}	0.16	0.01	yr^{-1}
F/F_{30}	0.9	0.5	-
SPR	0.33	0.16	-
SPR < 0.30 iterations	42	-	%
Lc_{30}	349	-	mm

Parameter	Median	SD	Unit
B from catch	758,000	1,590,000	kg
B from survey	434,419	83,661	kg
Commercial catch	36,867	11,226	kg
Recreational catch	51,001	38,316	kg
Total catch	92,248	36,805	kg
C_{30} from catch	104,000	226,000	kg
C_{30} from survey	60,000	12,100	kg

General comments

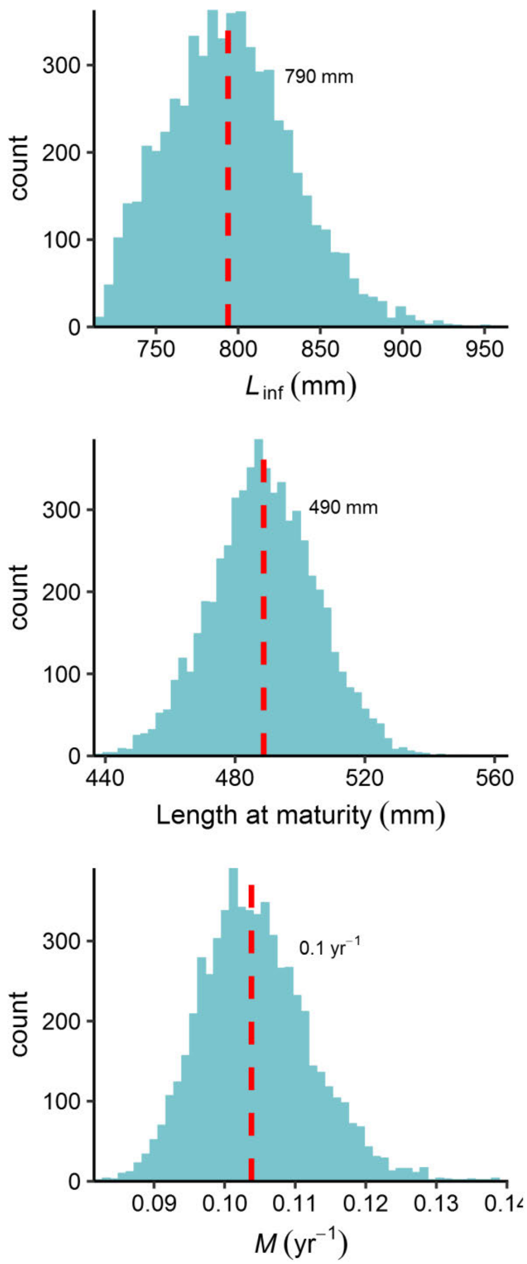
Population abundance appeared to be increasing from 2003 to 2016. The commercial catch also appeared to be increasing although it has been flat in the last 2 years. Recreational catch, although fairly variable, appeared to be relatively stable. L_{bar} from both the commercial and UVS data sets were similar and mostly stable, suggesting that the population was mostly at equilibrium.

The life history parameters for this species came from a local study conducted by the PIFSC life history group (J. O'Malley) with a fairly large sample size. Length at maturity came from a local study as well. Given the reliability of these sources, we did not deem it necessary to run the stepwise analyses for this species.

The diver L_{bar} was lower than the commercial one. A sensitivity run using this L_{bar} generated the following results: *F*: 0.33, F/F_{30}: 2.1, *SPR*: 0.15. Another sensitivity run using selectivity parameters of 475 mm and 525 mm resulted in the following values: *F*: 0.18, F/F_{30}: 1.1, *SPR*: 0.30.

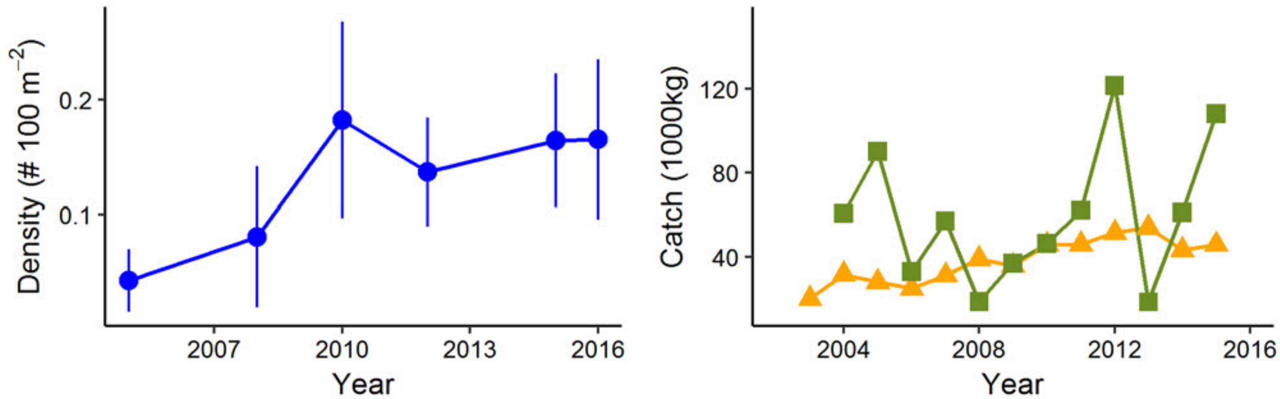
There were also sufficient diver observations to obtain a population size estimate (434,419 kg) which was relatively close to the one derived from the total catch estimate (758,000 kg). The lower population estimate from diver surveys could be related to the depth limitation of these surveys compared to the full population range for this species (30 m vs. 203 m).

Aprion virescens

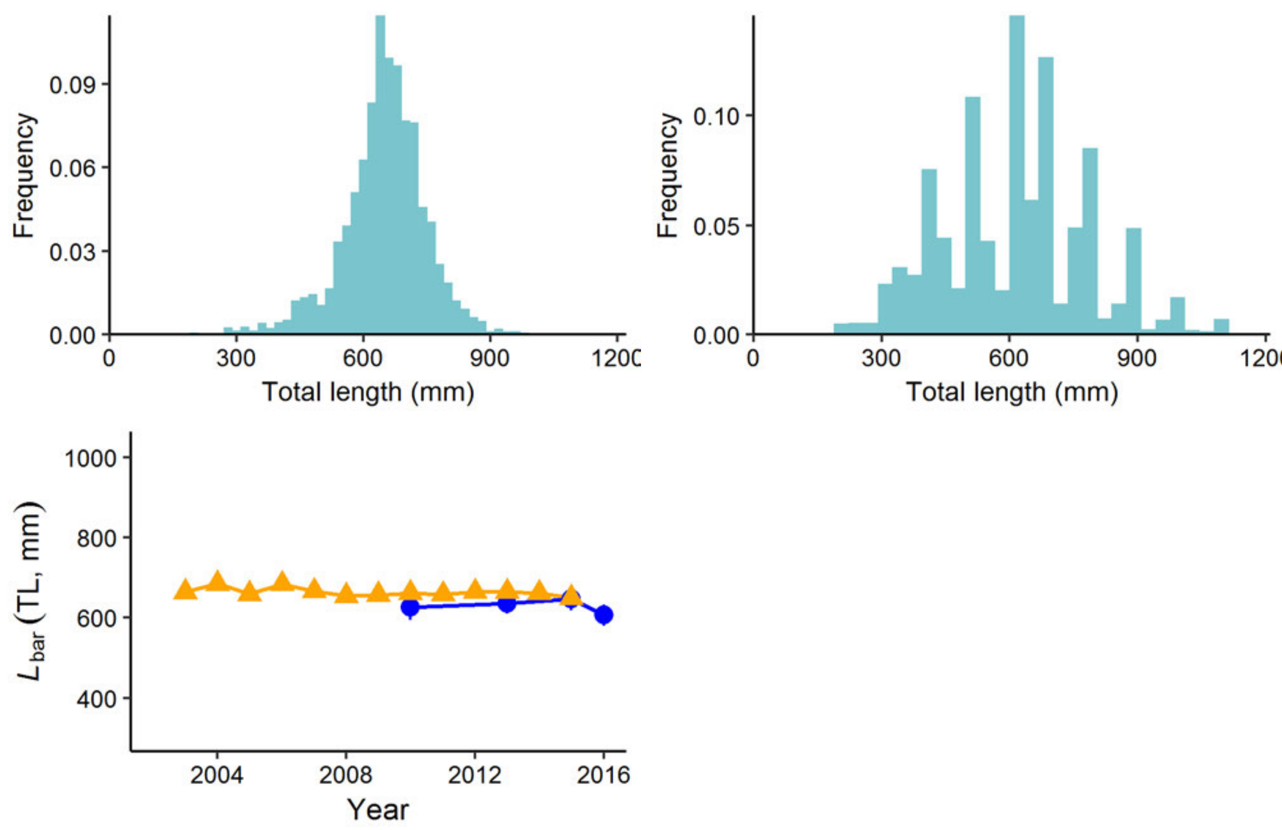


Life history parameter distributions.

Aprion virescens

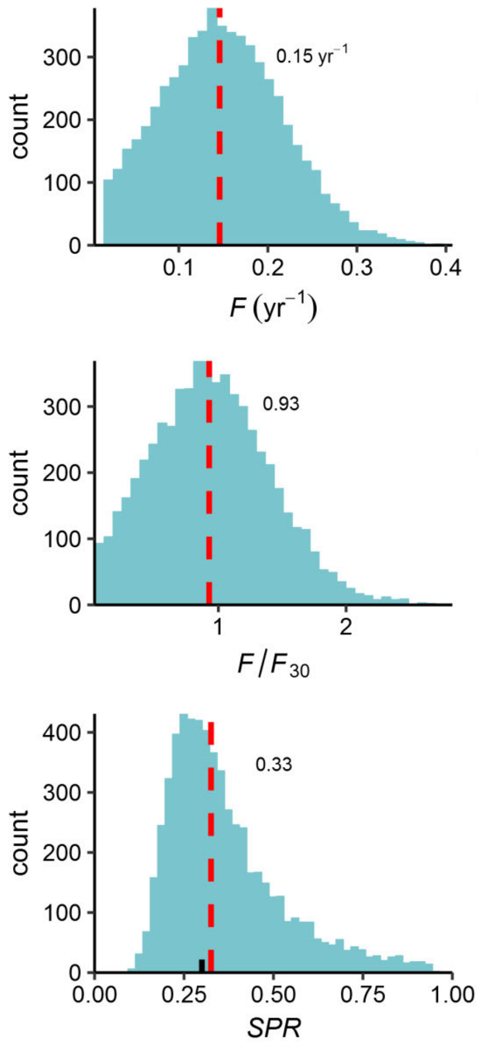


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



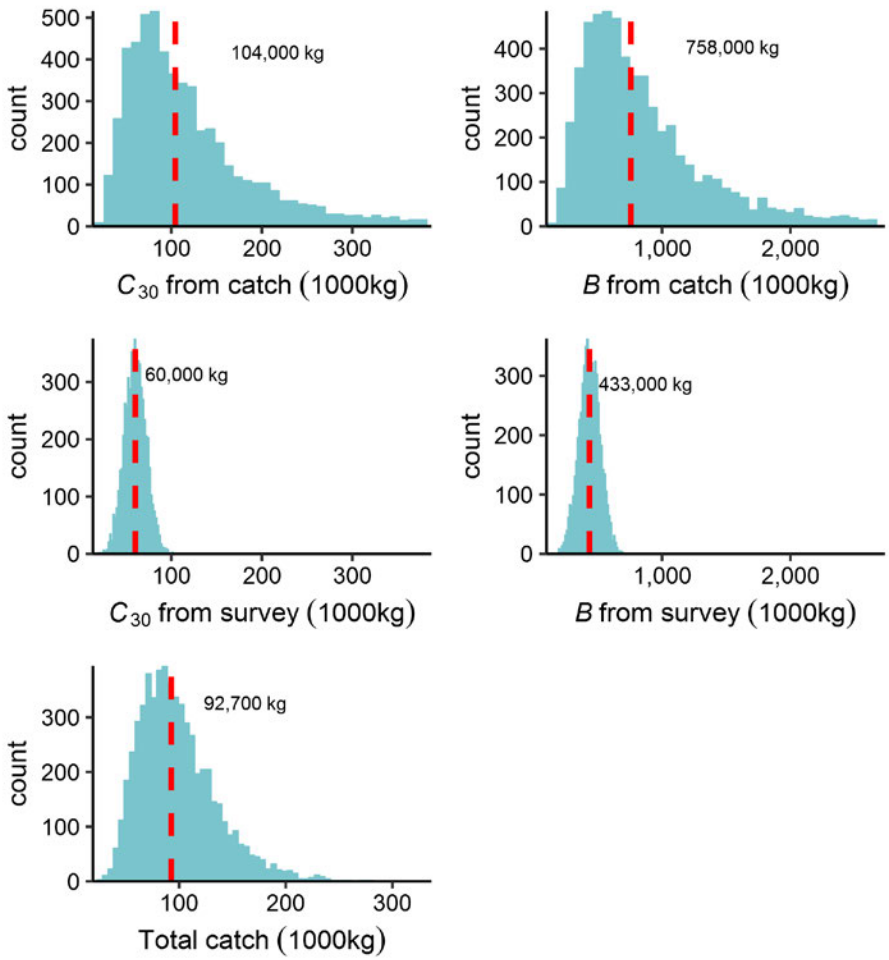
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Aprion virescens



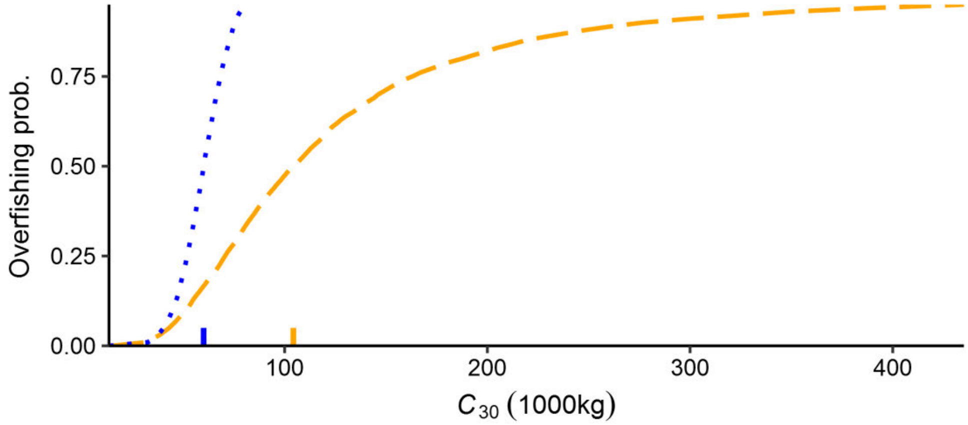
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Aprion virescens



C_{30} and current total catch (left) and population size (right) distributions.

Aprion virescens



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	51.3	44.6	0.31	78.3	54.0
0.11	52.9	45.4	0.32	79.1	54.4
0.12	54.0	46.1	0.33	80.2	54.7
0.13	55.0	46.7	0.34	81.4	55.1
0.14	56.4	47.3	0.35	82.6	55.5
0.15	57.8	47.7	0.36	84.0	55.7
0.16	59.1	48.2	0.37	85.3	56.1
0.17	60.5	48.6	0.38	86.4	56.4
0.18	61.8	49.0	0.39	87.7	56.6
0.19	63.2	49.4	0.40	89.3	57.0
0.20	64.8	49.8	0.41	90.5	57.4
0.21	66.1	50.2	0.42	91.8	57.7
0.22	67.3	50.7	0.43	93.3	58.0
0.23	68.4	51.2	0.44	94.9	58.4
0.24	69.5	51.5	0.45	96.3	58.6
0.25	70.6	51.9	0.46	97.9	58.9
0.26	71.7	52.3	0.47	99.4	59.2
0.27	73.0	52.6	0.48	100.9	59.5
0.28	74.4	53.0	0.49	102.4	59.8
0.29	75.8	53.3	0.50	104.3	60.0
0.30	76.9	53.7			

Aprion virescens

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	625	0.31	502
0.11	616	0.32	497
0.12	608	0.33	489
0.13	604	0.34	480
0.14	595	0.35	476
0.15	591	0.36	468
0.16	586	0.37	463
0.17	582	0.38	455
0.18	574	0.39	446
0.19	570	0.40	438
0.20	565	0.41	429
0.21	557	0.42	425
0.22	552	0.43	421
0.23	548	0.44	408
0.24	540	0.45	404
0.25	536	0.46	391
0.26	531	0.47	378
0.27	523	0.48	370
0.28	518	0.49	357
0.29	514	0.50	348
0.30	506		

Lutjanus fulvus

Blacktail snapper, *to'au*
Lutjanidae (snappers)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	342	19	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 372 (7) from MHI diver data
K	0.43	0.17	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	240	37	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	19	7	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	2.04e-5	-	-	-	Kulbicki (2005)
L-W β	2.97				
L_{S50}	210	-	mm	-	DAR commercial data
L_{S95}	220				
$\bar{L}$ diver survey	264	3	mm	471	NOAA-CREP diver survey
$\bar{L}$ commercial	295	2	mm	4771	DAR commercial data
$\bar{L}$ combined	283	2	mm	-	-
Max. depth	128	-	m	-	Pyle et al. (2016)
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.17	0.07	yr^{-1}
F	0.20	0.18	yr^{-1}
F_{30}	0.22	0.09	yr^{-1}
F/F_{30}	0.9	0.9	-
SPR	0.33	0.23	-
SPR < 0.30 iterations	45	-	%
Lc_{30}	132	-	mm

Parameter	Median	SD	Unit
B from catch	47,900	161,000	kg
B from survey	180,433	29,498	kg
Commercial catch	1,606	832	kg
Recreational catch	6,682	2,358	kg
Total catch	8,488	2,488	kg
C_{30} from catch	8,670	36,000	kg
C_{30} from survey	33,100	11,400	kg

General comments

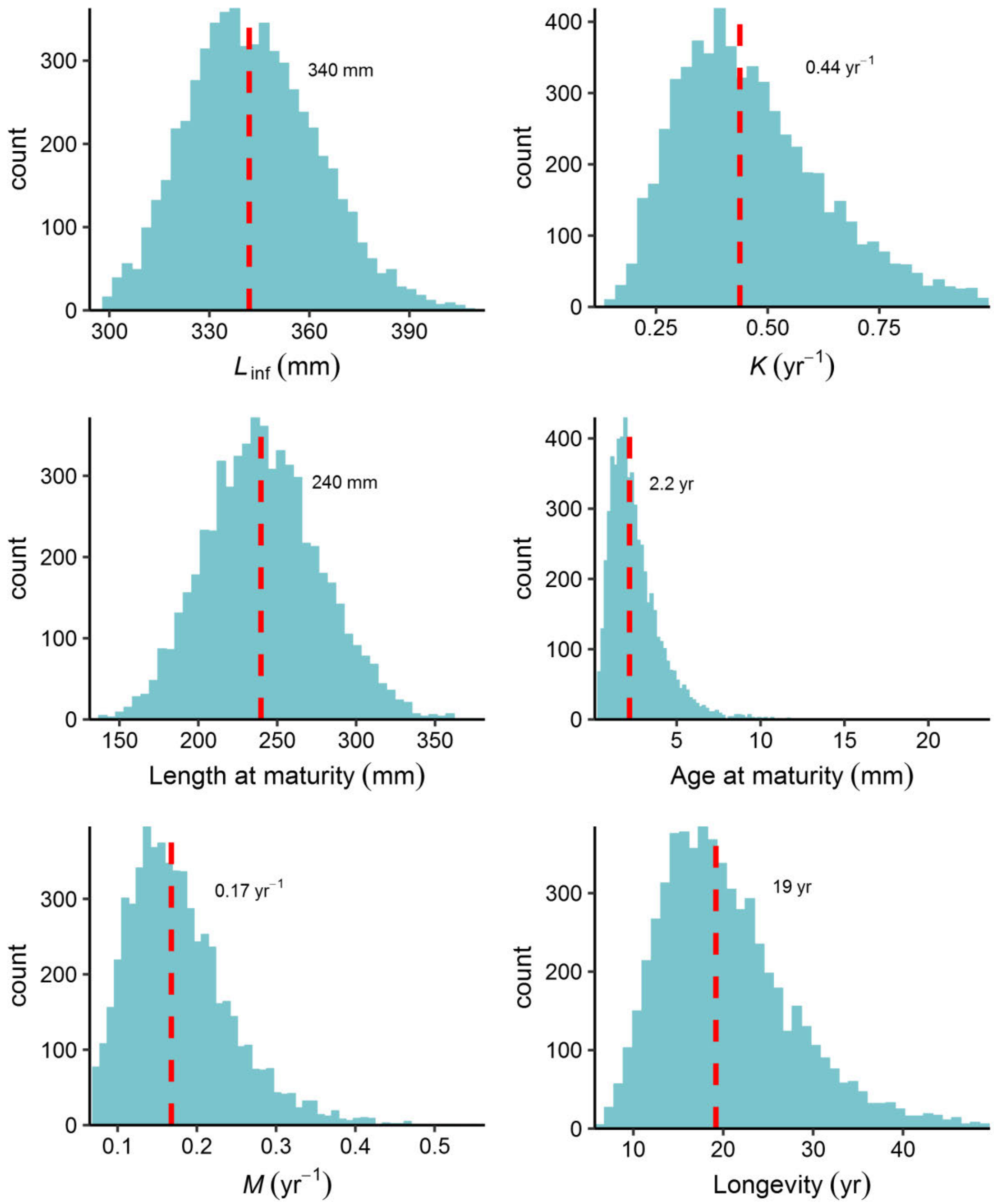
Note: this species is non-native and considered invasive. It was introduced in 1956 from Tahiti.

Population abundance for this species has been stable. The commercial L_{bar} have been stable as well, while the recreational L_{bar} have declined a bit from the early years. The recreational catch was much larger than the commercial one and both have been steady in recent years (with the recreational catch declining slightly in the last 2 years).

There is no published life history parameters for this species. We therefore used the stepwise approach to generate estimates, using an L_{max} value of 372 mm from diver survey data (from the MHI, since this species is not present in the NWHI). A sensitivity run with a higher L_{max} (400 mm), generated the following estimates: L_{inf}: 364 mm, K: 0.40, M: 0.17, F_{30}: 0.21, F: 0.32, C_{30} survey: 32,359 kg).

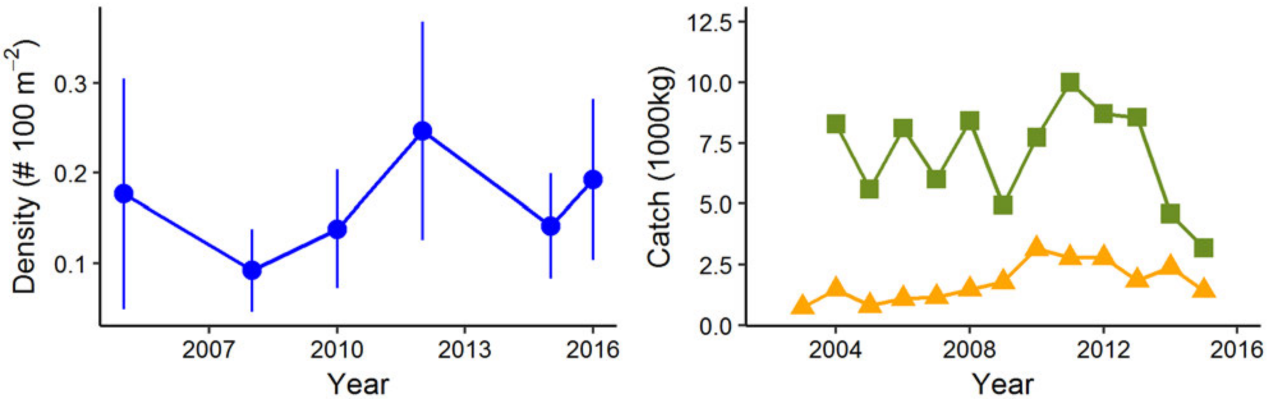
The population size estimate derived from the catch was lower than the estimate from diver survey. This could be expected given the uncertainty in both the total catch estimate and the life history parameters. The population size estimate derived from the diver survey is likely more reliable given that this is a common species that is easily identifiable. Consequently, the C_{30} derived from the diver survey population estimate is likely more reliable.

Lutjanus fulvus

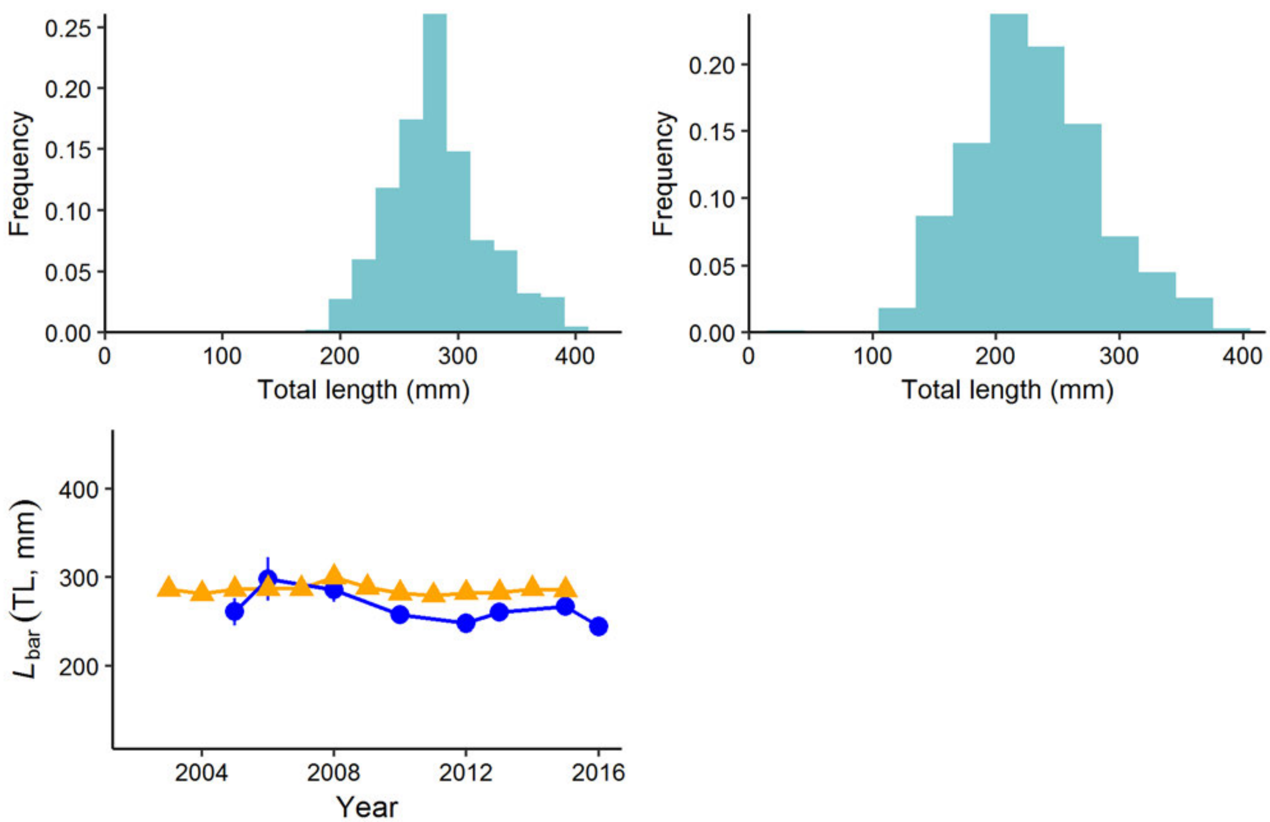


Life history parameter distributions.

Lutjanus fulvus

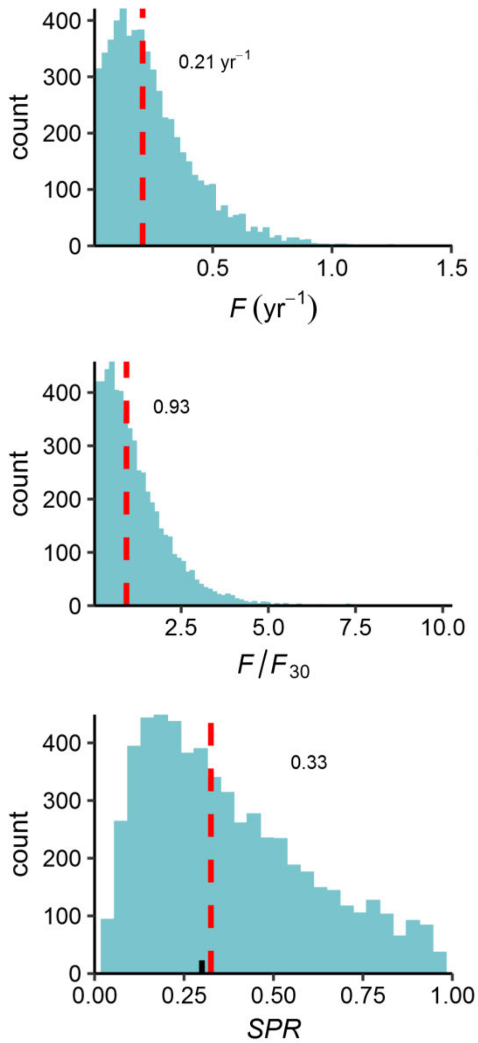


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



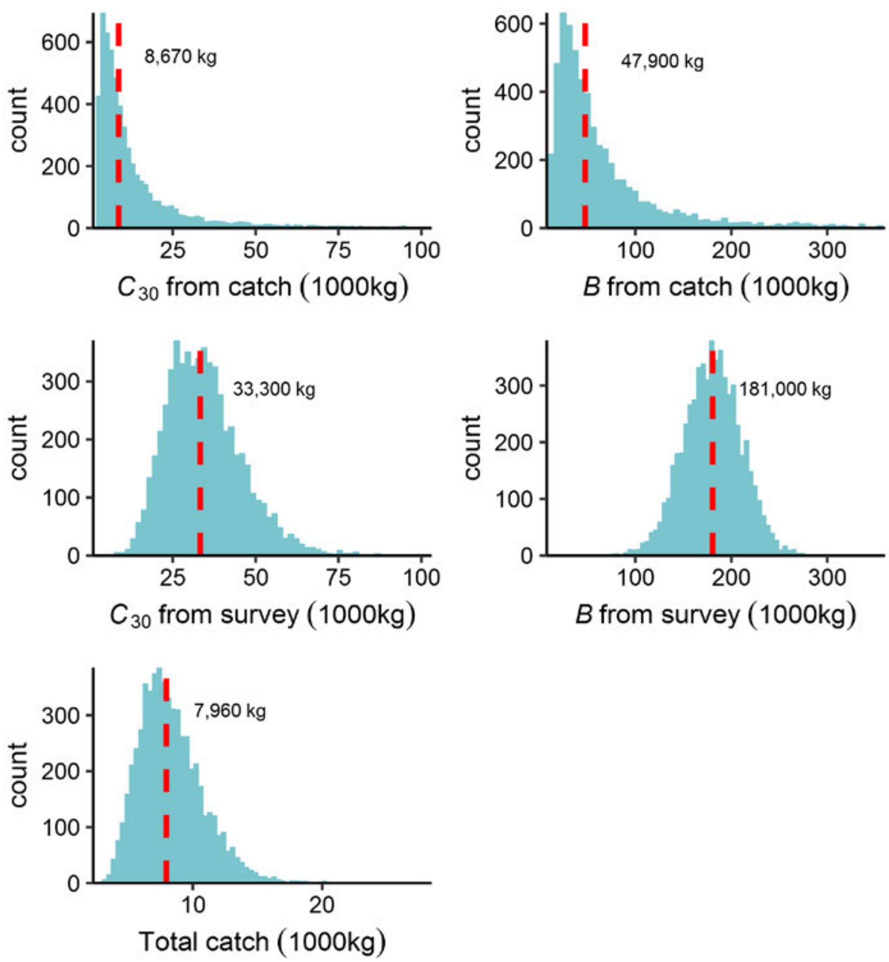
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Lutjanus fulvus



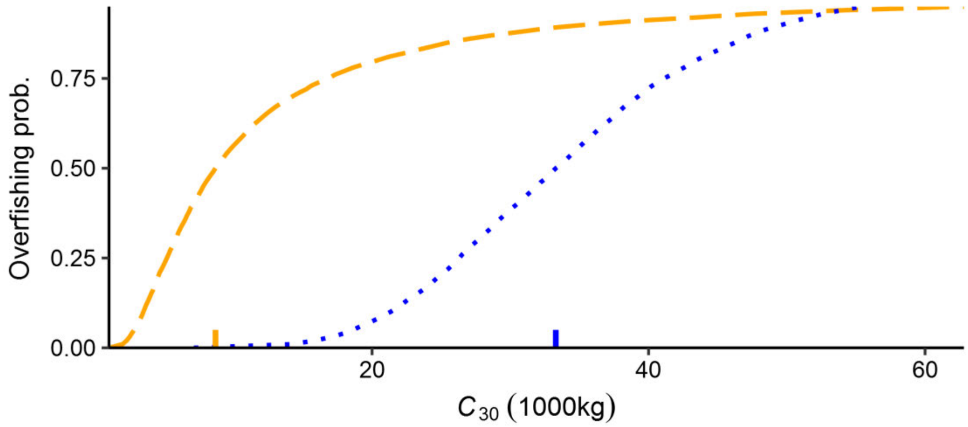
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Lutjanus fulvus



C_{30} and current total catch (left) and population size (right) distributions.

Lutjanus fulvus



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	3.5	21.3	0.31	5.9	28.0
0.11	3.6	21.7	0.32	6.0	28.2
0.12	3.7	22.1	0.33	6.1	28.5
0.13	3.8	22.5	0.34	6.2	28.8
0.14	3.9	22.8	0.35	6.4	29.0
0.15	4.0	23.2	0.36	6.5	29.3
0.16	4.1	23.6	0.37	6.6	29.6
0.17	4.2	24.0	0.38	6.8	29.8
0.18	4.3	24.3	0.39	6.9	30.2
0.19	4.4	24.6	0.40	7.1	30.5
0.20	4.5	24.9	0.41	7.3	30.8
0.21	4.6	25.2	0.42	7.4	31.1
0.22	4.8	25.5	0.43	7.5	31.3
0.23	4.9	25.8	0.44	7.7	31.6
0.24	5.0	26.0	0.45	7.8	31.9
0.25	5.2	26.3	0.46	8.0	32.2
0.26	5.3	26.5	0.47	8.1	32.5
0.27	5.4	26.8	0.48	8.3	32.8
0.28	5.5	27.0	0.49	8.5	33.0
0.29	5.6	27.4	0.50	8.7	33.3
0.30	5.7	27.7			

Lutjanus fulvus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	294	0.31	231
0.11	290	0.32	229
0.12	288	0.33	225
0.13	284	0.34	220
0.14	281	0.35	218
0.15	279	0.36	216
0.16	275	0.37	210
0.17	273	0.38	208
0.18	271	0.39	202
0.19	268	0.40	197
0.20	265	0.41	193
0.21	263	0.42	187
0.22	260	0.43	181
0.23	258	0.44	174
0.24	254	0.45	168
0.25	250	0.46	162
0.26	248	0.47	156
0.27	246	0.48	147
0.28	242	0.49	141
0.29	239	0.50	132
0.30	235		

Lutjanus kasmira

Bluestripe snapper, *ta'ape*
Lutjanidae (snappers)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	340	15	mm	171	Mean: Morales-Nin and Ralston (1990), SD: Kritzer (2001)
K	0.29	0.05	yr^{-1}		
a_0	-1.37	-	yr		
L_{mat}	200	5	mm	100?	Mean: Allen (1985), SD: Nadon (unpublished)
Longevity	8	1	yr	171	Mean: Loubens (1980), SD: Kritzer (2001)
L-W α	4.30e-6	-	-	-	Kulbicki (2001)
L-W β	3.25				
L_{S50}	220	-	mm	-	DAR commercial data
L_{S95}	240				
$\bar{L}$ diver survey	274	4	mm	1402	NOAA-CREP diver survey
$\bar{L}$ commercial	271	1	mm	7460	DAR commercial data
$\bar{L}$ combined	271	1	mm	-	-
Max. depth	265	-	m	-	Pyle et al. (2016)
Federal waters	26	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.39	0.04	yr^{-1}
F	0.21	0.13	yr^{-1}
F_{30}	0.75	0.14	yr^{-1}
F/F_{30}	0.3	0.2	-
SPR	0.62	0.16	-
SPR < 0.30 iterations	0	-	%
Lc_{30}	0	-	mm

Parameter	Median	SD	Unit
B from catch	181,000	576,000	kg
B from survey	496,235	98,182	kg
Commercial catch	16,165	2,813	kg
Recreational catch	10,734	7,534	kg
Total catch	27,968	7,429	kg
C_{30} from catch	80,100	288,000	kg
C_{30} from survey	221,000	50,000	kg

General comments

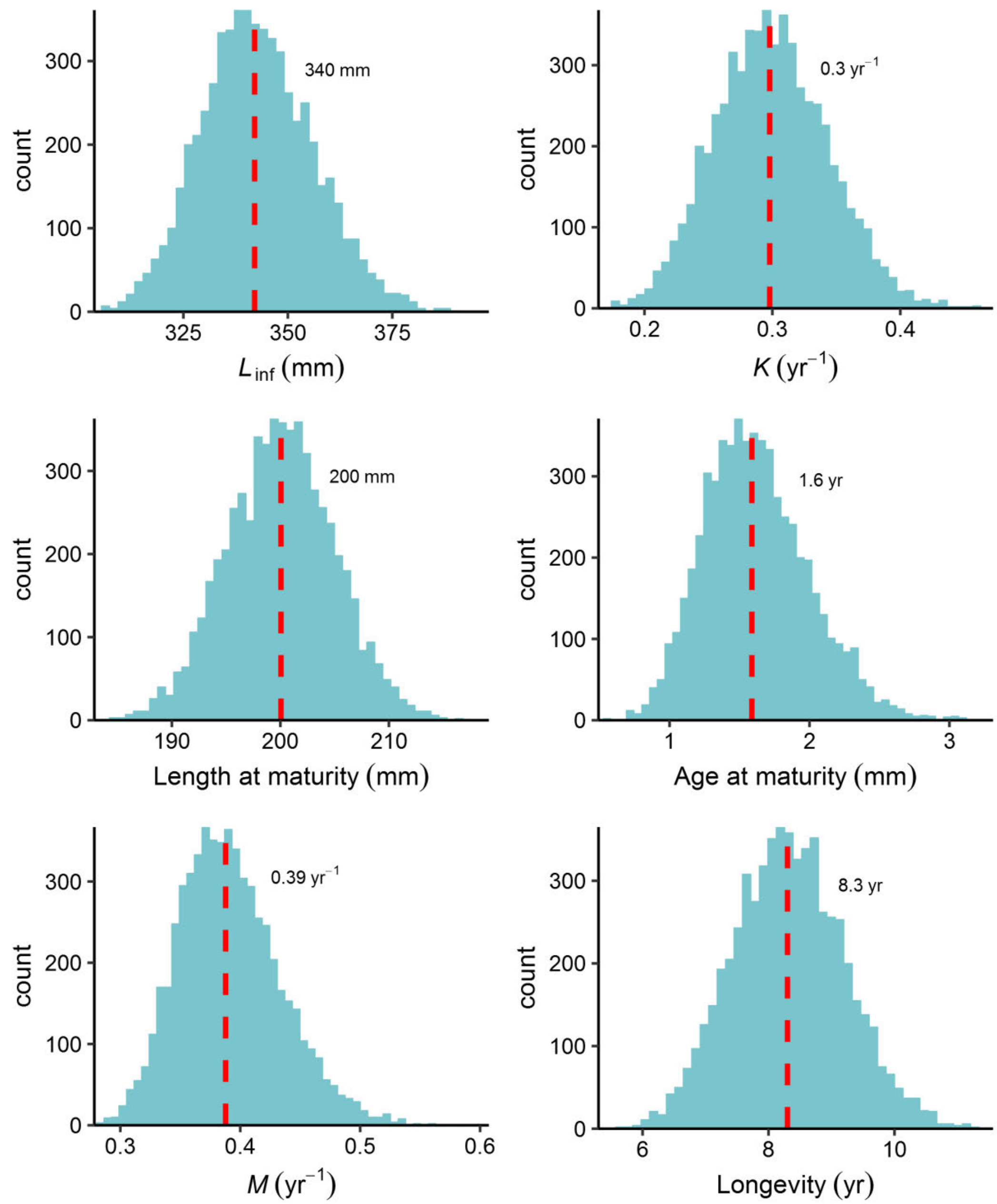
Note: this species is non-native and considered invasive. It was introduced in 1956 from Tahiti.

Population abundance appears to have declined from a peak in 2005. However, the survey effort in this early year had a limited sample size and this may simply be an outlier. Abundance appeared to be fairly stable for the rest of the time series. L_{bar} from both data sets were very similar and constant throughout the years, which suggest a population near equilibrium. The commercial catch has been declining in recent years while the recreational catch has remained highly variable but stable.

The growth parameters for this species came from a local study with a proper sample size. However, the maturity parameter source was not ideal (i.e. a fish ID guide). The stepwise approach for this species provided the following results: L_{max}: 340 mm, L_{inf}: 316 mm, L_{mat}: 224, K: 0.45, M: 0.20, F: 0.37, F_{30}: 0.30, SPR: 0.23, C_{30} survey: 118,185 kg. The L_{mat} value obtained from the stepwise approach was close to the original one. The rest of the parameters were similar except for a higher longevity and thus higher M. The max age for this species is estimated at 8 years while snapper typically live longer (16 years). This lead to the higher F value and low SPR value.

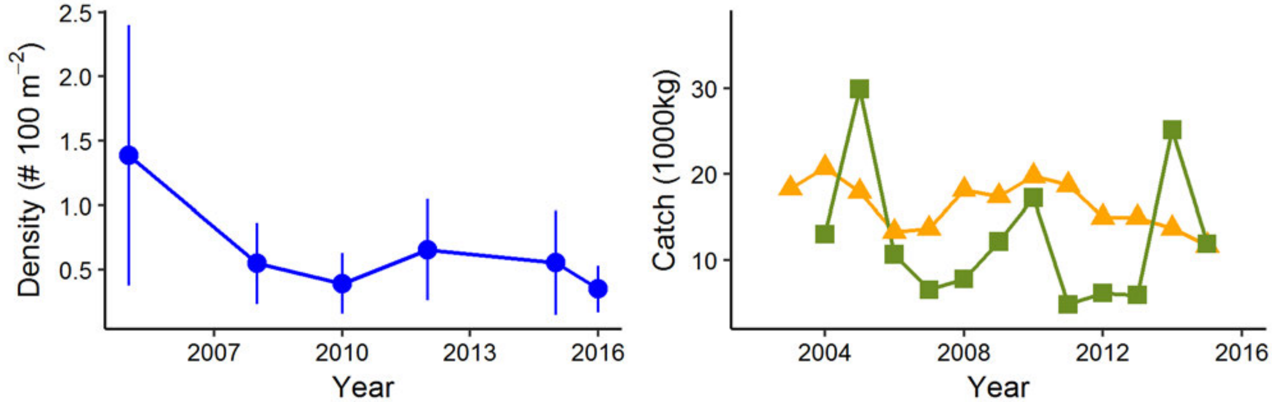
The population size estimate derived from the catch was less than half the estimate from diver surveys. This can be expected given the uncertainty in the total catch estimate. The population size estimate derived from the diver survey is likely more reliable given that this is a common species that is easily identifiable. The OFL derived from the diver survey population estimate is therefore likely more reliable.

Lutjanus kasmira

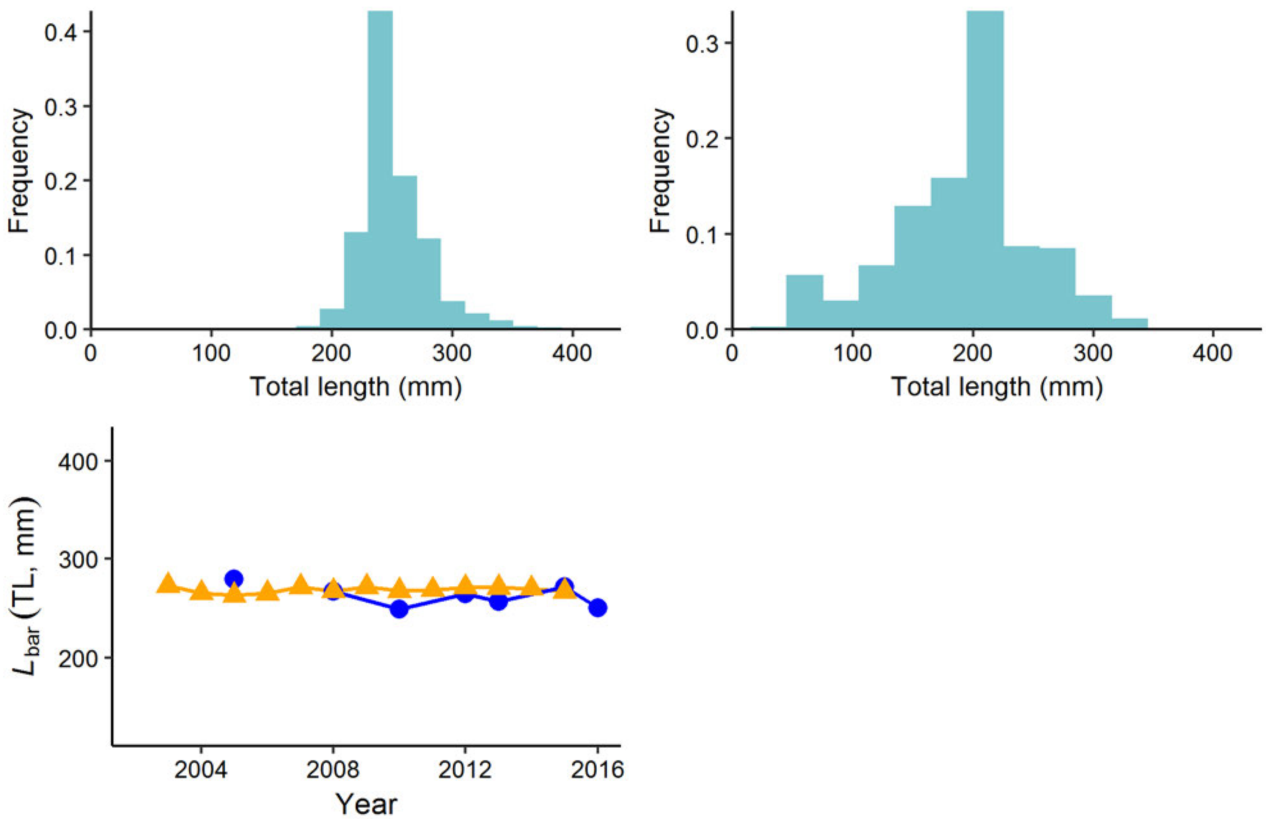


Life history parameter distributions.

Lutjanus kasmira

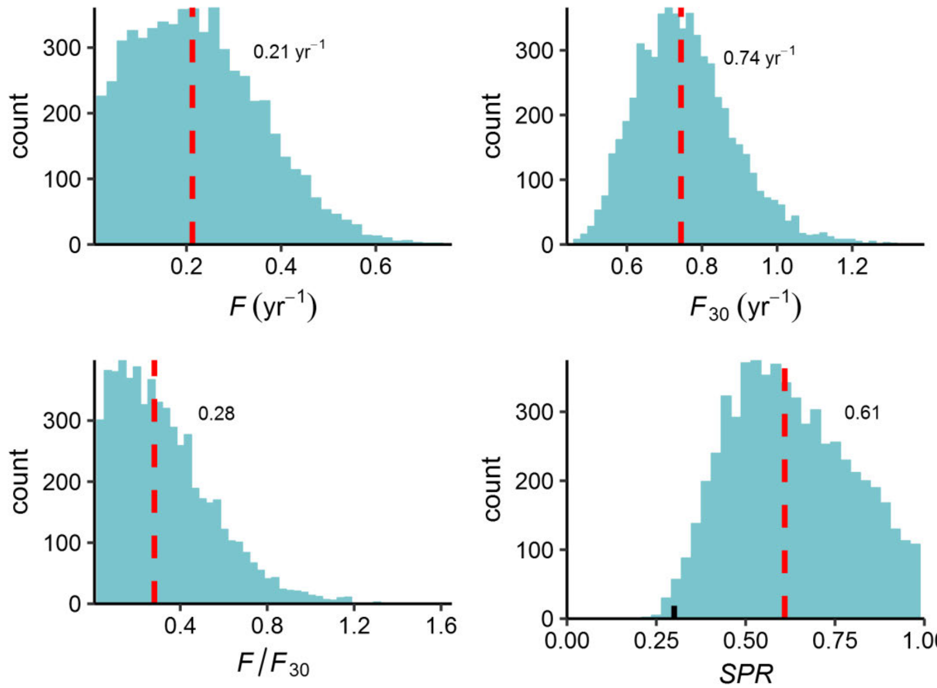


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Lutjanus kasmira



Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

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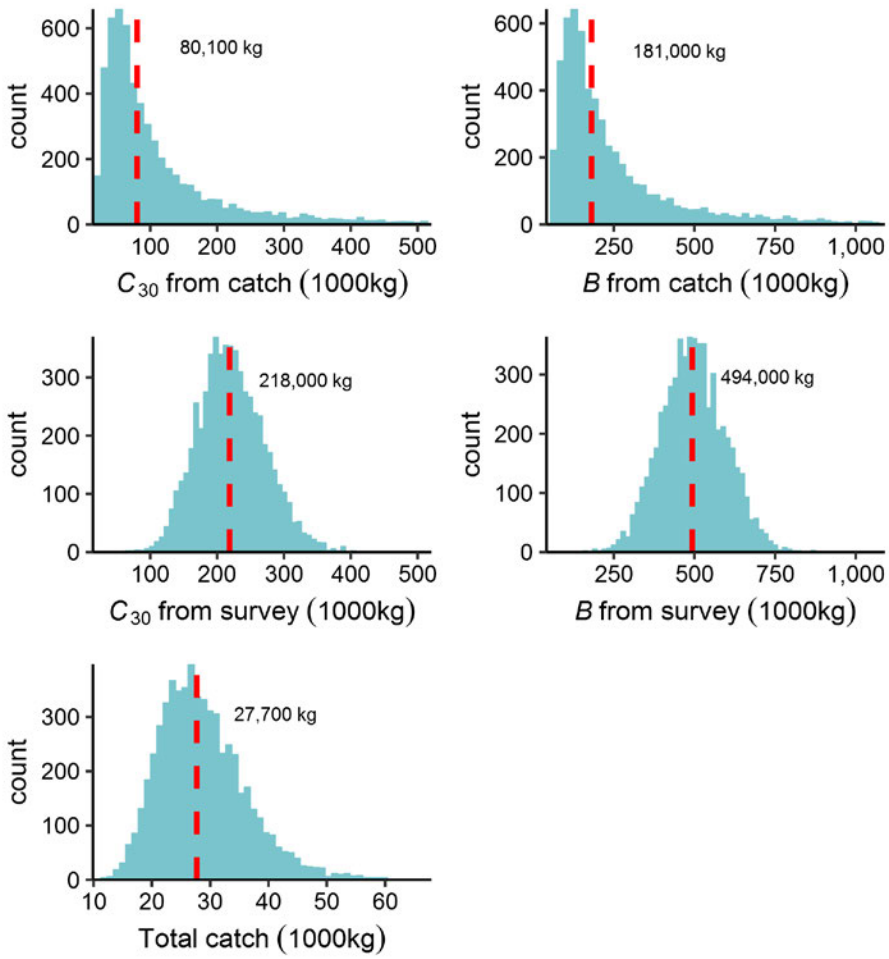
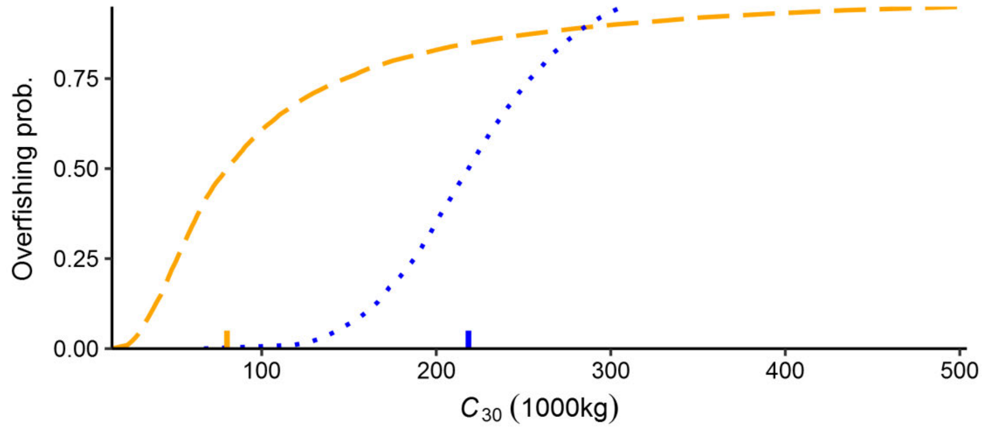
Lutjanus kasmira



C_{30} and current total catch (left) and population size (right) distributions.

Lutjanus kasmira



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	36.6	161.4	0.31	57.2	197.0
0.11	37.7	163.5	0.32	58.1	198.0
0.12	38.8	165.5	0.33	59.1	199.6
0.13	39.9	167.3	0.34	60.0	200.8
0.14	41.1	169.1	0.35	61.1	202.2
0.15	42.3	171.2	0.36	62.1	203.4
0.16	43.3	173.7	0.37	63.0	204.5
0.17	44.1	175.5	0.38	64.1	205.6
0.18	45.0	177.2	0.39	65.0	206.8
0.19	45.9	179.1	0.40	66.2	208.5
0.20	46.7	180.9	0.41	67.3	209.7
0.21	47.6	182.5	0.42	68.4	210.9
0.22	48.4	184.0	0.43	69.8	212.1
0.23	49.5	185.8	0.44	71.1	213.4
0.24	50.6	187.2	0.45	72.3	214.6
0.25	51.5	188.7	0.46	73.7	215.7
0.26	52.4	190.2	0.47	75.4	216.9
0.27	53.4	191.5	0.48	77.1	218.2
0.28	54.3	193.0	0.49	78.6	219.4
0.29	55.2	194.2	0.50	80.1	220.5
0.30	56.3	195.7			

Lutjanus kasmira

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	172	0.31	0
0.11	169	0.32	0
0.12	167	0.33	0
0.13	163	0.34	0
0.14	161	0.35	0
0.15	158	0.36	0
0.16	156	0.37	0
0.17	152	0.38	0
0.18	150	0.39	0
0.19	146	0.40	0
0.20	143	0.41	0
0.21	141	0.42	0
0.22	136	0.43	0
0.23	134	0.44	0
0.24	130	0.45	0
0.25	128	0.46	0
0.26	123	0.47	0
0.27	119	0.48	0
0.28	112	0.49	0
0.29	0	0.50	0
0.30	0		

Mulloidichthys flavolineatus

Yellowstripe goatfish, *weke'a*
Mullidae (goatfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	371	41	mm	50	Mean: Holland (1993), SD: Kritzer (2001)
K	0.564	0.170	yr^{-1}		
a_0	-0.36	-	yr		
L_{mat}	199	7	mm	95	Mean: Cole (2009), SD: Nadon (unpublished)
Longevity	6	2	yr	-	Mean: Estimated, SD: estimated
L-W α	4.12e-6	-	-	-	Holland (1993)
L-W β	3.21				
L_{S50}	215	-	mm	-	DAR commercial data
L_{S95}	230				
$\bar{L}$ diver survey	281	10	mm	414	NOAA-CREP diver survey
$\bar{L}$ commercial	293	5	mm	2035	DAR commercial data
$\bar{L}$ combined	291	6	mm	-	-
Max. depth	97	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.46	0.12	yr^{-1}
F	0.33	0.26	yr^{-1}
F_{30}	0.64	0.18	yr^{-1}
F/F_{30}	0.5	0.5	-
SPR	0.49	0.22	-
SPR < 0.30 iterations	18	-	%
Lc_{30}	0	-	mm

Parameter	Median	SD	Unit
B from catch	307,000	1,840,000	kg
B from survey	42,455	14,919	kg
Commercial catch	2,152	843	kg
Recreational catch	61,857	68,173	kg
Total catch	64,806	65,901	kg
C_{30} from catch	118,000	787,000	kg
C_{30} from survey	16,300	6,260	kg

General comments

Population abundance from UVS was fairly variable, but overall appeared constant. The commercial catch was relatively small and stable. The recreational catch was very high but this is likely an artefact of the HMRFS sampling protocol (see discussion below). L_{bar} from both data sets were similar and appear to be slightly increasing in recent years.

The growth parameters for this species came from a local mark-recapture study. There is, however, no estimate of maximum age. Longevity for this species is estimated at around 6 years, which is the average for the goatfish family. A sensitivity run with longevity set at the highest value recorded for goatfishes (11 years) gave the following estimates: M: 0.29, F_{30}: 0.41, SPR: 0.30, C_{30} survey: 12,487 kg.

The recreational catch for this species is 25× larger than the commercial catch, which is highly unusual (i.e., the next highest catch ratio for goatfishes is 5× for *P. cyclostomus*. There is a fishery for the juvenile of this species (called oama). It is very likely that HMRFS surveyors do not often measure lengths or weights when encountering oama (Hongguang Ma, pers. comm.), but still record counts. This likely biases the average weight upward. Since average weight multiplied by number recorded is used to infer total catch by weight, the total recreational catch estimate is very likely positively biased. If we multiply the commercial catch by the (continued on next page)

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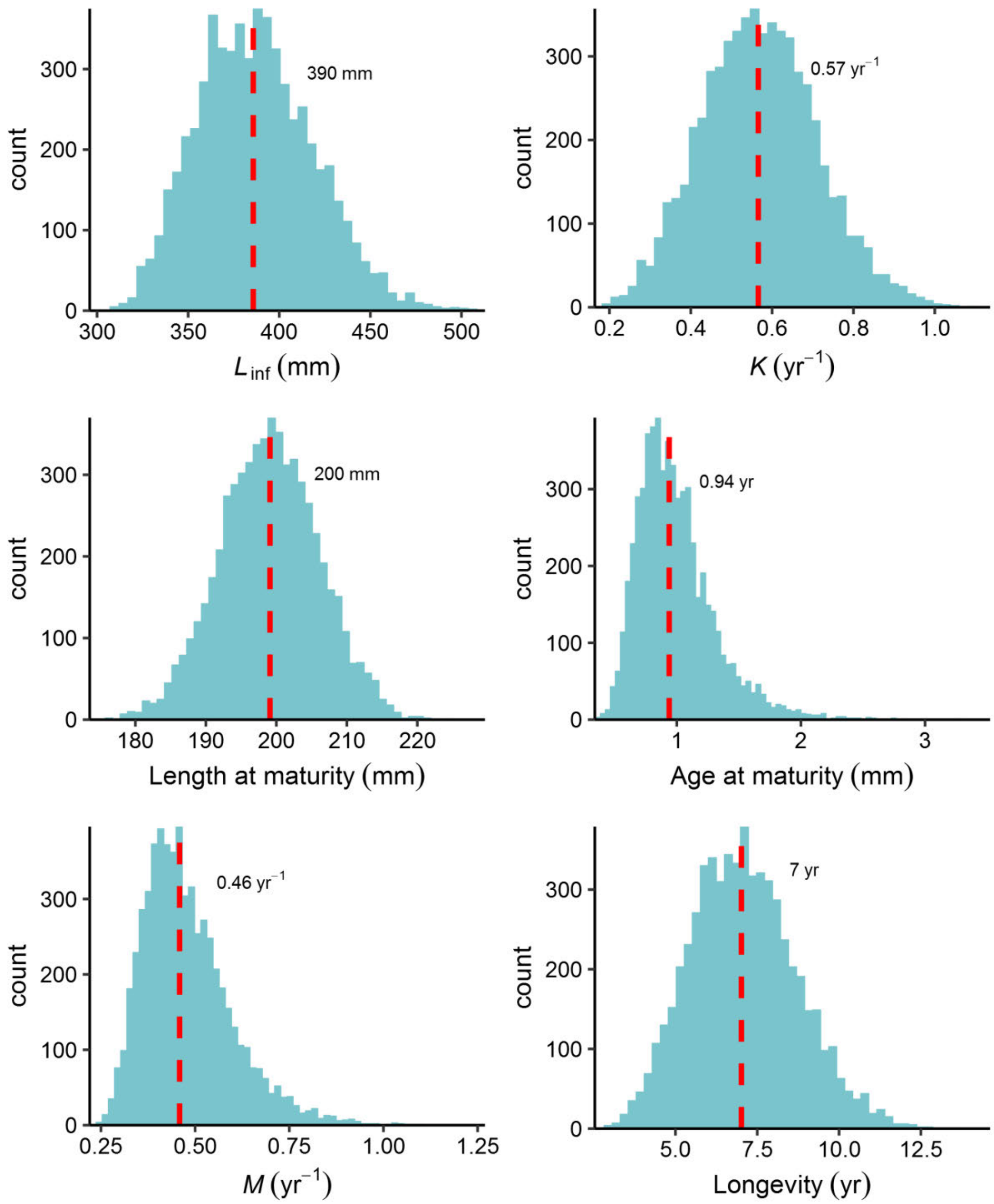
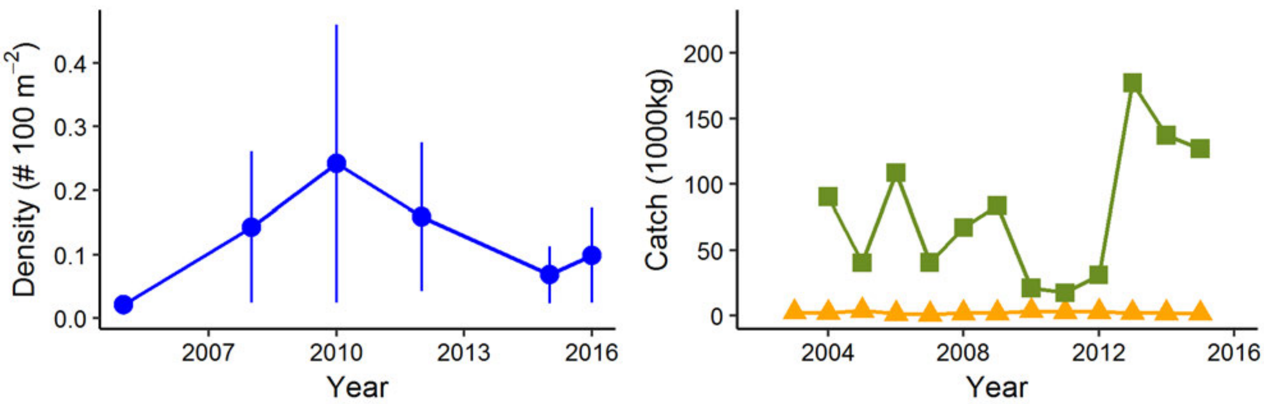
average recreational to commercial catch ratio for goatfishes (4), we get an estimated recreational catch of 8,608 kg, which, combined with the commercial catch, provides a population biomass estimate of 47,164 kg. This value is close to the population biomass estimate from diver surveys (42,455 kg). Given this issue, the diver survey C_{30} estimates should be used for this species. The "corrected" total catch estimate of 10,760 kg is significantly below the *OFL* value of 16,300 kg which is concordant with the *SPR* value of 0.49.

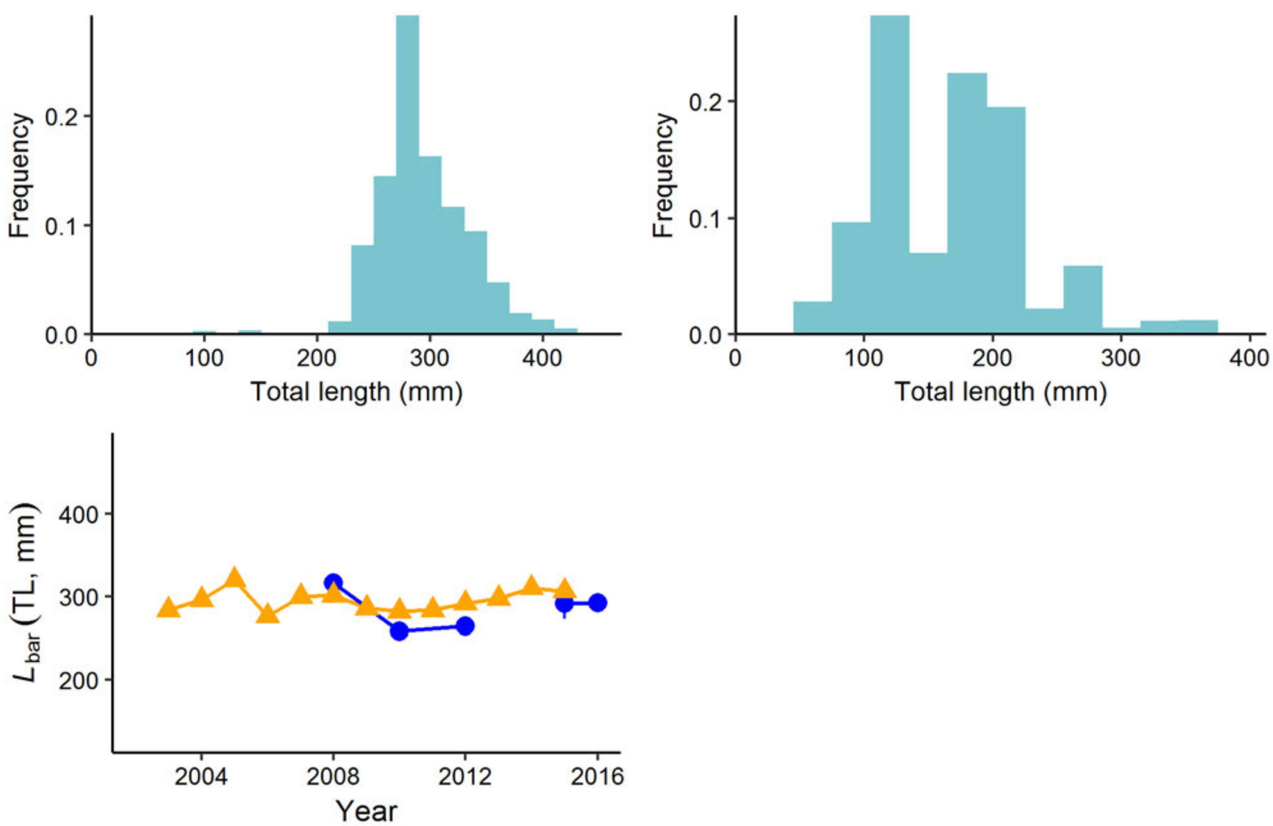


Life history parameter distributions.

Mulloidichthys flavolineatus

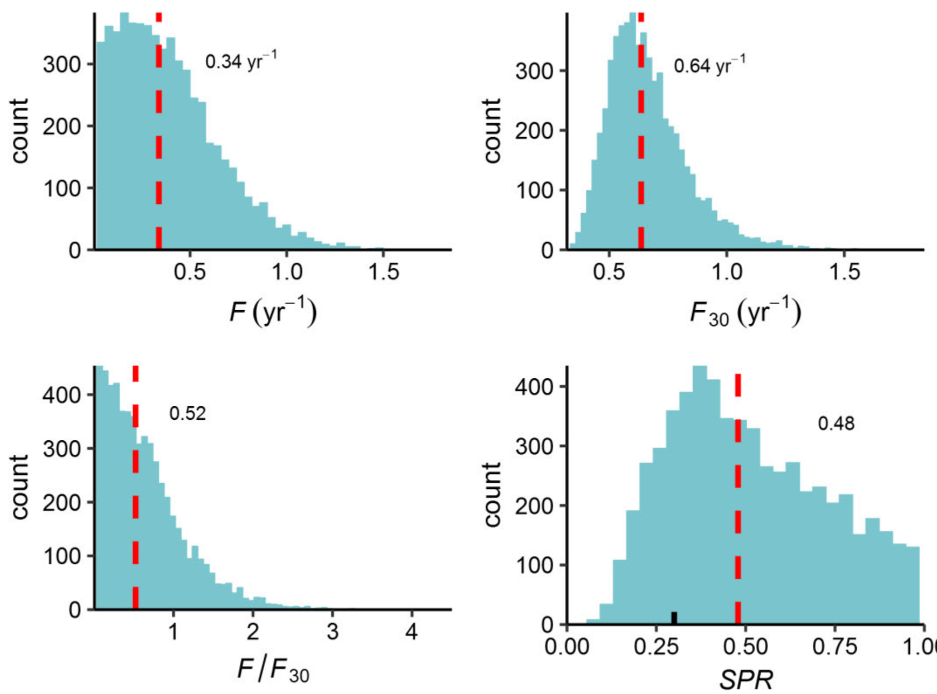


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



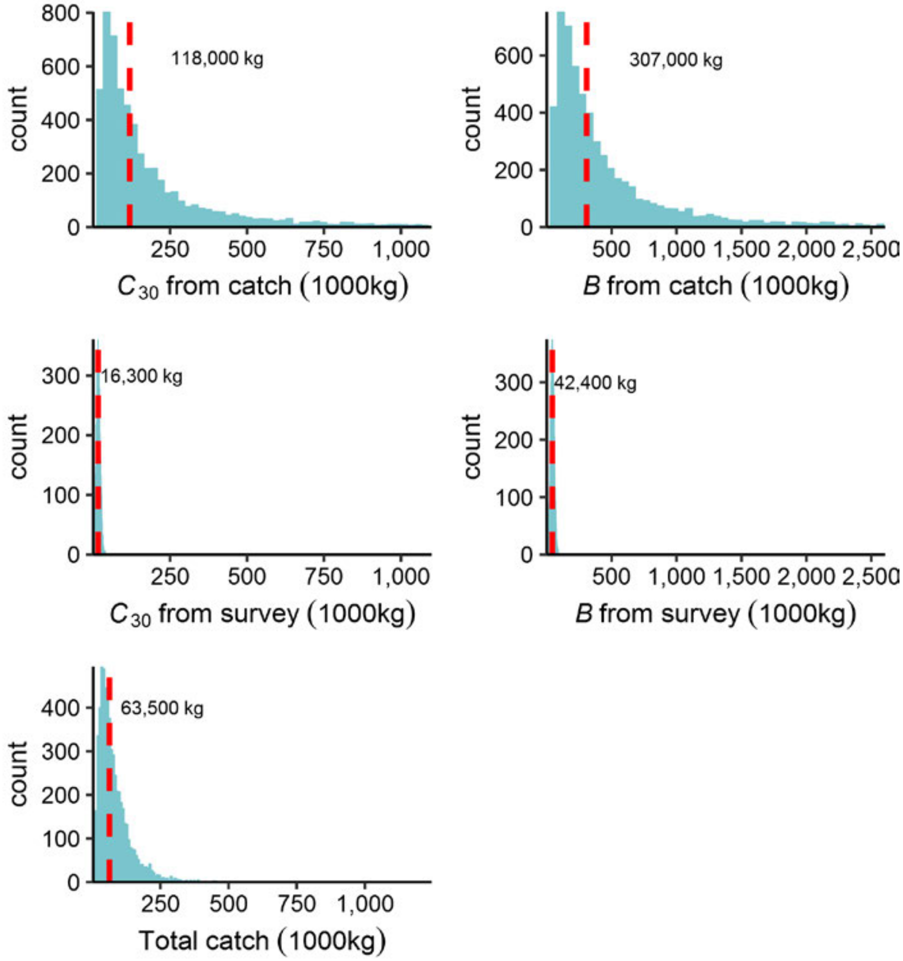
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Mulloidichthys flavolineatus



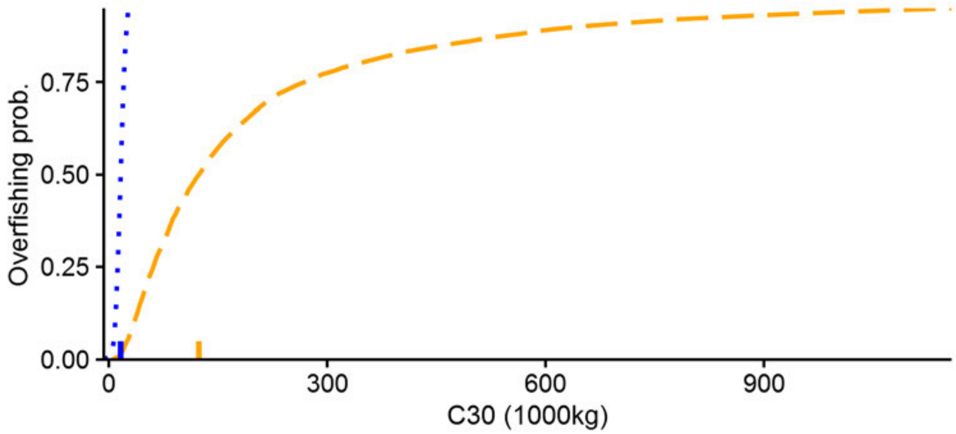
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Mulloidichthys flavolineatus



C_{30} and current total catch (left) and population size (right) distributions.

Mulloidichthys flavolineatus



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	34.9	8.8	0.31	70.5	13.2
0.11	36.6	9.1	0.32	72.3	13.4
0.12	38.2	9.3	0.33	74.3	13.6
0.13	39.6	9.6	0.34	76.2	13.8
0.14	40.9	9.9	0.35	78.5	14.0
0.15	42.4	10.1	0.36	80.7	14.2
0.16	44.3	10.3	0.37	83.1	14.3
0.17	45.8	10.5	0.38	85.2	14.5
0.18	47.3	10.7	0.39	87.6	14.7
0.19	48.9	10.9	0.40	89.7	14.8
0.20	50.3	11.2	0.41	92.3	15.0
0.21	52.0	11.4	0.42	95.0	15.1
0.22	54.0	11.6	0.43	98.4	15.3
0.23	55.5	11.8	0.44	100.6	15.4
0.24	57.4	12.0	0.45	103.8	15.6
0.25	59.7	12.2	0.46	106.9	15.7
0.26	61.4	12.4	0.47	109.8	15.9
0.27	62.7	12.6	0.48	112.6	16.0
0.28	64.8	12.8	0.49	115.2	16.1
0.29	66.6	12.9	0.50	118.3	16.3
0.30	68.2	13.1			

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	245	0.31	161
0.11	241	0.32	157
0.12	234	0.33	153
0.13	230	0.34	148
0.14	226	0.35	142
0.15	224	0.36	138
0.16	219	0.37	131
0.17	215	0.38	127
0.18	211	0.39	118
0.19	209	0.40	114
0.20	204	0.41	108
0.21	200	0.42	101
0.22	198	0.43	92
0.23	194	0.44	84
0.24	189	0.45	64
0.25	185	0.46	0
0.26	181	0.47	0
0.27	176	0.48	0
0.28	174	0.49	0
0.29	170	0.50	0
0.30	166		

Mulloidichthys pfluegeri

Pflueger’s goatfish, *weke nono*
Mullidae (goatfishes)

Life history and other input parameter

Parameter	Value	SD	Unit	n	Source
L_{inf}	557	26	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 484 (1) from DAR data
K	0.55	0.14	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	270	31	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	5.6	2.0	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	2.87e-6	-	-	-	Kulbicki (2005)
L-W β	3.29				
L_{S50}	300	-	mm	-	DAR commercial data
L_{S95}	330				
$\overline{L}$ diver survey	-	-	mm	-	-
$\overline{L}$ commercial	401	1	mm	3541	DAR commercial data
$\overline{L}$ combined	-	-	mm	-	-
Max. depth	242	-	m	-	BRFA BotCam project
Federal waters	26	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.57	0.19	yr^{-1}
F	0.53	0.37	yr^{-1}
F_{30}	0.81	0.33	yr^{-1}
F/F_{30}	0.7	0.7	-
SPR	0.41	0.23	-
SPR < 0.30 iterations	31	-	%
Lc_{30}	168	-	mm

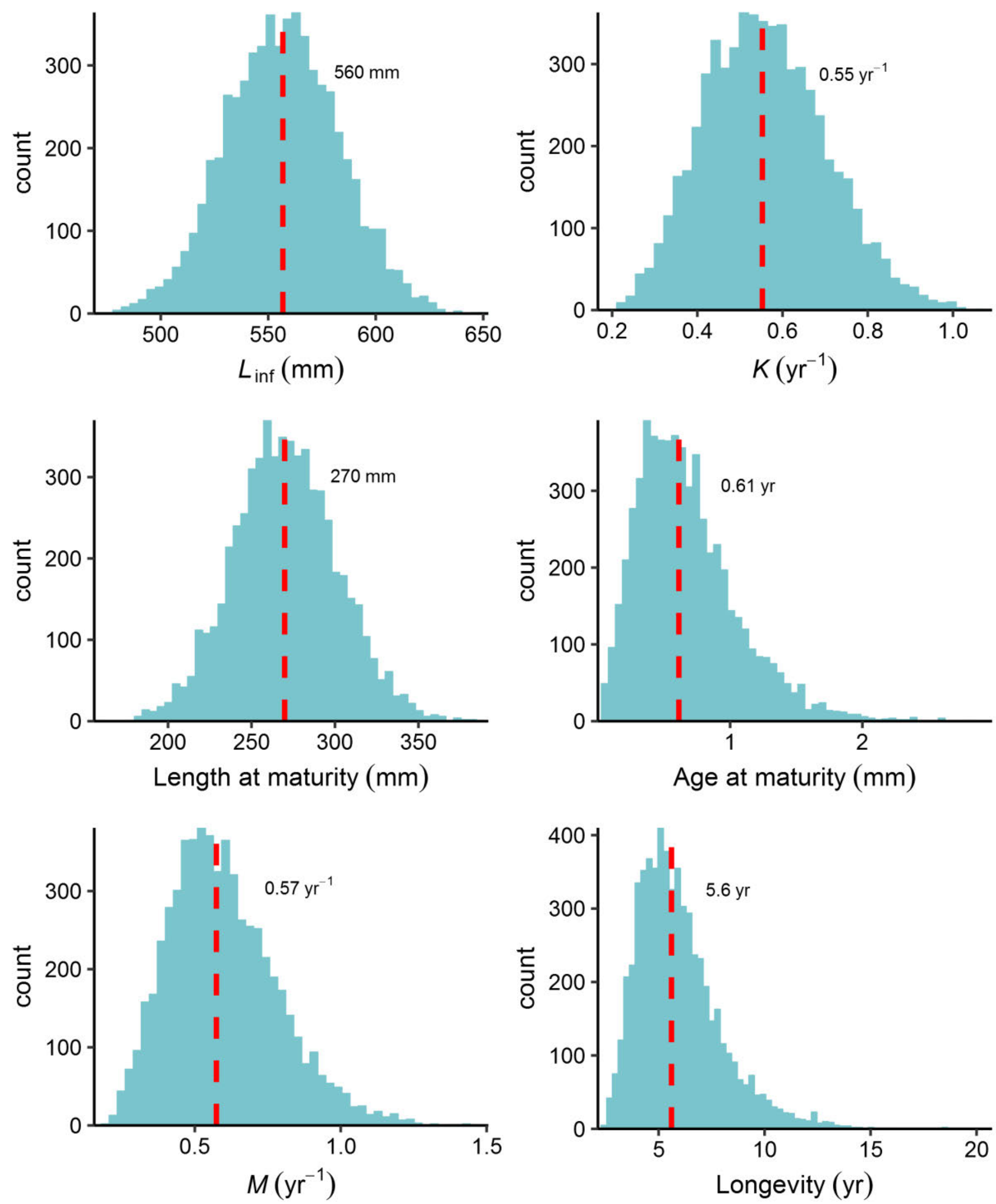
Parameter	Median	SD	Unit
B from catch	21,100	167,000	kg
B from survey	-	-	kg
Commercial catch	2,195	668	kg
Recreational catch	3,036	9,128	kg
Total catch	6,042	5,736	kg
C_{30} from catch	9,010	89,100	kg
C_{30} from survey	-	-	kg

General comments

This species mostly occurs in deep water and therefore was not encountered during the diver surveys. The recreational and commercial catch were similar and relatively constant (except for a spike in 2004 from the recreational catch, which is likely spurious). The L_{bar} from the commercial data has been constant since 2003 reflecting a population likely near equilibrium conditions.

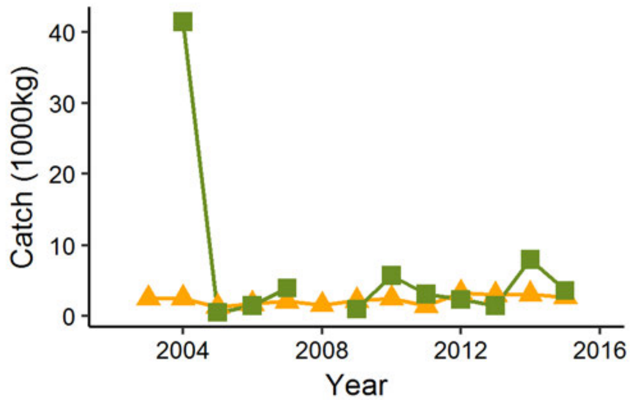
There were no published life history parameters for this species and we therefore used the stepwise approach to generate estimates from an L_{max} value of 484 mm. This L_{max} value was close to the maximum length value reported on fishbase.org (480 mm) and no specimen were reported above 500 mm in the commercial data set. A sensitivity run with an L_{max} of 520 mm generated the following estimates: L_{inf}: 520 mm, K: 0.52, M: 0.61, F_{30}: 0.82, F: 0.73, *SPR*: 0.34, C_{30} catch: 6,923 kg. These values were reasonably similar to the original results and did not change the conclusion of our analyses for this species.

Mulloidichthys pfluegeri

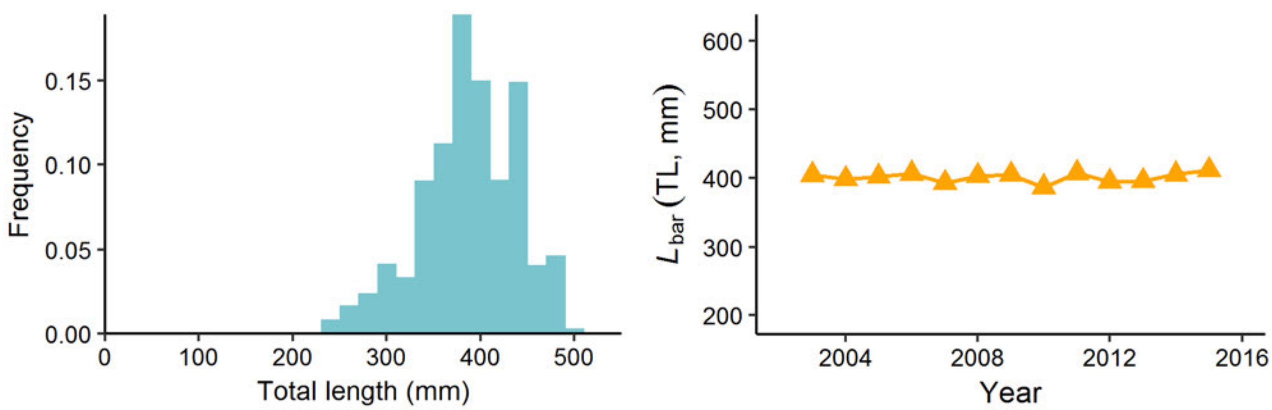


Life history parameter distributions.

Mulloidichthys pfluegeri

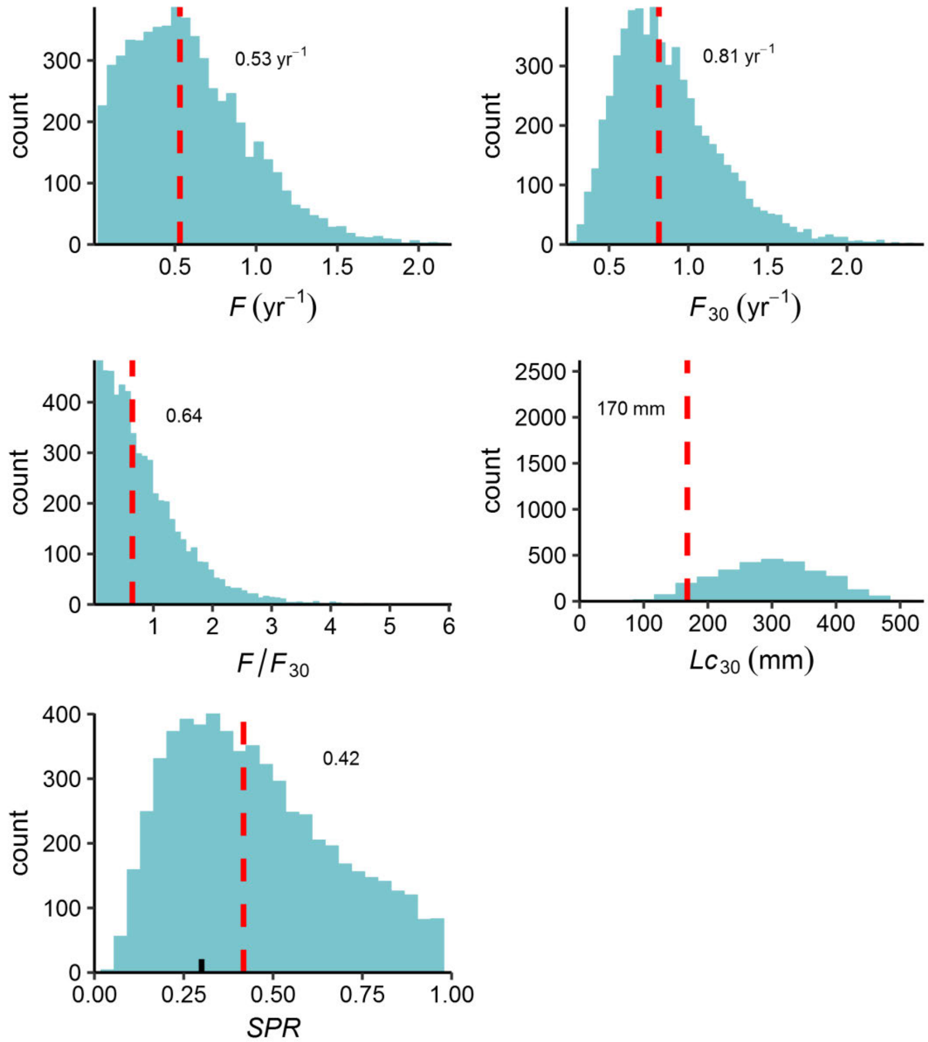


Total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



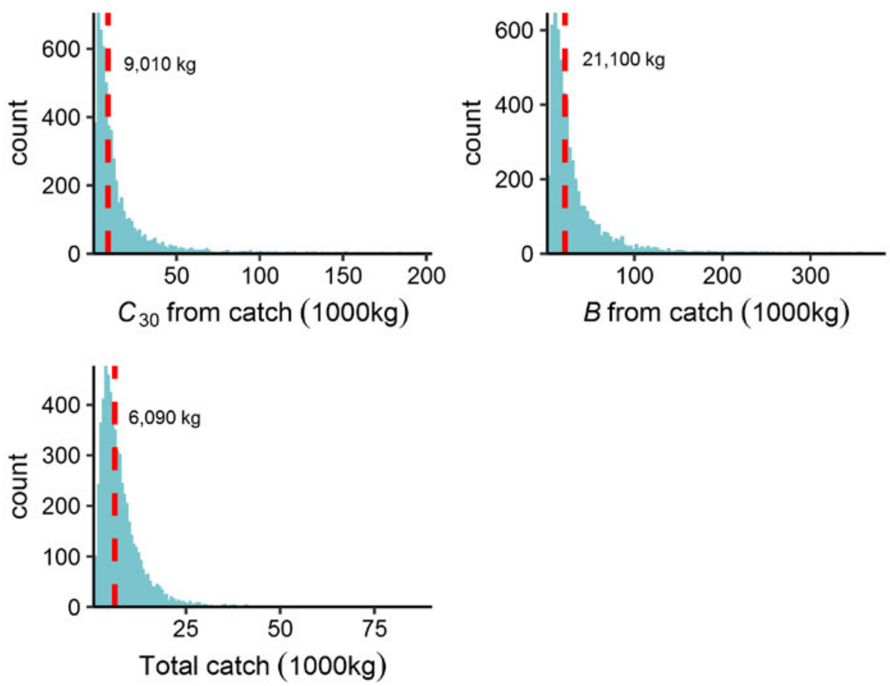
Size structure and average length time series from commercial data (±SE).

Mulloidichthys pfluegeri



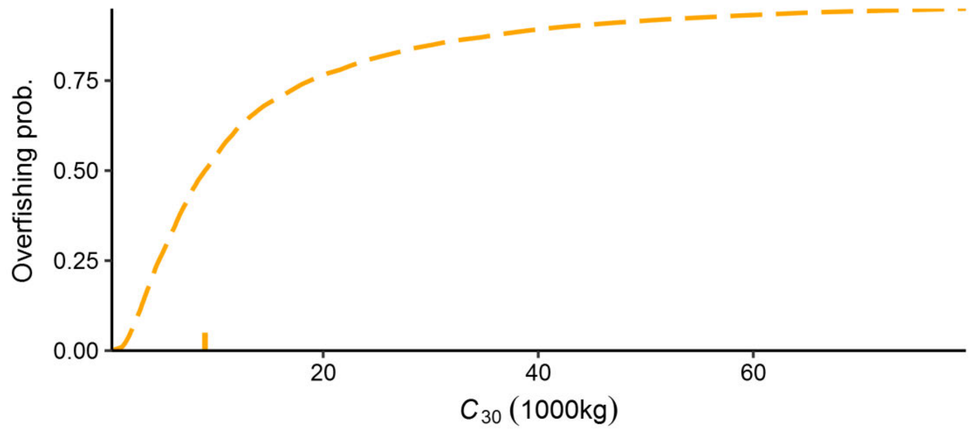
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Mulloidichthys pfluegeri



***C_{30}* and current total catch (left) and population size (right) distributions.**

Mulloidichthys pfluegeri



Overfishing probability for a range of C_{30} levels (commercial data – orange dashed line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from catch (1000 kg)	Overfishing probability	C_{30} from catch (1000 kg)
0.10	2.80	0.31	5.64
0.11	2.94	0.32	5.80
0.12	3.07	0.33	5.95
0.13	3.18	0.34	6.12
0.14	3.31	0.35	6.27
0.15	3.42	0.36	6.40
0.16	3.55	0.37	6.55
0.17	3.67	0.38	6.70
0.18	3.82	0.39	6.87
0.19	3.95	0.40	7.05
0.20	4.08	0.41	7.24
0.21	4.20	0.42	7.42
0.22	4.30	0.43	7.59
0.23	4.42	0.44	7.74
0.24	4.56	0.45	7.91
0.25	4.72	0.46	8.13
0.26	4.88	0.47	8.31
0.27	5.04	0.48	8.54
0.28	5.20	0.49	8.78
0.29	5.35	0.50	9.01
0.30	5.50		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	372	0.31	279
0.11	366	0.32	276
0.12	360	0.33	270
0.13	354	0.34	267
0.14	351	0.35	261
0.15	345	0.36	258
0.16	342	0.37	252
0.17	336	0.38	249
0.18	333	0.39	243
0.19	330	0.40	237
0.20	324	0.41	231
0.21	321	0.42	225
0.22	315	0.43	222
0.23	312	0.44	215
0.24	306	0.45	207
0.25	303	0.46	201
0.26	297	0.47	192
0.27	294	0.48	186
0.28	291	0.49	180
0.29	288	0.50	168
0.30	282		

Mulloidichthys vanicolensis

Yellowtail goatfish, *weke ‘ula*
Mullidae (goatfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	267	30	mm	50	Mean: Cole (2009), SD: Kritzer (2001)
K	1.3	0.39	yr^{-1}		
a_0	-1.1	-	yr		
L_{mat}	206	6	mm	118	Mean: Cole (2009), SD: Nadon (unpublished)
Longevity	5	1	yr	50	Mean: Cole (2009), SD: Kritzer (2001)
L-W α	1.83e-5	-	-	-	Jehangeer (2003)
L-W β	2.96				
L_{S50}	200	-	mm	-	DAR commercial data
L_{S95}	210				
$\bar{L}$ diver survey	256	8	mm	595	NOAA-CREP diver survey
$\bar{L}$ commercial	278	2	mm	2175	DAR commercial data
$\bar{L}$ combined	276	3	mm	-	-
Max. depth	132	-	m	-	BRFA BotCam project
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.61	0.12	yr^{-1}
F	0.35	0.40	yr^{-1}
F_{30}	0.83	0.22	yr^{-1}
F/F_{30}	0.4	0.5	-
SPR	0.55	0.23	-
SPR < 0.30 iterations	15	-	%
Lc_{30}	-	-	mm

Parameter	Median	SD	Unit
B from catch	139,000	897,000	kg
B from survey	34,896	17,672	kg
Commercial catch	14,267	4,772	kg
Recreational catch	9,875	38,536	kg
Total catch	28,511	22,058	kg
C_{30} from catch	61,600	402,000	kg
C_{30} from survey	15,500	7,710	kg

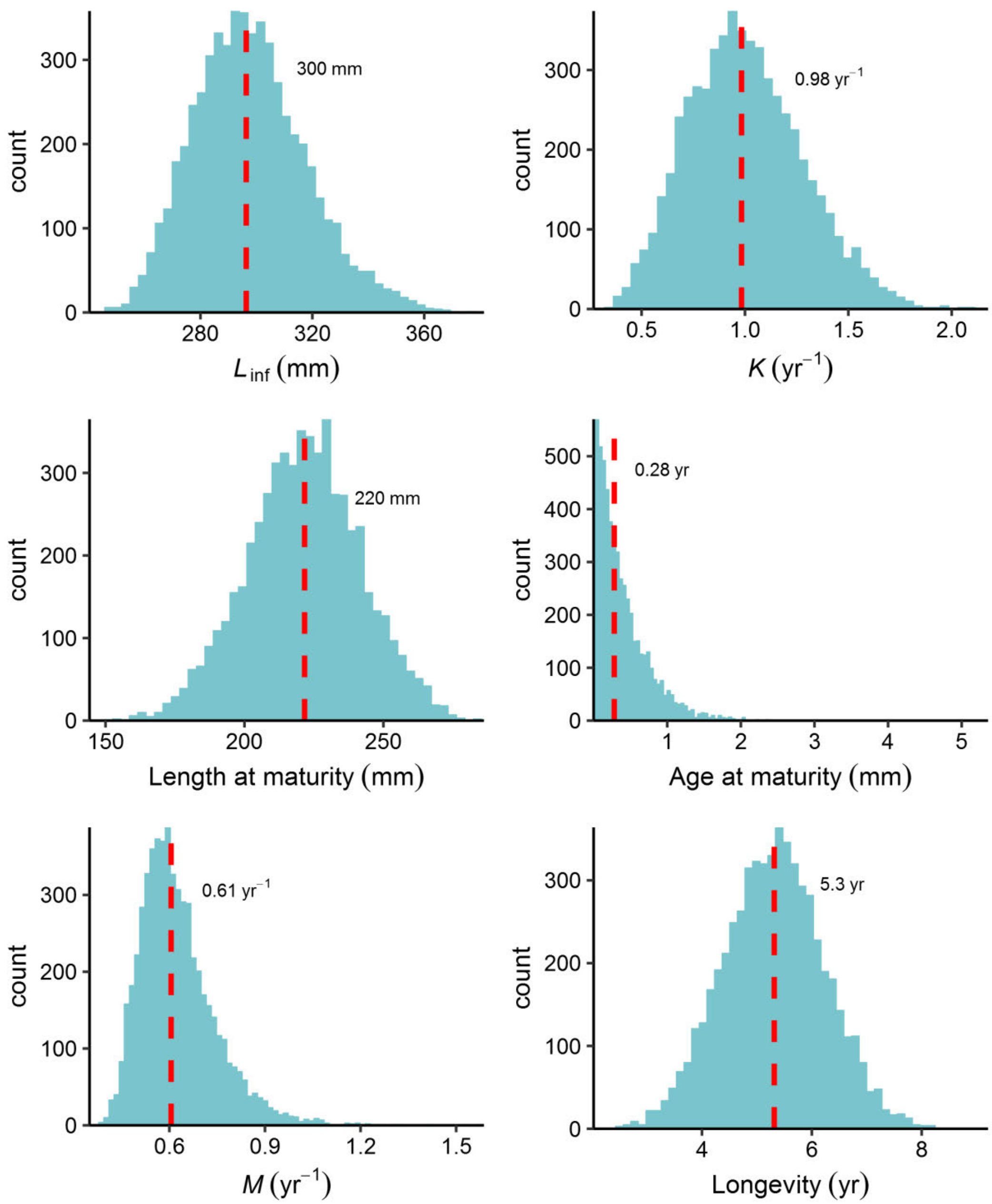
General comments

Population abundance appeared to be declining in the last year of the UVS surveys. Further surveys should clarify if this is a clear pattern or caused by an outlier data point. The catch from both sectors were similar and constant, except for an anomalous jump in the recreational catch in 2015. This jump could be due to the same juvenile goatfish reporting issue as for *M. flavolineatus* (see discussion for this species). It is unlikely to reflect a real increase in recreational catch for this species. Commercial and recreational L_{bar} appeared relatively constant for this species, suggesting a population near equilibrium. However, the commercial L_{bar} was higher than L_{inf} for this species, which is problematic given the low M/K ratio. We thus ran the analyses with the diver survey L_{bar}, given the high observation count.

The life history parameters for this species came from a local study with a limited sample size. Using the stepwise approach, we obtained the following results: L_{max}: 325 mm, L_{inf}: 377 mm, K: 0.59, M: 0.61, F_{30}: 0.80, F: 0.70, *SPR*: 0.34, C_{30} survey: 13,890 kg. Note that goatfishes usually have indeterminate growth curves, resulting in a fairly high L_{inf} value for the stepwise approach in this example.

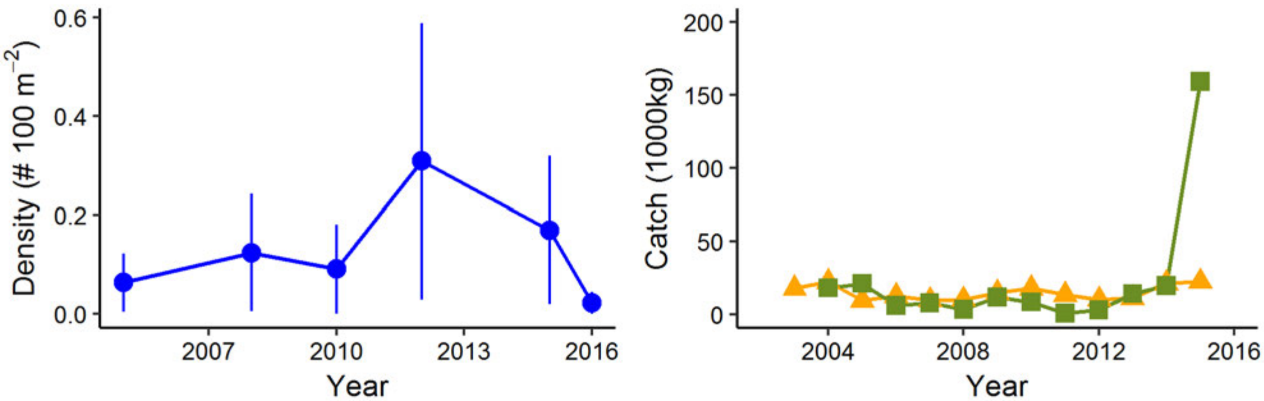
Similarly to *M. flavolineatus*, there was a discrepancy between the population sizes estimated from the catch vs. diver surveys (139,000 kg vs. 34,896 kg). This lead to significant difference in C_{30} estimates from the catch vs. diver surveys as well. The smaller population estimate could be due to the depth limit associated with diver surveys (30 m) vs. the actual depth range of this species (132 m). Note that the catch-derived population size form the sensitivity run was much smaller (80,965 kg) given the much higher F value (0.70 vs. 0.35). The C_{30} from the diver survey is likely more reliable than the catch-derived estimates.

Mulloidichthys vanicolensis

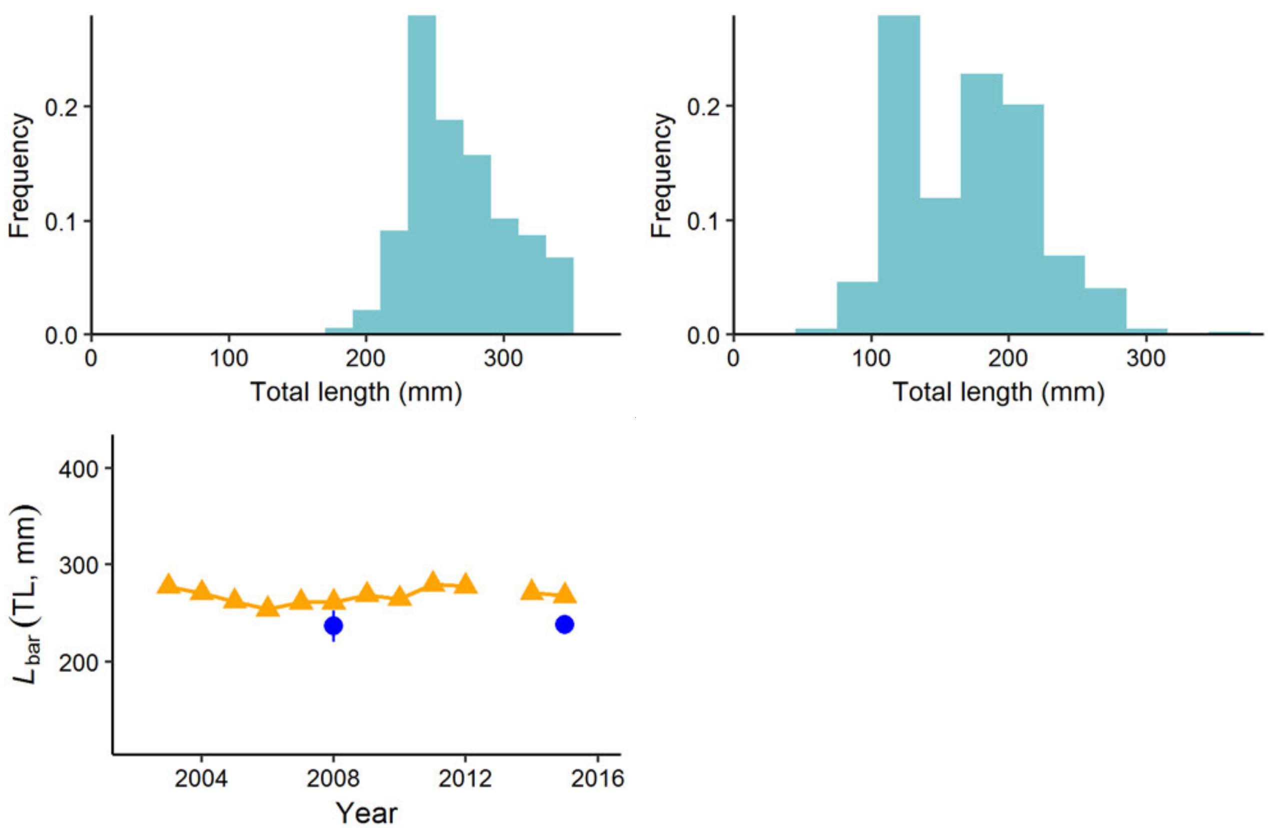


Life history parameter distributions.

Mulloidichthys vanicolensis

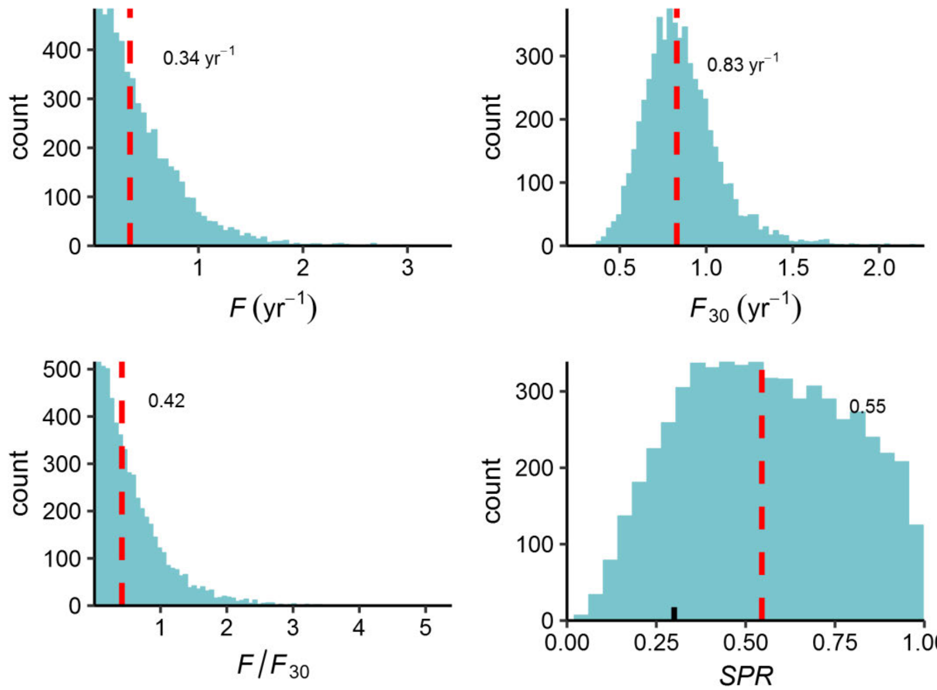


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



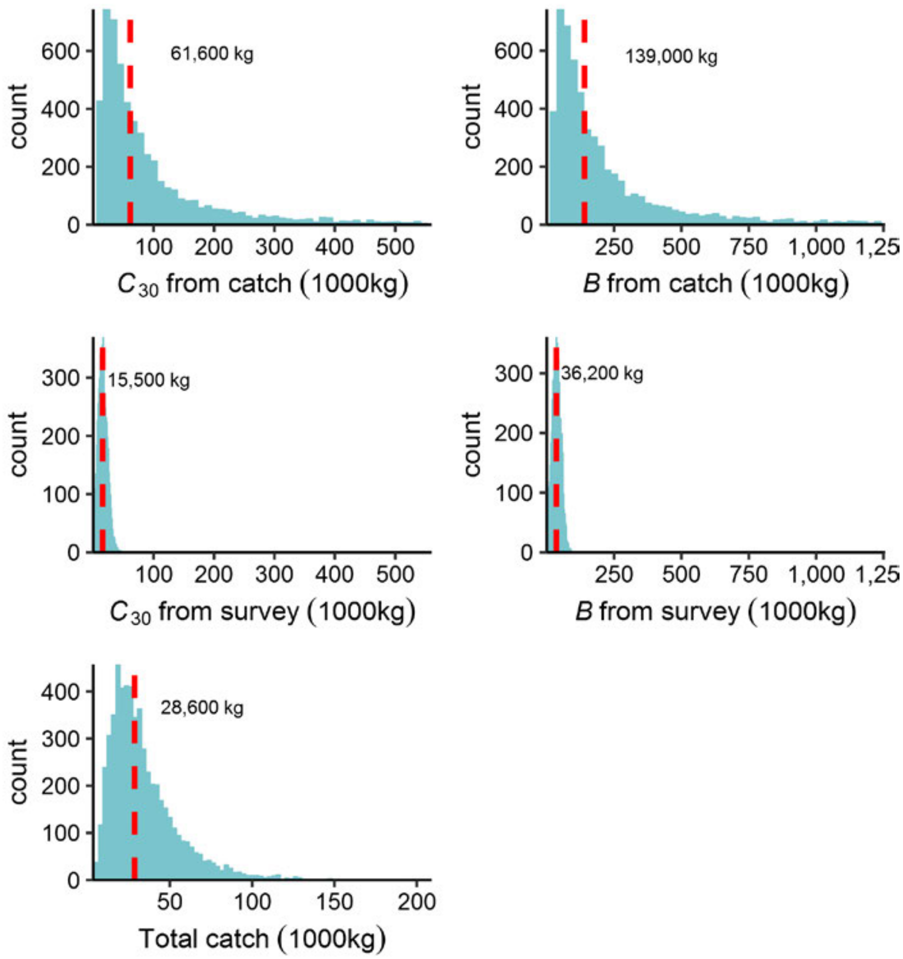
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Mulloidichthys vanicolensis



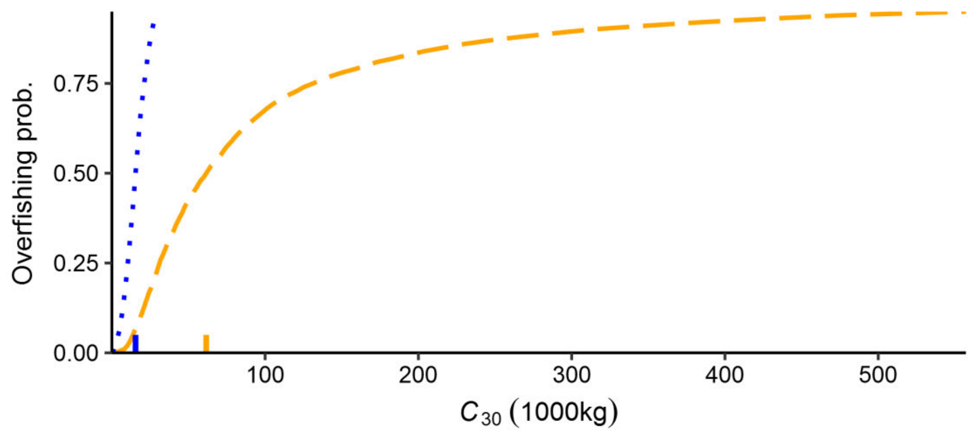
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Mulloidichthys vanicolensis



C_{30} and current total catch (left) and population size (right) distributions.

Mulloidichthys vanicolensis



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	18.7	6.4	0.31	37.0	11.7
0.11	19.6	6.7	0.32	38.2	11.9
0.12	20.4	7.0	0.33	39.2	12.1
0.13	21.3	7.3	0.34	40.3	12.3
0.14	22.0	7.6	0.35	41.3	12.5
0.15	22.9	7.9	0.36	42.3	12.8
0.16	23.6	8.2	0.37	43.5	13.0
0.17	24.4	8.4	0.38	44.7	13.2
0.18	25.5	8.7	0.39	45.9	13.4
0.19	26.4	9.0	0.40	46.9	13.6
0.20	27.2	9.2	0.41	48.0	13.8
0.21	28.1	9.5	0.42	49.5	14.0
0.22	28.9	9.7	0.43	50.8	14.1
0.23	29.6	10.0	0.44	52.3	14.3
0.24	30.3	10.2	0.45	53.7	14.5
0.25	31.2	10.4	0.46	55.3	14.7
0.26	31.8	10.6	0.47	56.5	14.9
0.27	33.1	10.9	0.48	58.1	15.1
0.28	34.0	11.1	0.49	60.1	15.2
0.29	35.0	11.3	0.50	61.6	15.5
0.30	35.9	11.5			

Parupeneus cyclostomus

Blue goatfish, *moano hulu*
Mullidae (goatfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	565	30	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 494 (10) from NWHI diver survey
K	0.512	0.146	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	269	33	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	5.4	1.9	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	8.28e-6	-	-	-	Kulbicki (2001)
L-W β	3.13				
L_{S50}	225	-	mm	-	DAR commercial data
L_{S95}	250				
$\bar{L}$ diver survey	318	4	mm	362	NOAA-CREP diver survey
$\bar{L}$ commercial	342	2	mm	3070	DAR commercial data
$\bar{L}$ combined	336	3	mm	-	-
Max. depth	113	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.60	0.18	yr^{-1}
F	0.73	0.46	yr^{-1}
F_{30}	0.59	0.17	yr^{-1}
F/F_{30}	1.3	1.0	-
SPR	0.24	0.22	-
SPR < 0.30 iterations	61	-	%
Lc_{30}	263	-	mm

Parameter	Median	SD	Unit
B from catch	12,000	66,300	kg
B from survey	77,428	30,321	kg
Commercial catch	700	257	kg
Recreational catch	3,684	1,871	kg
Total catch	4,474	1,829	kg
C_{30} from catch	4,000	25,200	kg
C_{30} from survey	25,600	11,300	kg

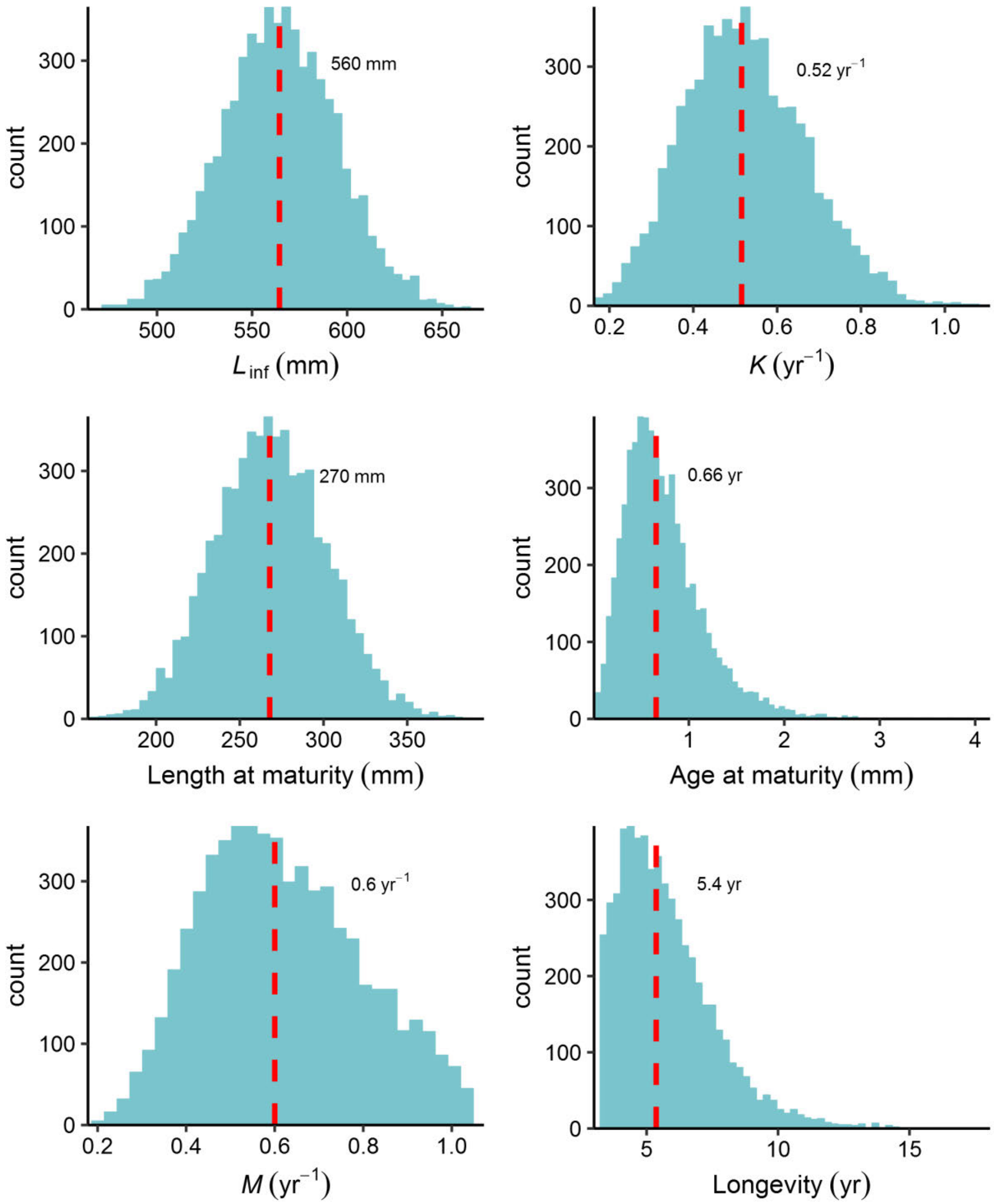
General comments

Population abundance jumped unexpectedly in 2012 with no easy explanation for this pattern. Future surveys should reveal if this is a persistent pattern or simply an anomaly. The commercial catch appeared to be rising slightly from 2003 to 2014 but fell in 2016. The recreational catch was fairly variable but also appear to be rising slightly. The commercial and recreational L_{bar} were reasonably similar and mostly stable in recent years.

There were no published life history parameters for this species and the stepwise approach was used to generate estimates. The L_{max} used for this analysis was obtained from the pristine NWHI and was likely a fairly reasonable estimate. A sensitivity run with a larger L_{max} (530 mm) generated the following estimates: L_{inf}: 608 mm, K: 0.50, M: 0.63, F_{30}: 0.57, F: 1.0, SPR: 0.16, C_{30} survey: 26,100 kg.

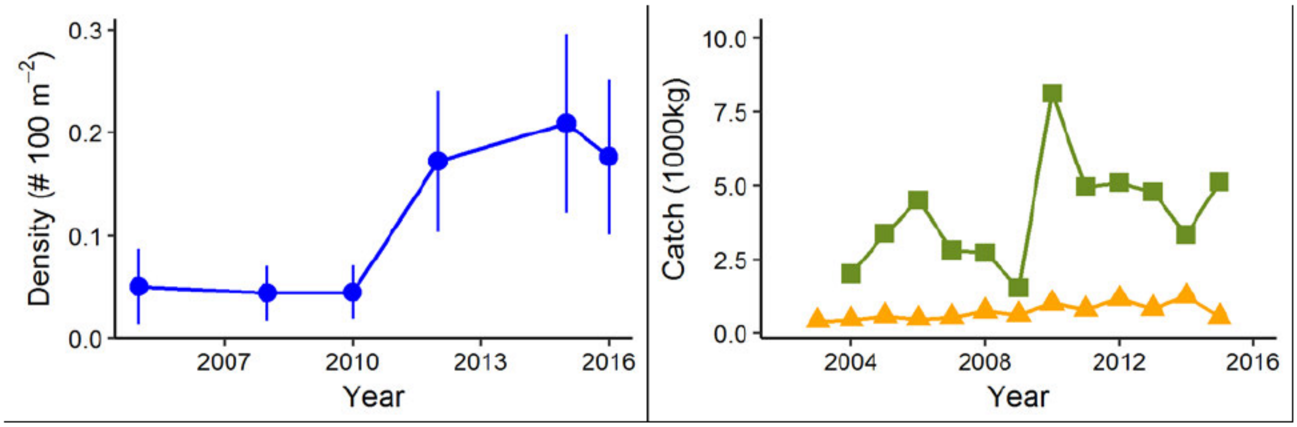
The catch data for this species seemed unusually small (4,474 kg) compared to other species with similar abundance (*M. vanicolensis*, *M. flavolineatus*). There is little reason to doubt the diver surveys, given that this is a fairly common and easily identifiable species. The diver survey C_{30} is likely more reliable than the catch-derived C_{30}.

Parupeneus cyclostomus

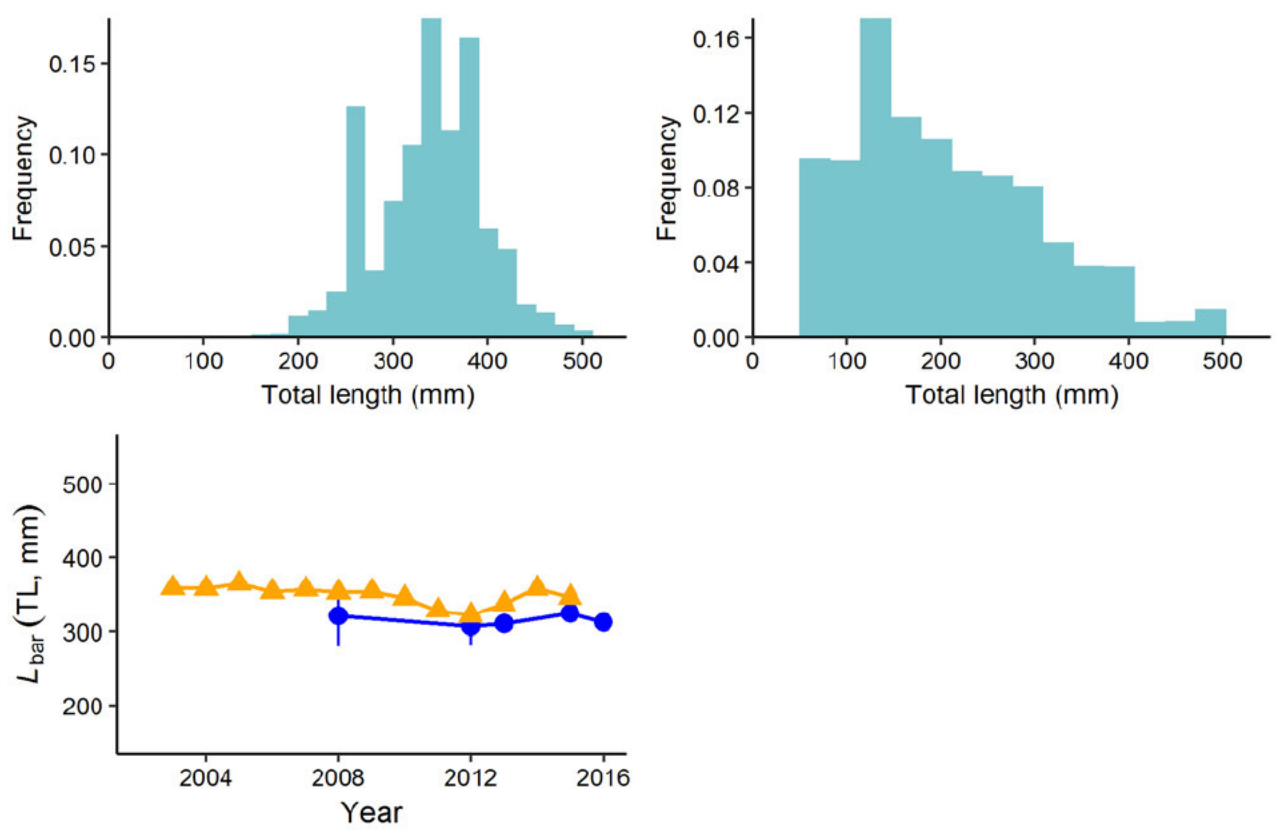


Life history parameter distributions.

Parupeneus cyclostomus

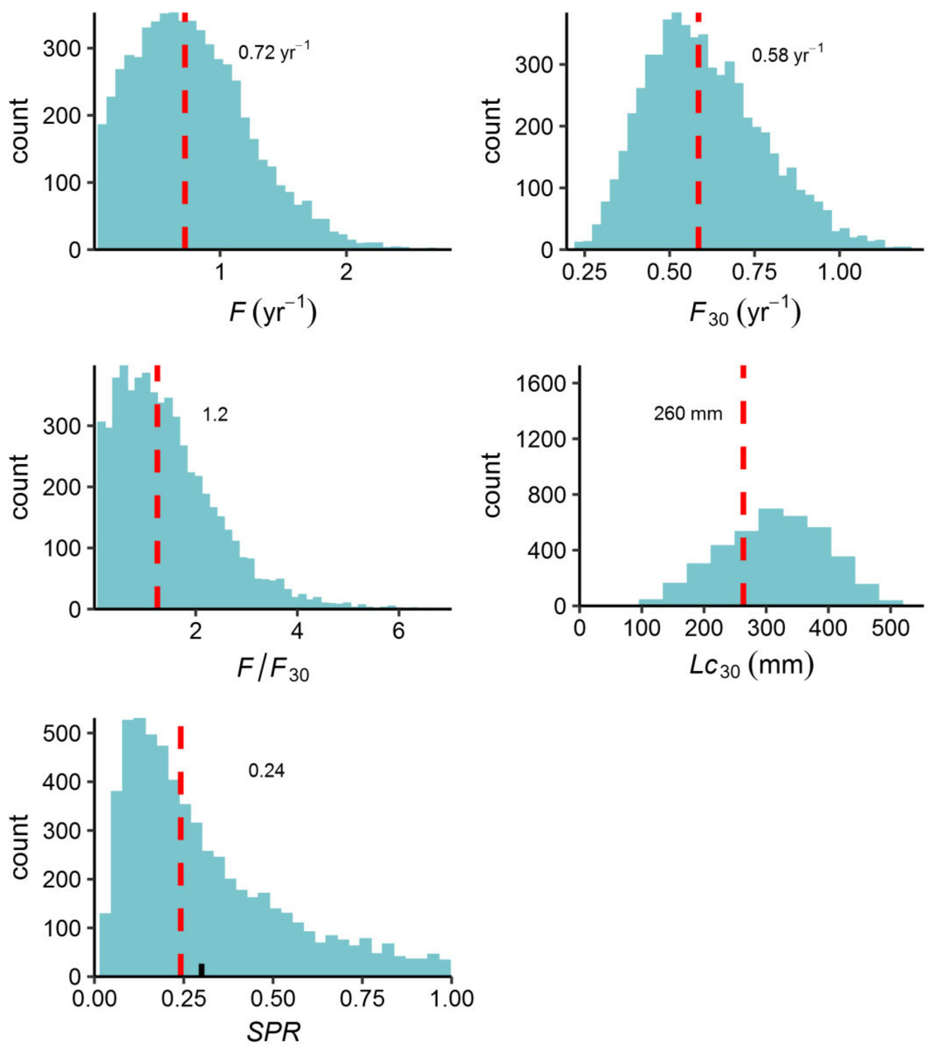


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



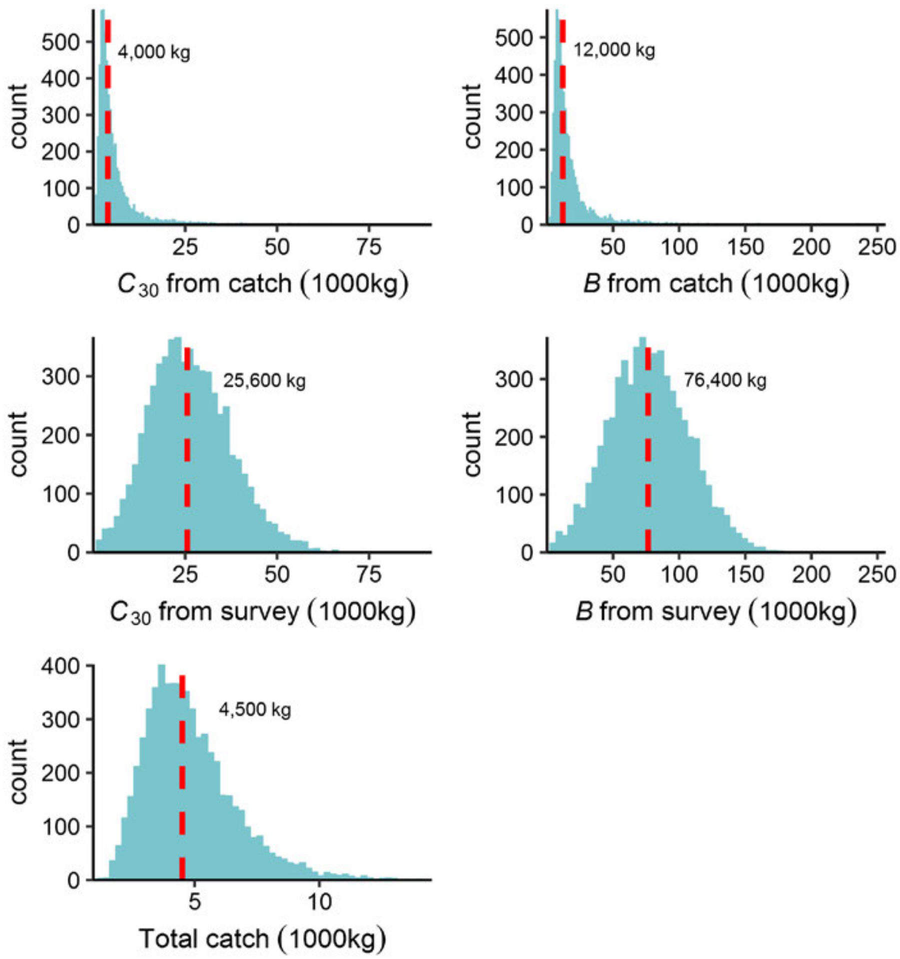
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Parupeneus cyclostomus



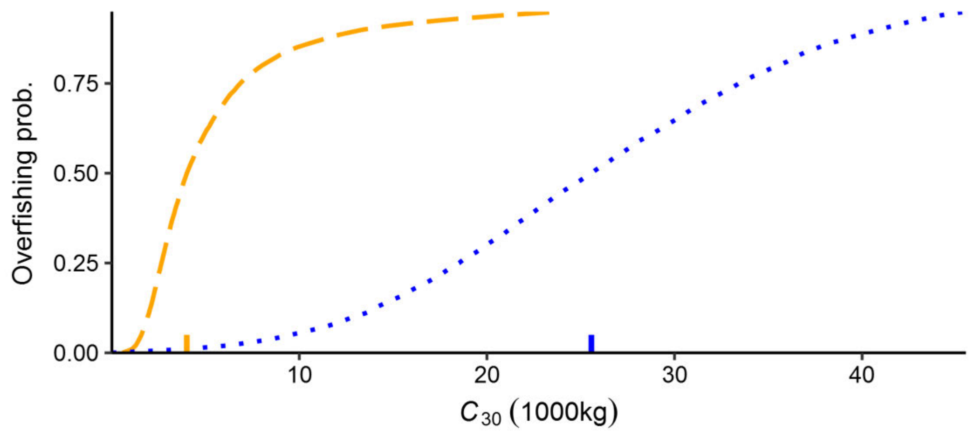
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Parupeneus cyclostomus



C_{30} and current total catch (left) and population size (right) distributions.

Parupeneus cyclostomus



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	1.92	12.3	0.31	2.93	20.3
0.11	1.99	12.9	0.32	2.99	20.6
0.12	2.03	13.4	0.33	3.03	20.9
0.13	2.09	14.0	0.34	3.08	21.2
0.14	2.14	14.4	0.35	3.13	21.5
0.15	2.19	15.0	0.36	3.17	21.8
0.16	2.24	15.3	0.37	3.22	22.0
0.17	2.28	15.8	0.38	3.28	22.3
0.18	2.33	16.1	0.39	3.34	22.6
0.19	2.37	16.5	0.40	3.39	22.8
0.20	2.41	16.9	0.41	3.45	23.1
0.21	2.46	17.3	0.42	3.52	23.4
0.22	2.51	17.6	0.43	3.57	23.7
0.23	2.56	18.0	0.44	3.63	23.9
0.24	2.61	18.2	0.45	3.69	24.2
0.25	2.65	18.5	0.46	3.76	24.5
0.26	2.70	18.8	0.47	3.81	24.7
0.27	2.75	19.1	0.48	3.87	25.0
0.28	2.79	19.4	0.49	3.94	25.3
0.29	2.84	19.7	0.50	4.00	25.6
0.30	2.89	20.1			

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	403	0.31	326
0.11	398	0.32	324
0.12	394	0.33	322
0.13	389	0.34	317
0.14	385	0.35	315
0.15	382	0.36	310
0.16	378	0.37	308
0.17	376	0.38	306
0.18	371	0.39	304
0.19	367	0.40	299
0.20	364	0.41	297
0.21	360	0.42	295
0.22	358	0.43	290
0.23	353	0.44	286
0.24	351	0.45	281
0.25	349	0.46	279
0.26	344	0.47	274
0.27	340	0.48	270
0.28	338	0.49	266
0.29	333	0.50	263
0.30	331		

Parupeneus insularis

Island goatfish, *munu*
Mullidae (goatfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	376	17	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 324 (4) from NWHI diver survey
K	0.60	0.14	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	203	25	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	6.4	2.2	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	9.15e-6	-	-	-	
L-W β	3.13				
L_{S50}	220	-	mm	-	DAR commercial data
L_{S95}	240				
$\overline{L}$ diver survey	278	3	mm	179	NOAA-CREP diver survey
$\overline{L}$ commercial	305	2	mm	1598	DAR commercial data
$\overline{L}$ combined	296	2	mm	-	-
Max. depth	90	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.50	0.16	yr^{-1}
F	0.28	0.24	yr^{-1}
F_{30}	0.72	0.25	yr^{-1}
F/F_{30}	0.4	0.4	-
SPR	0.57	0.22	-
SPR < 0.30 iterations	12	-	%
Lc_{30}	0	-	mm

Parameter	Median	SD	Unit
B from catch	4,740	37,500	kg
B from survey	41,983	7,557	kg
Commercial catch	176	153	kg
Recreational catch	496	1,358	kg
Total catch	776	1,011	kg
C_{30} from catch	1,960	16,900	kg
C_{30} from survey	17,100	4,300	kg

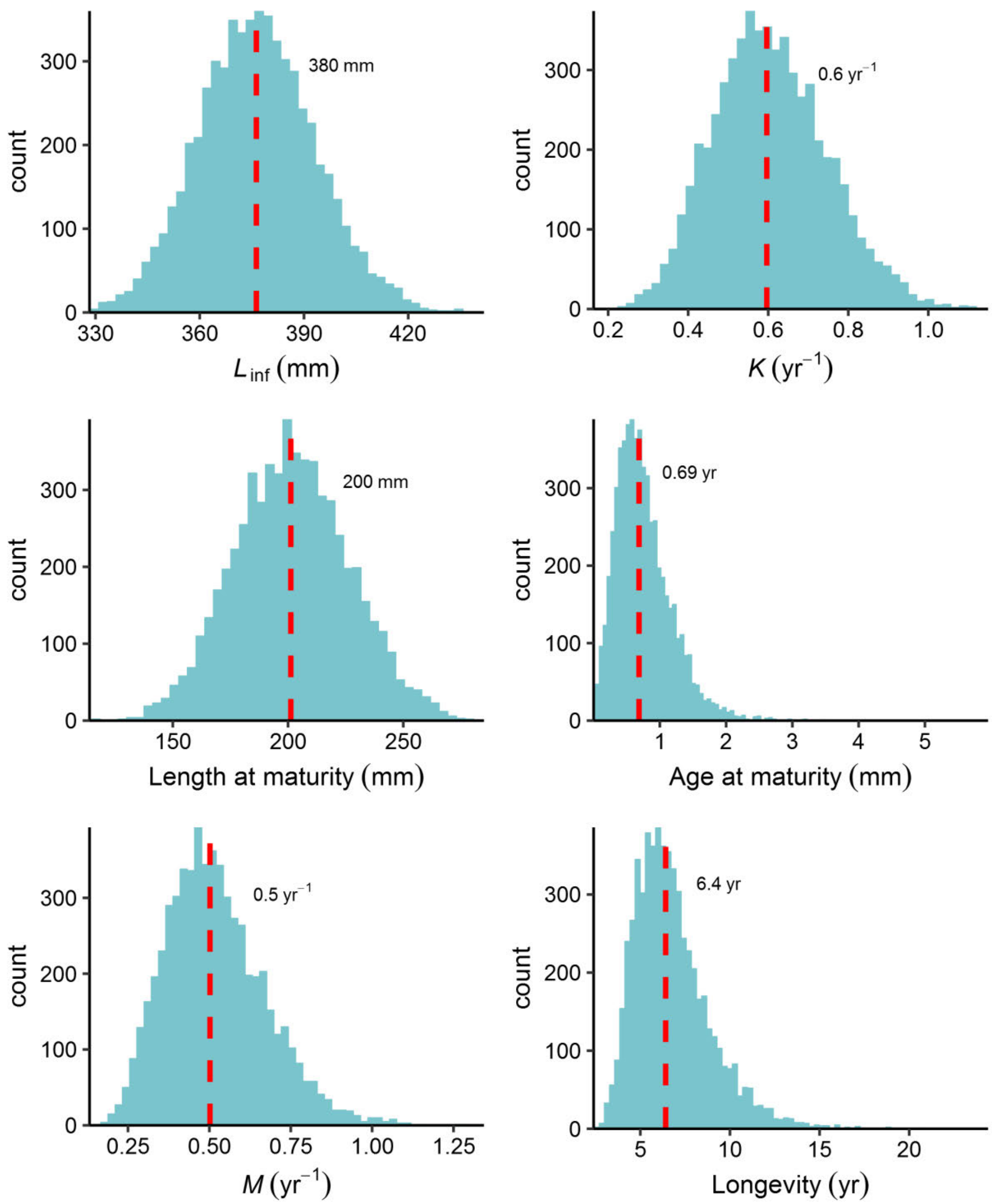
General comments

Population abundance was stable from 2005 to 2016. The commercial catch increased in the early year before going down from 2013 to 2016. The recreational catch was elevated in the early years and lower in recent years, although it is not clear if this is a real pattern given the variability associated with this data set. L_{bar} from both data set appeared to be declining slightly.

There are no published life history parameters for this species and the stepwise approach was used to generate estimates using an L_{max} from NWHI surveys. A sensitivity run with a L_{max} of 360 mm generated the following results: L_{inf}: 412 mm, K: 0.56, M: 0.57, F_{30}: 0.73, F: 0.48, *SPR*: 0.42, C_{30} survey: 16,783 kg.

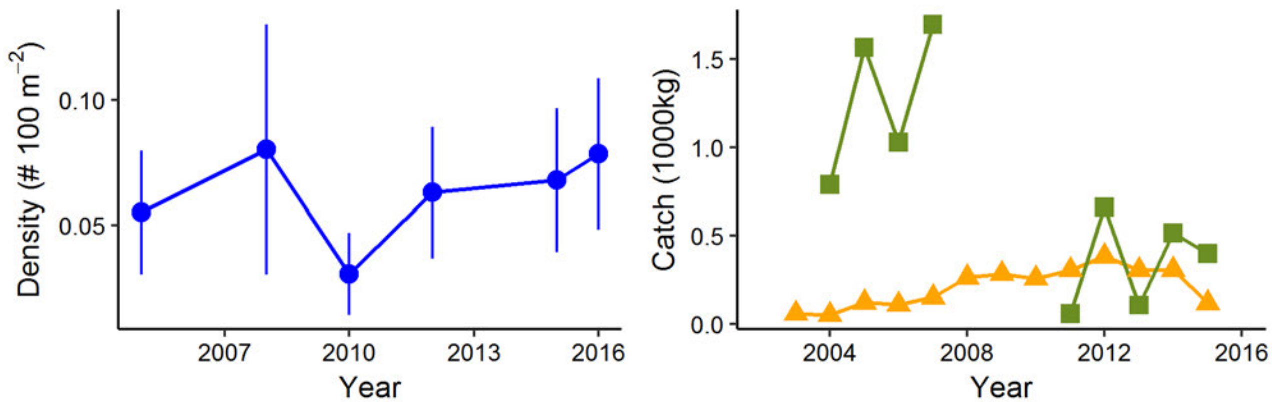
Similarly to *P. cyclostomus*, The catch data for this species seemed unusually small (776 kg) compared to other species with similar abundance (*M. vanicolensis*, *M. flavolineatus*). There is no clear explanation for this observation. However, the diver survey data is likely more reliable to estimate population size and *OFLs*.

Parupeneus insularis

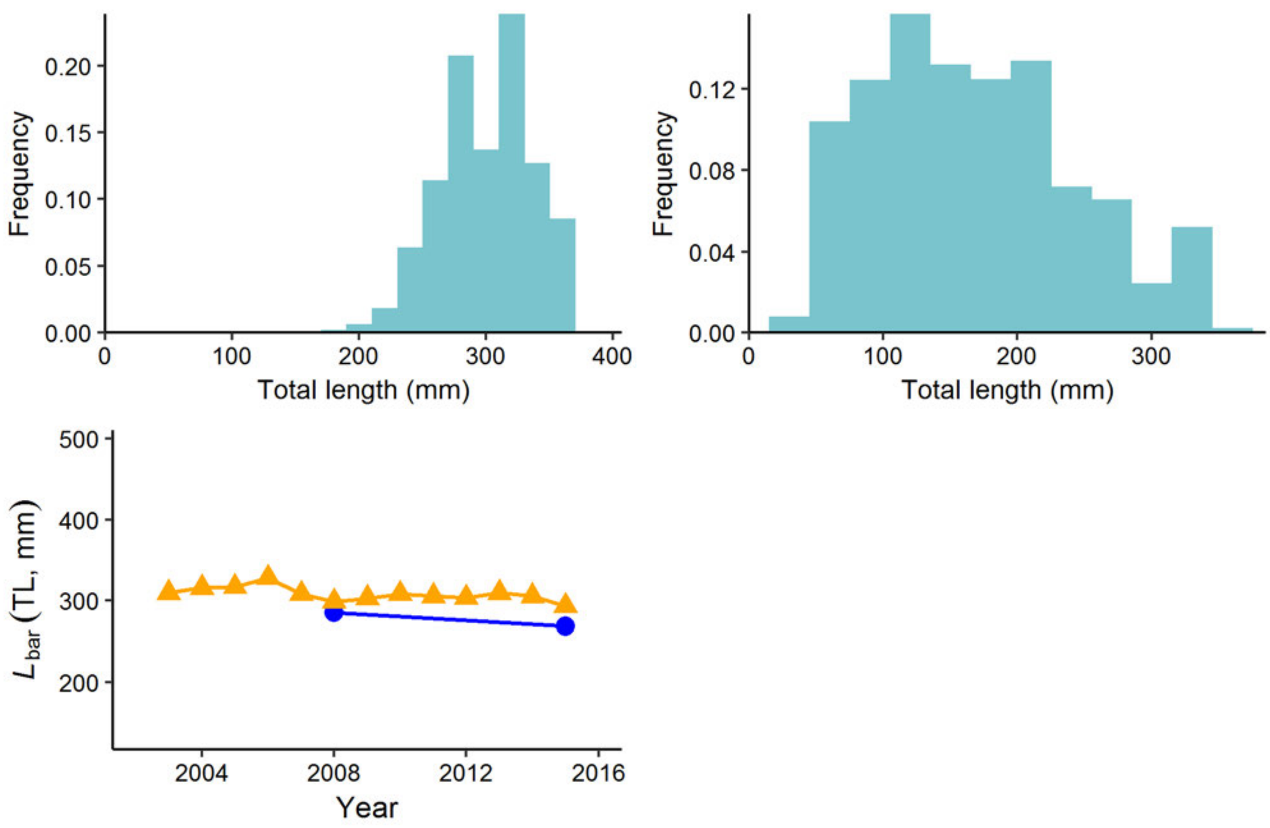


Life history parameter distributions.

Parupeneus insularis

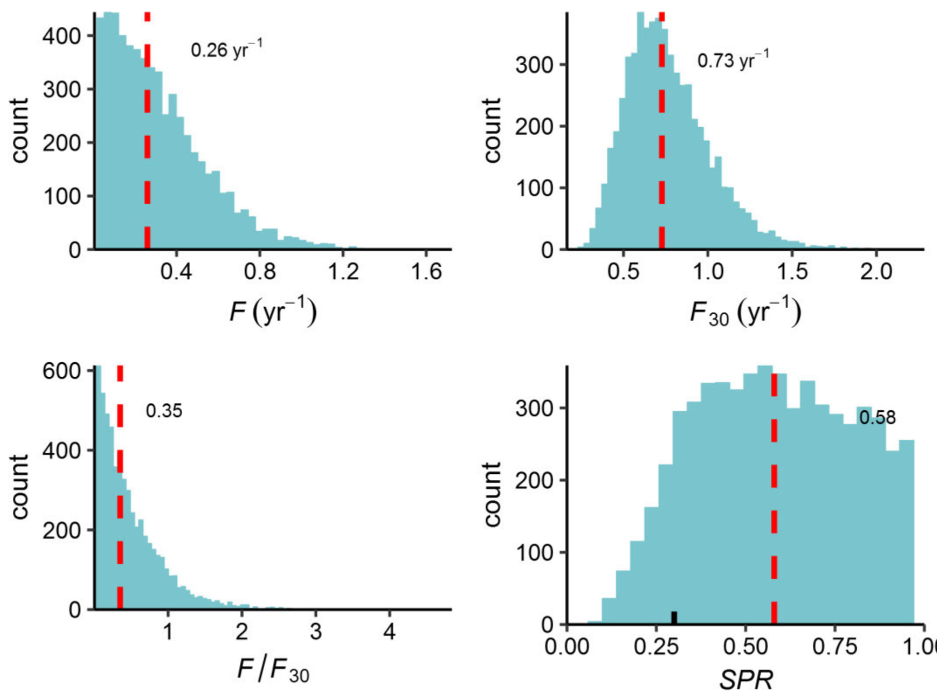


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



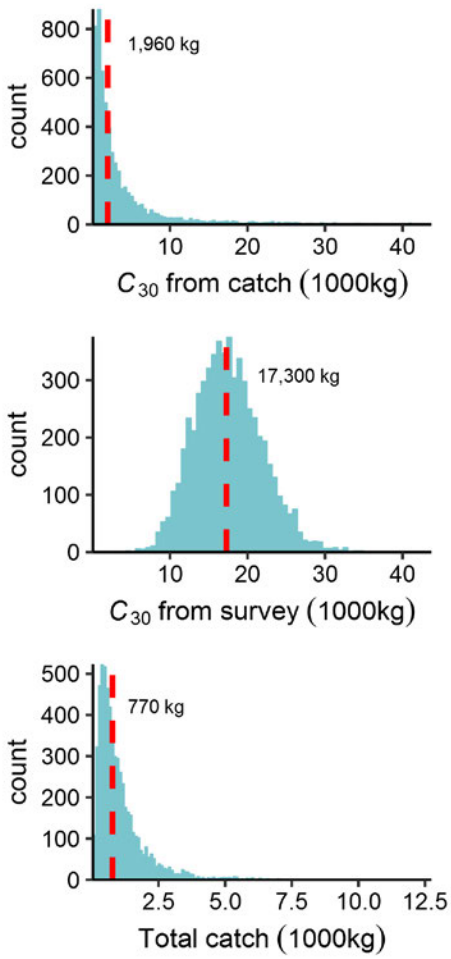
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Parupeneus insularis



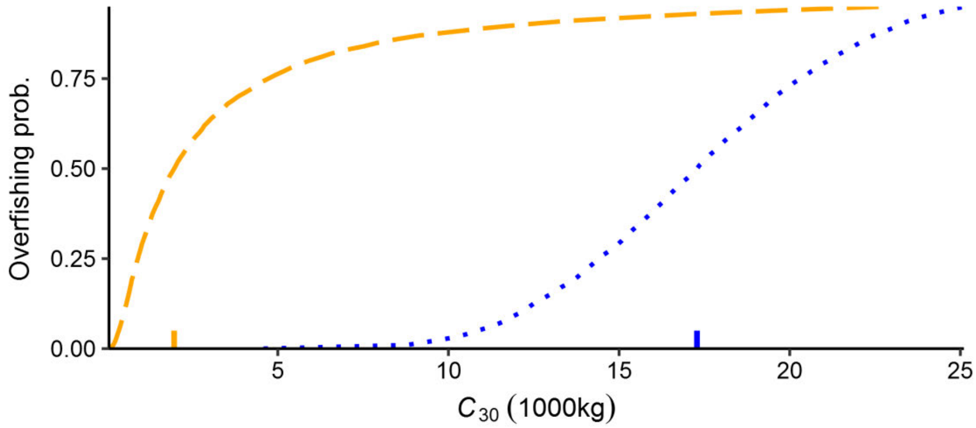
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Parupeneus insularis



C_{30} and current total catch (left) and population size (right) distributions.

Parupeneus insularis



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	0.49	12.1	0.31	1.09	15.1
0.11	0.52	12.3	0.32	1.13	15.1
0.12	0.55	12.5	0.33	1.17	15.2
0.13	0.58	12.6	0.34	1.20	15.4
0.14	0.60	12.8	0.35	1.24	15.5
0.15	0.63	13.0	0.36	1.28	15.6
0.16	0.65	13.1	0.37	1.31	15.7
0.17	0.67	13.3	0.38	1.35	15.8
0.18	0.70	13.4	0.39	1.40	15.9
0.19	0.72	13.6	0.40	1.45	16.1
0.20	0.75	13.7	0.41	1.50	16.2
0.21	0.78	13.8	0.42	1.55	16.3
0.22	0.82	14.0	0.43	1.58	16.4
0.23	0.84	14.1	0.44	1.63	16.5
0.24	0.87	14.2	0.45	1.69	16.6
0.25	0.90	14.3	0.46	1.74	16.7
0.26	0.93	14.4	0.47	1.79	16.8
0.27	0.96	14.5	0.48	1.83	16.9
0.28	0.99	14.7	0.49	1.90	17.0
0.29	1.02	14.8	0.50	1.96	17.1
0.30	1.06	14.9			

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	216	0.31	0
0.11	209	0.32	0
0.12	205	0.33	0
0.13	200	0.34	0
0.14	196	0.35	0
0.15	189	0.36	0
0.16	183	0.37	0
0.17	178	0.38	0
0.18	172	0.39	0
0.19	165	0.40	0
0.20	158	0.41	0
0.21	152	0.42	0
0.22	145	0.43	0
0.23	136	0.44	0
0.24	128	0.45	0
0.25	117	0.46	0
0.26	91	0.47	0
0.27	0	0.48	0
0.28	0	0.49	0
0.29	0	0.50	0
0.30	0		

Parupeneus porphyreus

White-saddle goatfish, *kumu*
Mullidae (goatfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	547	76	mm	36	Mean: Moffitt (1979), SD: Kritzer (2001)
K	0.538	0.231	yr^{-1}		
a_0	-0.446	-	yr		
L_{mat}	264	13	mm	36	Mean: Moffitt (1979), SD: Nadon (unpublished)
Longevity	6	1.1	yr	36	Mean: Moffitt (1979), SD: Kritzer (2001)
L-W α	6.99e-6	-	-	-	Kulbicki (2005) - *P. multifasciatus*
L-W β	3.211				
L_{S50}	225	-	mm	-	DAR commercial data
L_{S95}	250				
$\overline{L}$ diver survey	299	8	mm	179	NOAA-CREP diver survey
$\overline{L}$ commercial	323	1	mm	5074	DAR commercial data
$\overline{L}$ combined	323	2	mm	-	-
Max. depth	140	-	m	-	Pyle et al. (2016)
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.53	0.11	yr^{-1}
F	1.00	0.58	yr^{-1}
F_{30}	0.54	0.11	yr^{-1}
F/F_{30}	1.9	1.1	-
SPR	0.15	0.17	-
SPR < 0.30 iterations	80	-	%
Lc_{30}	317	-	mm

Parameter	Median	SD	Unit
B from catch	14,600	73,000	kg
B from survey	13,810	4,225	kg
Commercial catch	1,717	1,507	kg
Recreational catch	5,045	2,266	kg
Total catch	7,130	2,704	kg
C_{30} from catch	4,860	25,000	kg
C_{30} from survey	4,580	1,480	kg

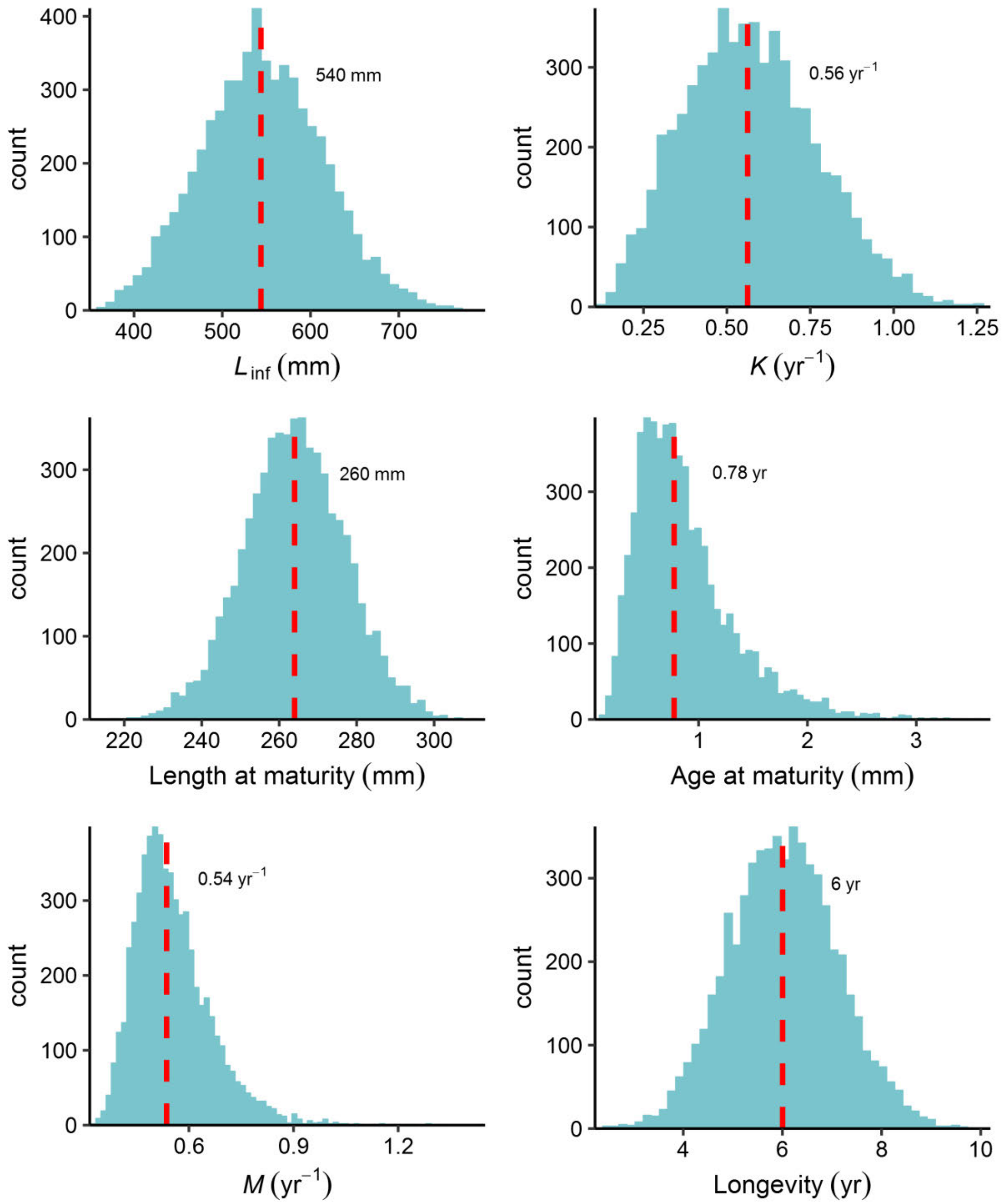
General comments

Population abundance was highly variable due to the number of observations in individual years for this species being low. The commercial catch increased from 2008 to 2011 but has been going down since then. The recreational catch also appeared to be declining. The commercial L_{bar} has been steady (there were not enough observations per year to generate a L_{bar} time series from UVS).

The life history parameters for this species came from a local study with a limited sample size. The stepwise approach applied to this species generated the following estimates: L_{max}: 435 mm, L_{inf}: 496 mm, K: 0.54, M: 0.59, F_{30}: 0.63, F: 0.60, *SPR*: 0.32, C_{30} survey: 5,157 kg, C_{30} catch: 7,931 kg. The lower L_{inf} estimate lead to a lower F and higher *SPR*.

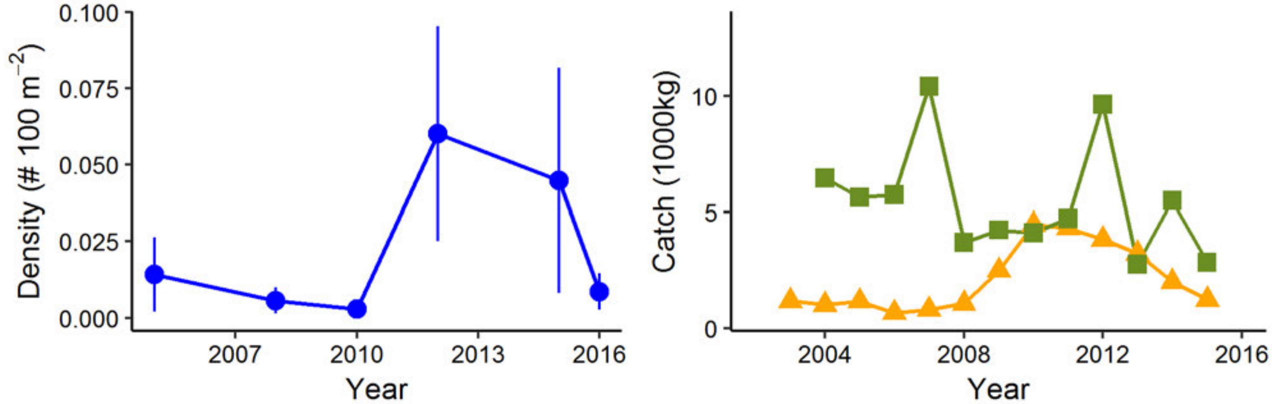
There was a good agreement between catch-derived and survey-derived population and C_{30} estimates. The survey-derived C_{30} had lower variability and is usually more reliable than catch-derived C_{30}.

Parupeneus porphyreus

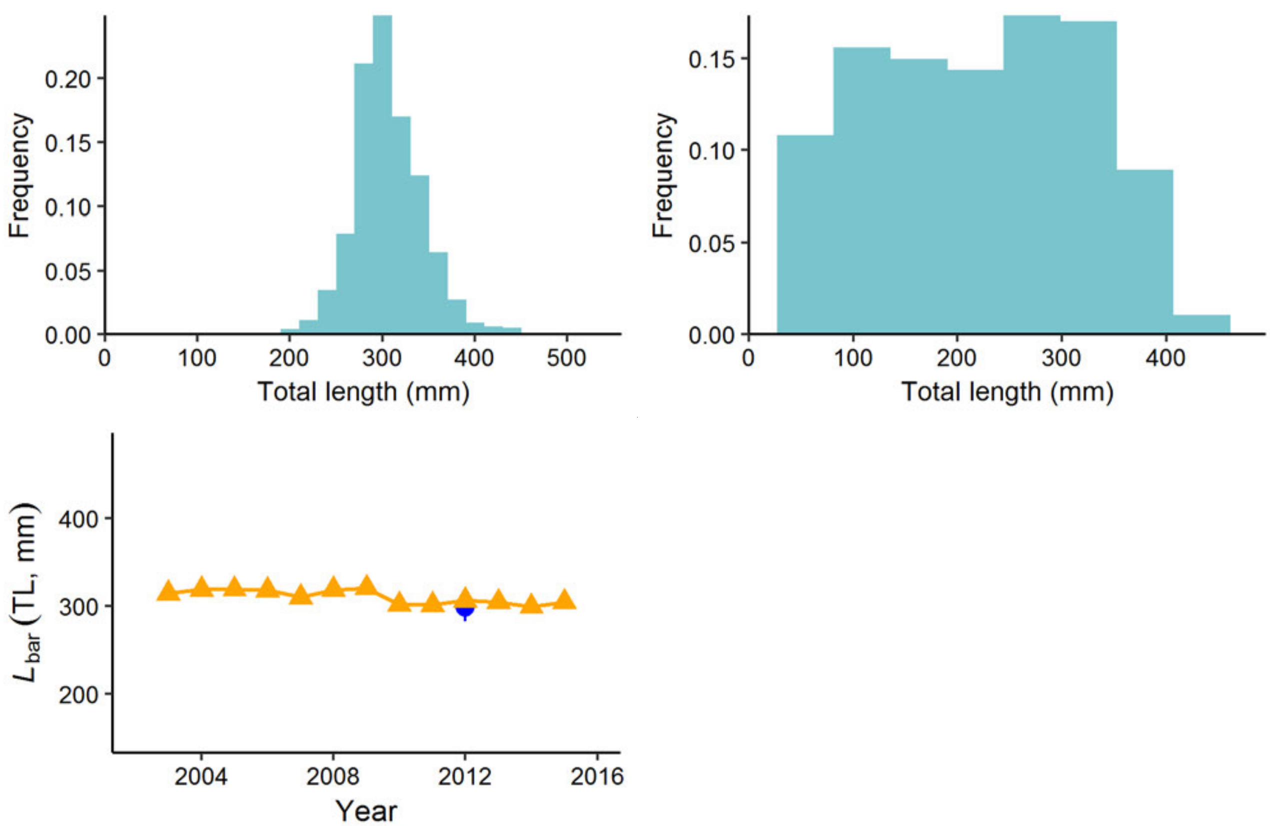


Life history parameter distributions.

Parupeneus porphyreus

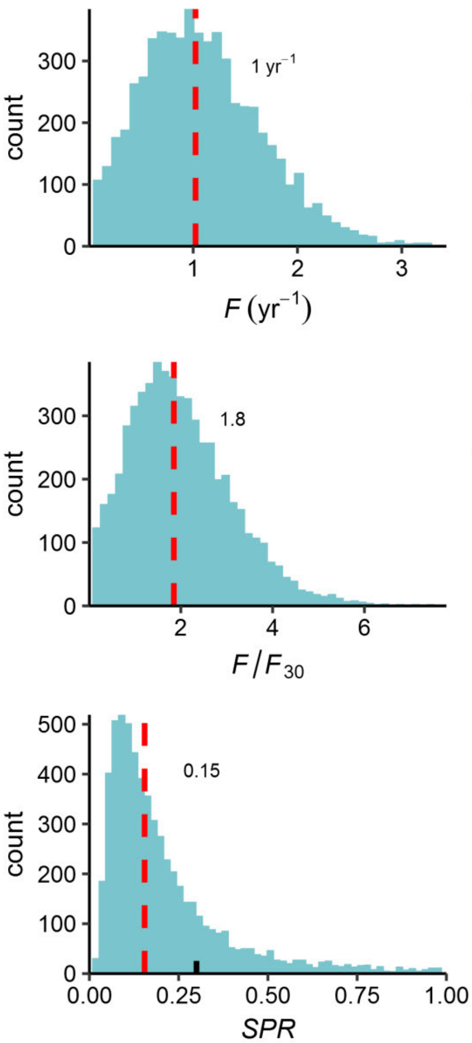


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



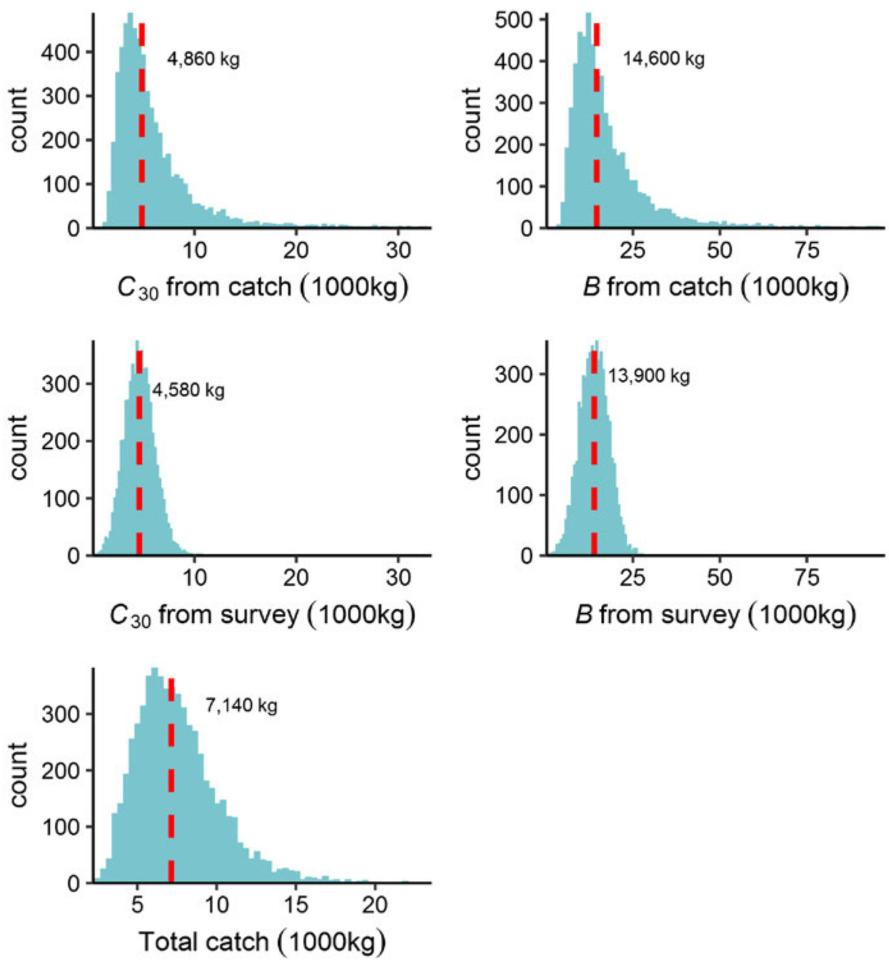
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Parupeneus porphyreus



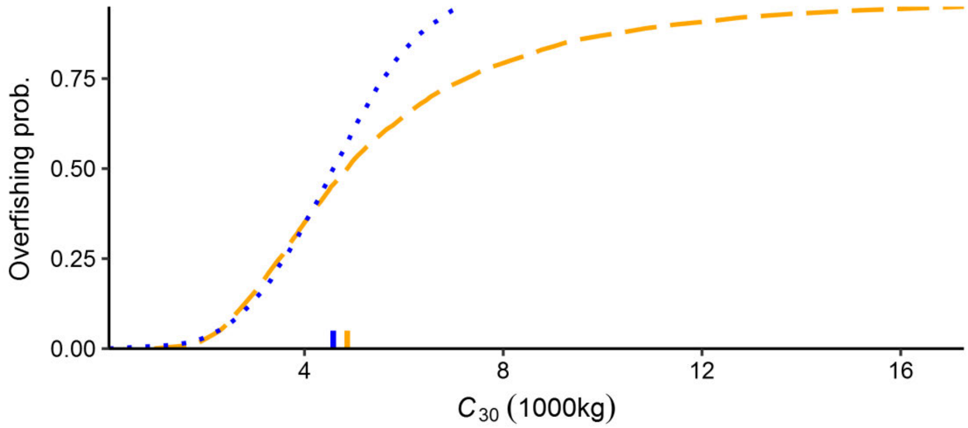
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Parupeneus porphyreus



C_{30} and current total catch (left) and population size (right) distributions.

Parupeneus porphyreus



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	2.64	2.73	0.31	3.80	3.84
0.11	2.70	2.80	0.32	3.86	3.88
0.12	2.77	2.86	0.33	3.90	3.92
0.13	2.83	2.93	0.34	3.95	3.96
0.14	2.89	3.00	0.35	4.00	4.00
0.15	2.95	3.05	0.36	4.06	4.05
0.16	3.01	3.11	0.37	4.10	4.09
0.17	3.07	3.17	0.38	4.16	4.14
0.18	3.12	3.23	0.39	4.22	4.18
0.19	3.18	3.30	0.40	4.27	4.22
0.20	3.23	3.34	0.41	4.33	4.25
0.21	3.28	3.39	0.42	4.39	4.28
0.22	3.33	3.44	0.43	4.44	4.32
0.23	3.39	3.49	0.44	4.49	4.36
0.24	3.44	3.54	0.45	4.54	4.39
0.25	3.50	3.59	0.46	4.61	4.42
0.26	3.56	3.64	0.47	4.67	4.47
0.27	3.60	3.68	0.48	4.73	4.50
0.28	3.66	3.72	0.49	4.80	4.54
0.29	3.70	3.77	0.50	4.86	4.58
0.30	3.75	3.80			

Parupeneus porphyreus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	418	0.31	360
0.11	414	0.32	358
0.12	412	0.33	356
0.13	407	0.34	353
0.14	405	0.35	351
0.15	400	0.36	349
0.16	398	0.37	346
0.17	396	0.38	344
0.18	394	0.39	342
0.19	389	0.40	340
0.20	387	0.41	338
0.21	385	0.42	335
0.22	382	0.43	333
0.23	380	0.44	331
0.24	376	0.45	328
0.25	374	0.46	326
0.26	374	0.47	324
0.27	369	0.48	322
0.28	367	0.49	320
0.29	364	0.50	317
0.30	362		

Calotomus carolinus

Stareye parrotfish, *ponuhunuhu*
Scaridae (parrotfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	366	25	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 430 (11) from NWHI diver survey
K	0.534	0.168	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	253	29	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	13	4.8	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	8.31e-6	-	-	-	Smith & Dalzell (1993)
L-W β	3.17				
L_{S50}	200	-	mm	-	Estimated.
L_{S95}	220				
$\overline{L}$ diver survey	275	4	mm	141	NOAA-CREP diver survey
$\overline{L}$ commercial	-	-	mm	-	-
$\overline{L}$ combined	-	-	mm	-	-
Max. depth	71	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.24	0.08	yr^{-1}
F	0.61	0.33	yr^{-1}
F_{30}	0.29	0.10	yr^{-1}
F/F_{30}	2.2	1.2	-
SPR	0.13	0.14	-
SPR < 0.30 iterations	87	-	%
Lc_{30}	276	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	38,102	9,192	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	8,430	3,010	kg

General comments

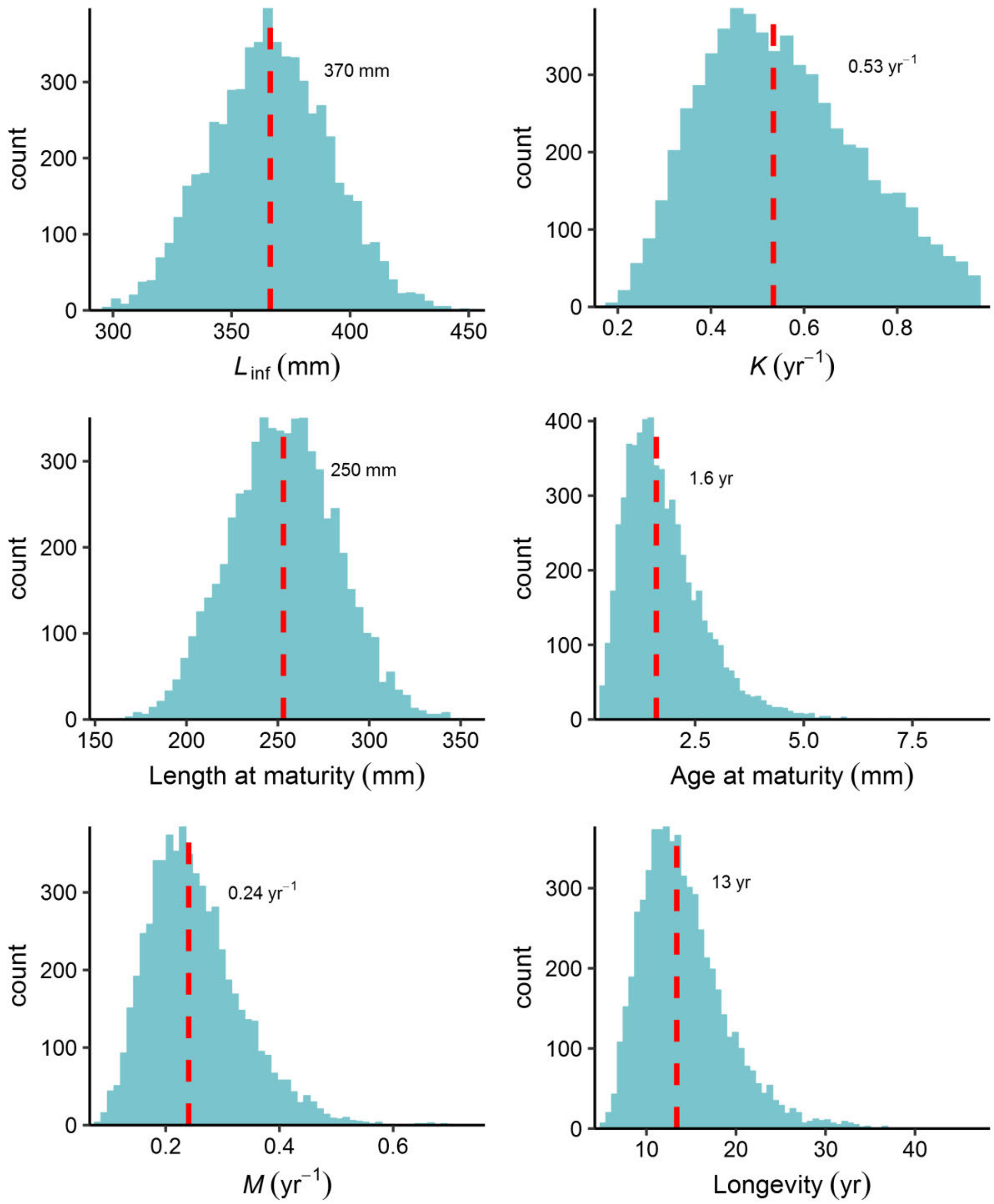
Parrotfish catches are grouped at the family level and therefore there is no species-level commercial data.

Population abundance for this species appeared to be increasing significantly. There were not enough observation in individual years to generate a L_{bar} time series.

There are currently no published life history parameters for this species. We used the stepwise approach to generate LH parameters, using a L_{max} value of 430 mm from the pristine NWHI. Analyses using the lower L_{max} value found in the MHI (410 mm) generated the following results: L_{inf}: 349 mm, K: 0.57, M: 0.25, F_{30}: 0.32, F: 0.46, *SPR*: 0.20, C_{30} survey: 8,879 kg. Furthermore, selectivity for parrotfishes had to be estimated, given the absence of catch data. A sensitivity run with L_{S50} at 230 mm and L_{S95} at 260 mm had little impact on the results (F: 0.62, *SPR*: 0.16).

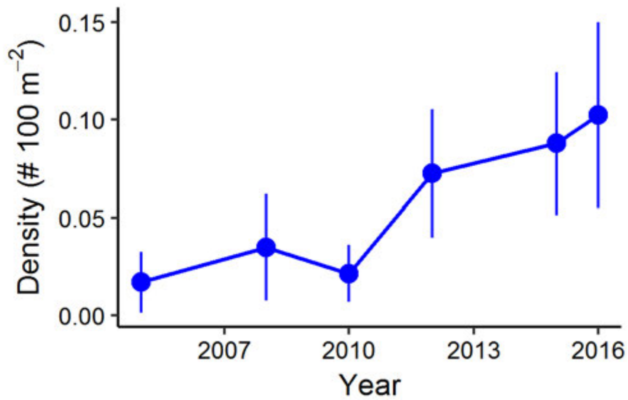
The population biomass estimate may be biased downward given that this species' range extends to 68 m depth, which is beyond the depth of the diver surveys (30 m).

Calotomus carolinus

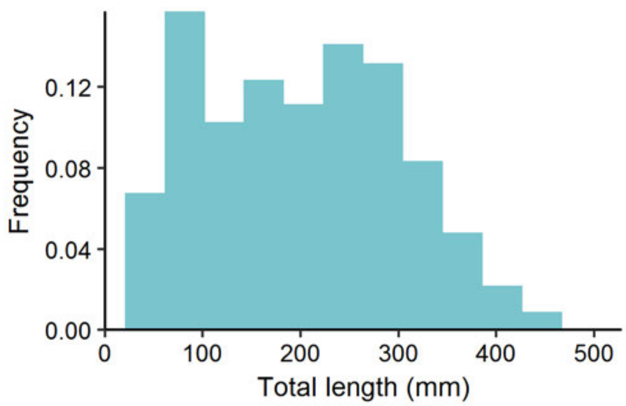


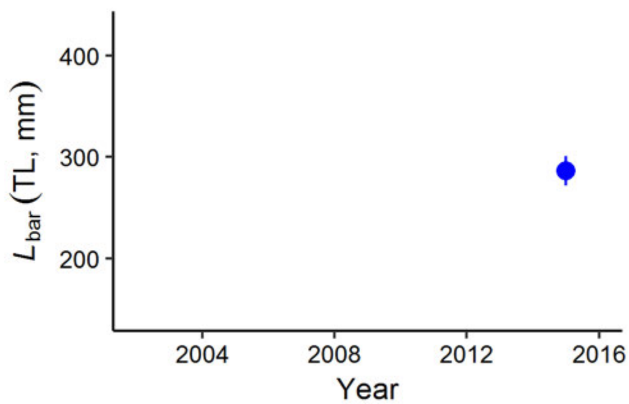
Life history parameter distributions.

Calotomus carolinus



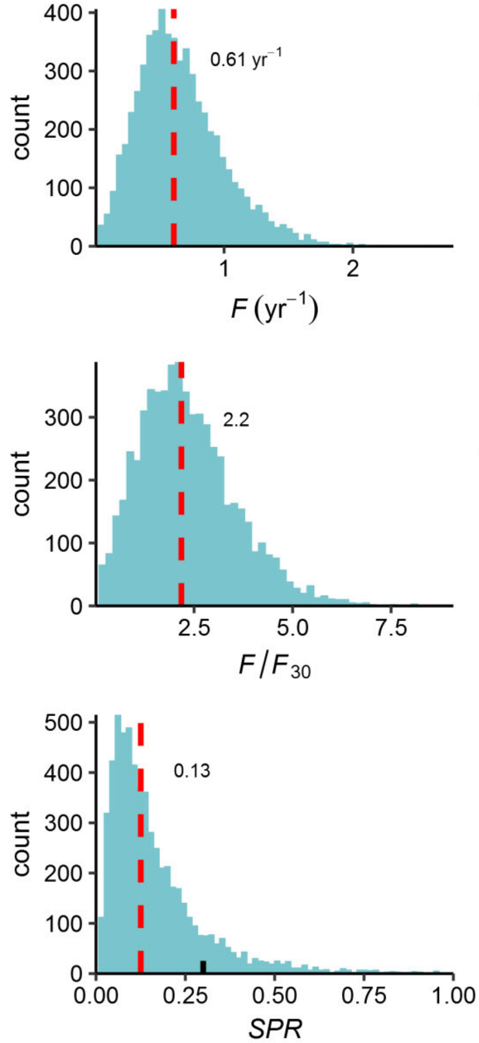
Abundance index from UVS (blue circles, ±SE).



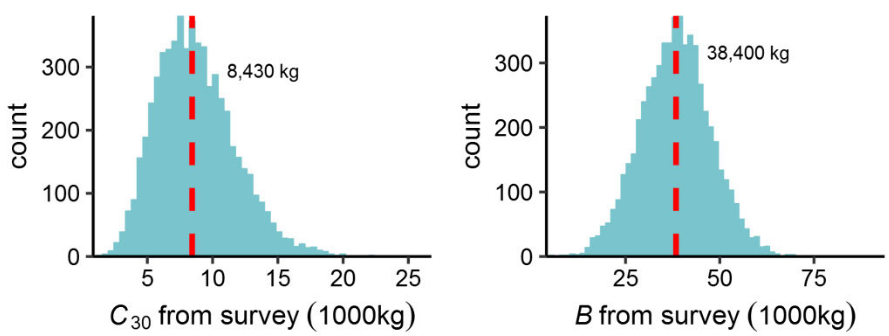


Size structure and average length time series from UVS (±SE).

Calotomus carolinus

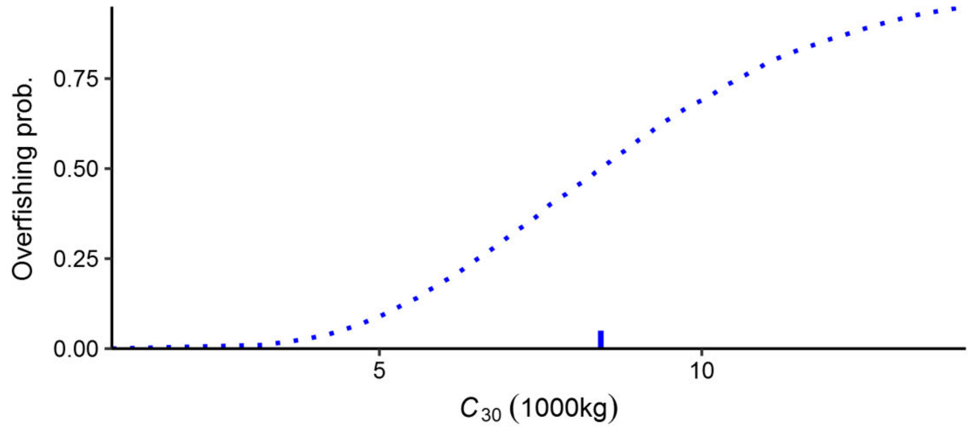


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Calotomus carolinus



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	5.12	0.31	6.99
0.11	5.24	0.32	7.07
0.12	5.34	0.33	7.15
0.13	5.46	0.34	7.23
0.14	5.58	0.35	7.32
0.15	5.66	0.36	7.39
0.16	5.74	0.37	7.46
0.17	5.85	0.38	7.51
0.18	5.94	0.39	7.58
0.19	6.03	0.40	7.64
0.20	6.13	0.41	7.73
0.21	6.22	0.42	7.81
0.22	6.29	0.43	7.90
0.23	6.37	0.44	7.97
0.24	6.45	0.45	8.04
0.25	6.53	0.46	8.13
0.26	6.63	0.47	8.22
0.27	6.70	0.48	8.29
0.28	6.77	0.49	8.35
0.29	6.84	0.50	8.43
0.30	6.92		

Calotomus carolinus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	334	0.31	302
0.11	332	0.32	302
0.12	330	0.33	300
0.13	328	0.34	298
0.14	326	0.35	296
0.15	324	0.36	296
0.16	324	0.37	294
0.17	322	0.38	292
0.18	320	0.39	292
0.19	320	0.40	290
0.20	318	0.41	288
0.21	316	0.42	288
0.22	314	0.43	286
0.23	312	0.44	284
0.24	312	0.45	282
0.25	310	0.46	282
0.26	310	0.47	280
0.27	308	0.48	278
0.28	306	0.49	278
0.29	306	0.50	276
0.30	304		

Chlorurus perspecillatus

Spectacled parrotfish, *uhu uliuli*
Scaridae (parrotfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	N	Source
L_{inf}	500	22	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 574 (4) from NWHI diver survey
K	0.377	0.135	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	348	28	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	19	6.5	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	1.06e-5	-	-	-	Smith & Dalzell (1993) taken for *S. rubroviolaceus*
L-W β	3.11				
L_{S50}	240	-	mm	-	Estimated.
L_{S95}	260				
$\bar{L}$ diver survey	404	13	mm	123	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	-
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	80	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.17	0.06	yr^{-1}
F	0.09	0.08	yr^{-1}
F_{30}	0.19	0.06	yr^{-1}
F/F_{30}	0.5	0.4	-
SPR	0.54	0.21	-
SPR < 0.30 iterations	13	-	%
Lc_{30}	0	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	78,752	22,829	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	12,400	5,050	kg

General comments

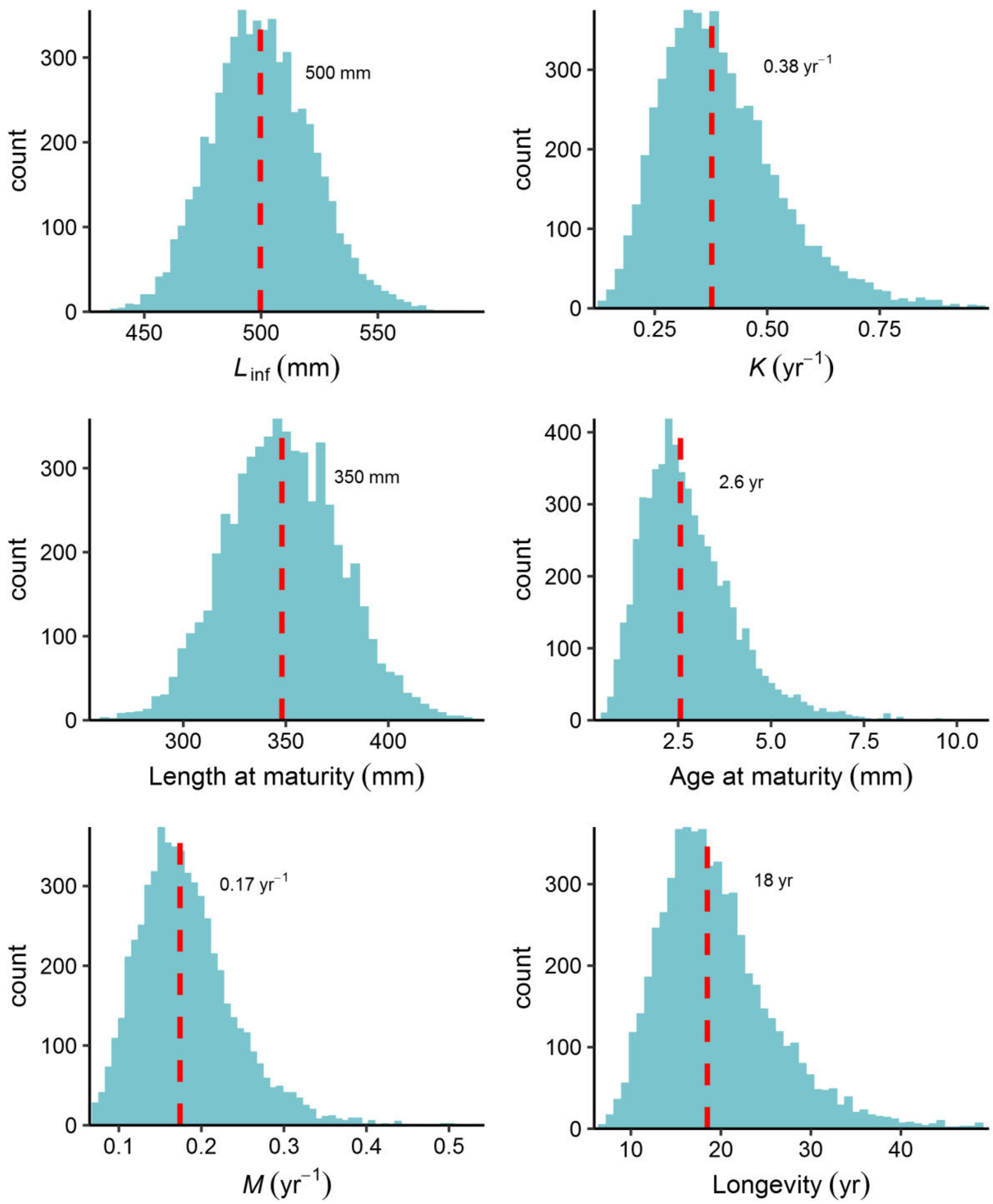
Parrotfish catches are grouped at the family level and therefore there is no species-level commercial data.

Population abundance was fairly variable from year to year for this species, likely due to the relatively low observation counts. Similarly, there were not enough yearly observations to generate an L_{bar} time series.

There are currently no published life history parameters for this species. We used the stepwise approach to generate LH parameters using an L_{max} value (574 mm) from the NWHI, where this species is fairly abundant. Analyses using a higher L_{max} estimate from the MHI (610 mm) generated the following results: L_{inf}: 526 mm, K: 0.33, M: 0.17, F_{30}: 0.17, F: 0.11, SPR: 0.45, C_{30} survey: 11,609 kg. Furthermore, selectivity for parrotfishes had to be estimated, given the absence of catch data. A sensitivity run with L_{S50} at 260 mm and L_{S95} at 300 mm had little impact on the results (F: 0.09, SPR: 0.52).

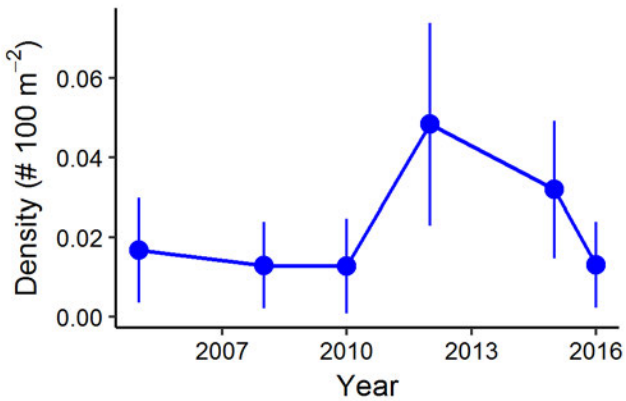
The population biomass estimate may be biased downward given that this species' range extends to 68 m depth, which is beyond the depth of the diver surveys (30 m).

Chlorurus perspicillatus

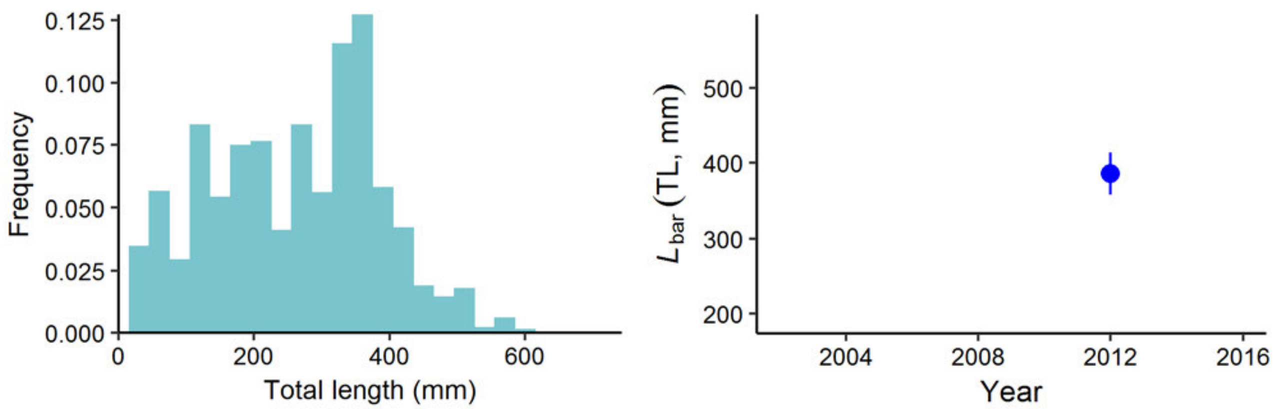


Life history parameter distributions.

Chlorurus perspicillatus

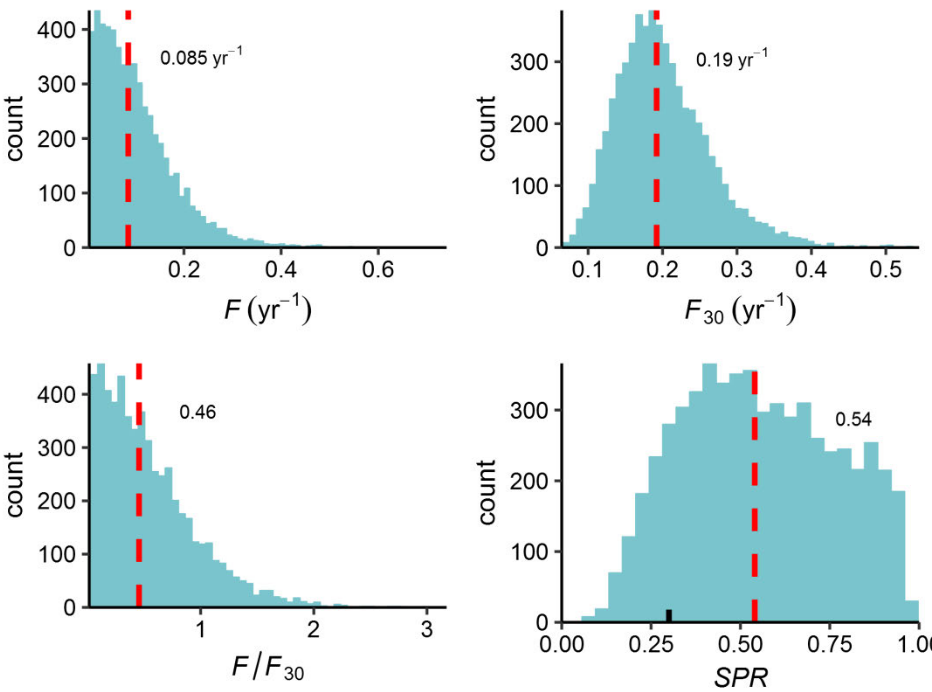


Abundance index from UVS (blue circles, ±SE).

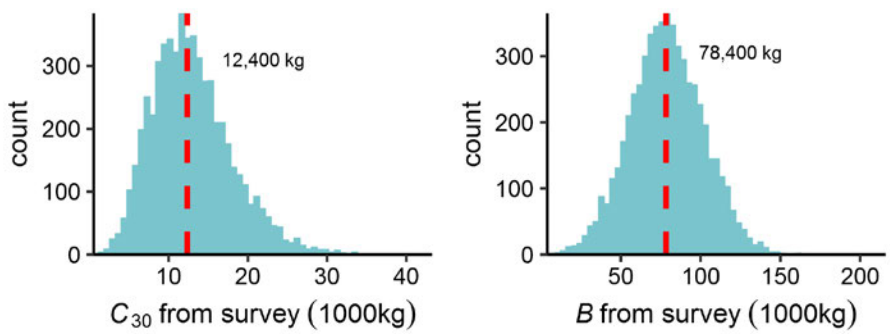


Size structure and average length time series from UVS (±SE).

Chlorurus perspicillatus

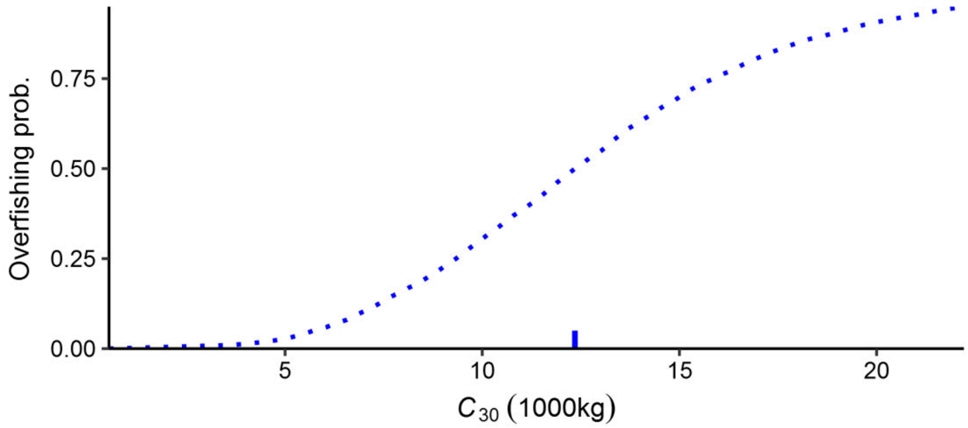


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



***C*$_{30}$ (left) and population size (right) distributions.**

Chlorurus perspicillatus



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	6.9	0.31	10.1
0.11	7.1	0.32	10.2
0.12	7.3	0.33	10.3
0.13	7.5	0.34	10.4
0.14	7.6	0.35	10.6
0.15	7.8	0.36	10.7
0.16	8.0	0.37	10.8
0.17	8.1	0.38	10.9
0.18	8.4	0.39	11.1
0.19	8.5	0.40	11.2
0.20	8.6	0.41	11.3
0.21	8.8	0.42	11.4
0.22	8.9	0.43	11.6
0.23	9.1	0.44	11.7
0.24	9.2	0.45	11.8
0.25	9.3	0.46	11.9
0.26	9.4	0.47	12.0
0.27	9.6	0.48	12.1
0.28	9.7	0.49	12.2
0.29	9.8	0.50	12.4
0.30	9.9		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	278	0.31	0
0.11	266	0.32	0
0.12	257	0.33	0
0.13	240	0.34	0
0.14	228	0.35	0
0.15	214	0.36	0
0.16	194	0.37	0
0.17	173	0.38	0
0.18	158	0.39	0
0.19	137	0.40	0
0.20	108	0.41	0
0.21	0	0.42	0
0.22	0	0.43	0
0.23	0	0.44	0
0.24	0	0.45	0
0.25	0	0.46	0
0.26	0	0.47	0
0.27	0	0.48	0
0.28	0	0.49	0
0.29	0	0.50	0
0.30	0		

Chlorurus spilurus

Bullethead parrotfish, *uhu*
Scaridae (parrotfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	341	21	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 397 (7) from NWHI diver survey
K	0.59	0.22	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	235	37	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	13	4.2	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	2.61e-5	-	-	-	Kulbicki (2005)
L-W β	2.97				
L_{S50}	220	-	mm	-	Estimated.
L_{S95}	240				
$\bar{L}$ diver survey	283	3	mm	435	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	-
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	34	-	m	-	NOAA-CREP BRUV survey
Federal waters	0	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.26	0.09	yr^{-1}
F	0.50	0.36	yr^{-1}
F_{30}	0.37	0.15	yr^{-1}
F/F_{30}	1.4	1.1	-
SPR	0.23	0.20	-
SPR < 0.30 iterations	64	-	%
Lc_{30}	222	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	139,438	17,478	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	38,400	11,000	kg

General comments

Parrotfish catches are grouped at the family level and therefore there is no species-level commercial data.

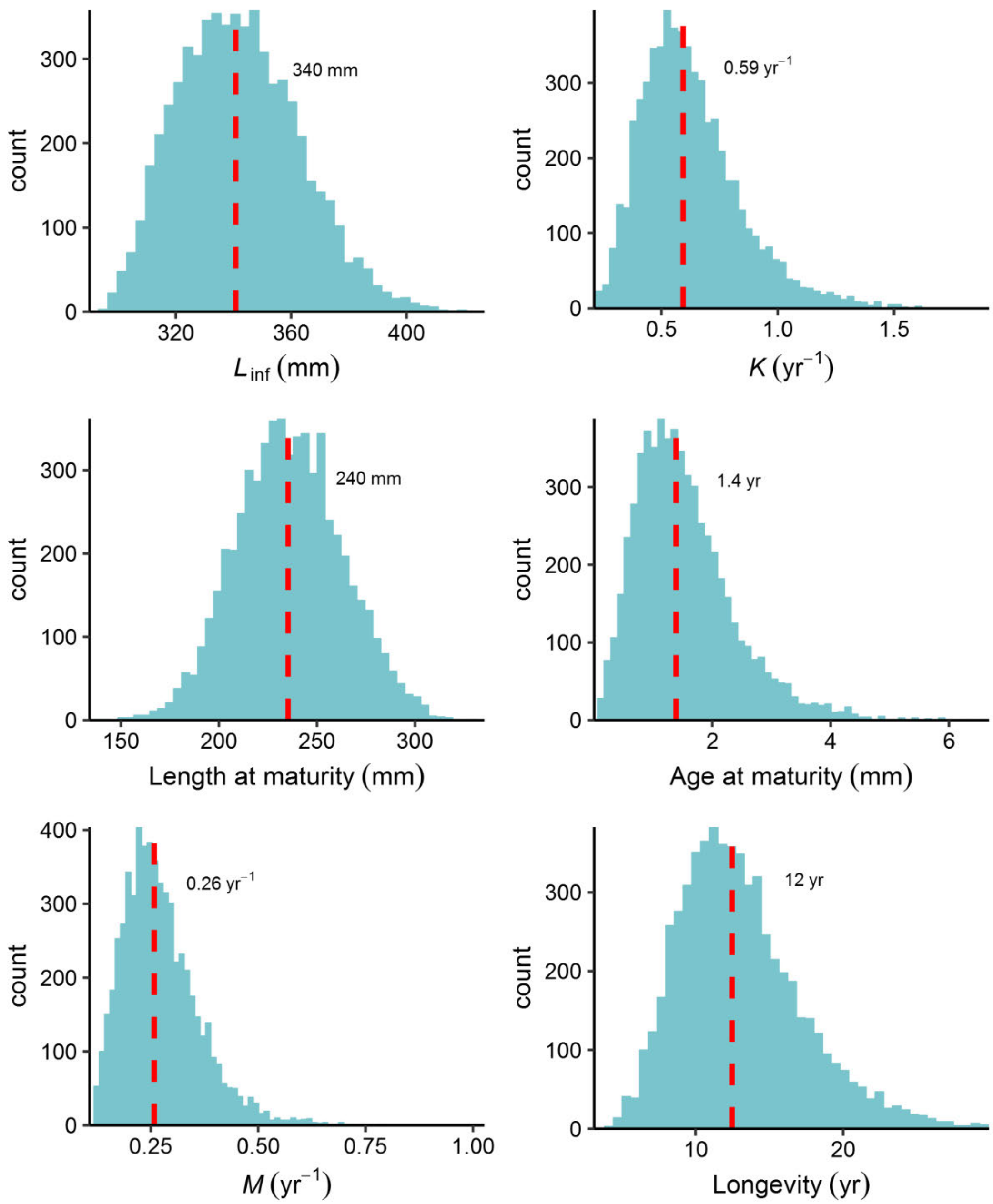
Population abundance has been rising steadily since 2008 while L_{bar} seemed to be slightly declining. Selectivity had to be estimated given the absence of fishery data. A sensitivity run with L_{S50} at 190 mm and L_{S95} at 220 mm had little impact on the results (*F*: 0.57, *SPR*: 0.16).

Life history parameters were available for this species from a study in American Samoa but the L_{inf} parameter was too small (289 mm vs. an L_{max} of 380 mm in the MHI). We therefore used the stepwise approach for this species. The American Samoa LH parameters generated the following estimates: *F*: 0.03, *SPR*: 0.88. The much lower *F* value (and higher *SPR* value) were expected given the unrealistically low L_{inf} estimate from this source.

Note that the longevity estimate obtained through the stepwise approach was similar to the maximum recorded age for this species (13 yr vs. 10 yr). The NWHI L_{max} is identical to the MHI estimate (397 mm), which suggested this number was appropriate.

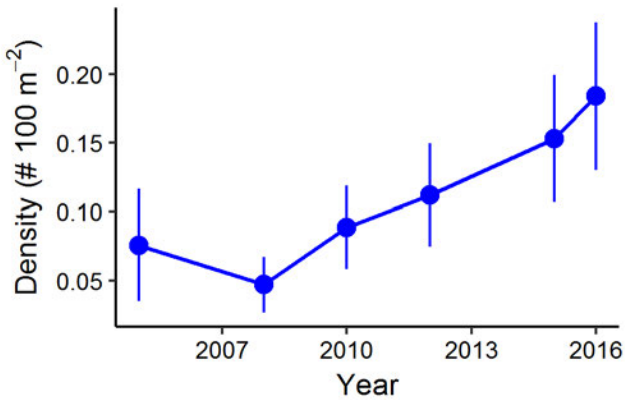
The population biomass estimate should be reasonably accurate given that this species extends only slightly beyond the maximum diver survey depth (30 m).

Chlorurus spilurus

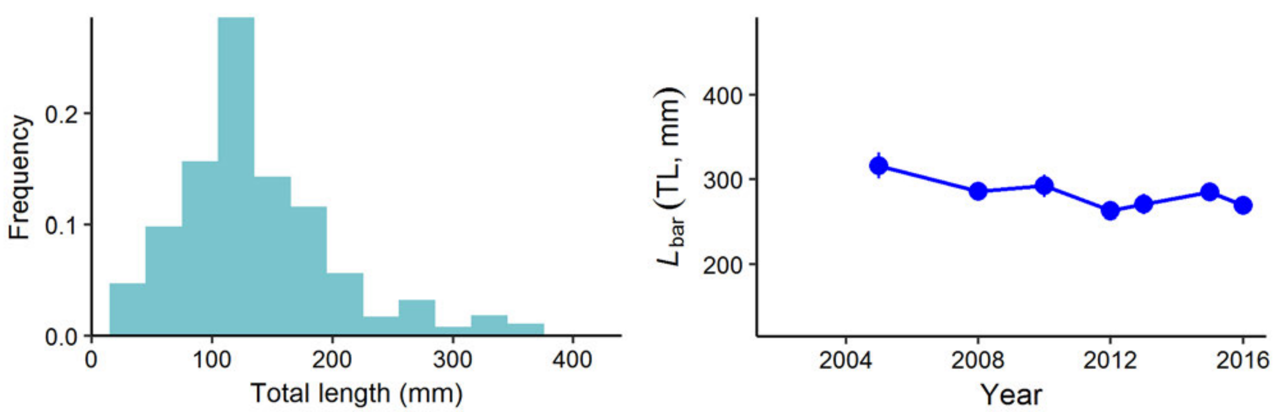


Life history parameter distributions.

Chlorurus spilurus

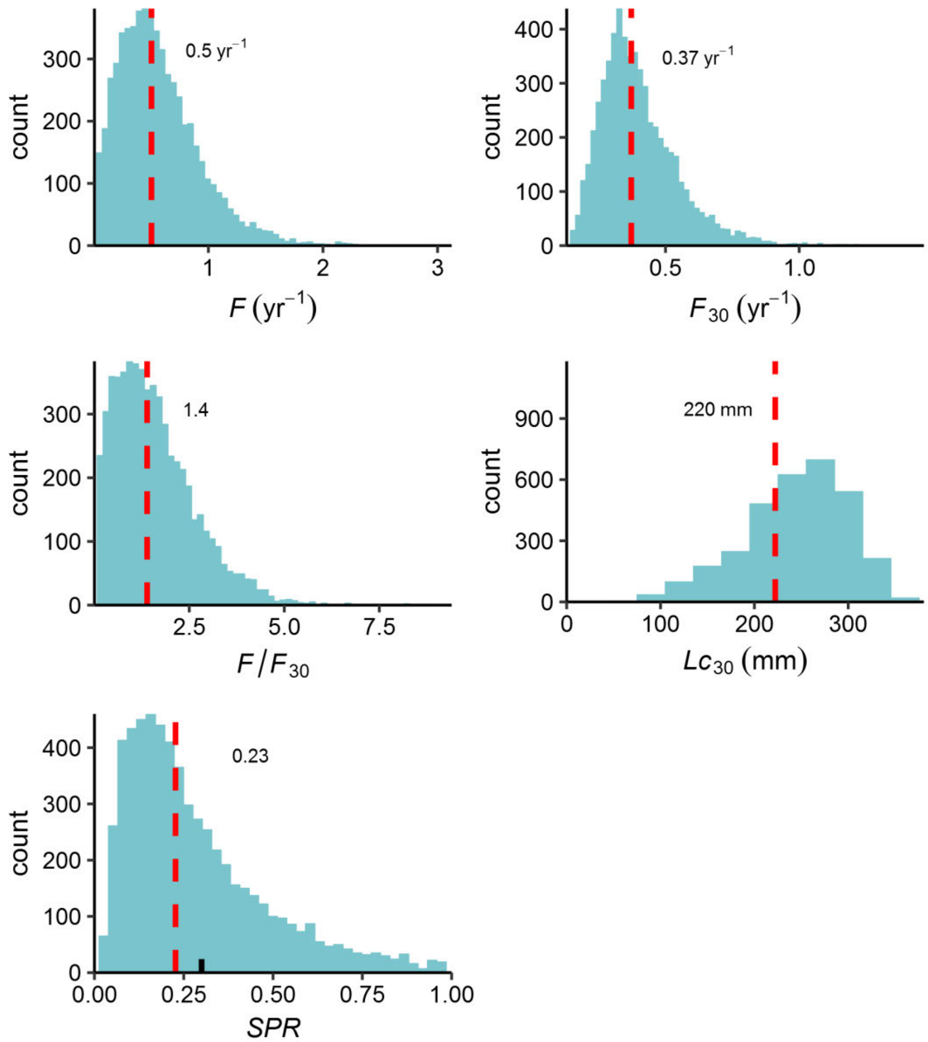


Abundance index from UVS (blue circles, ±SE).

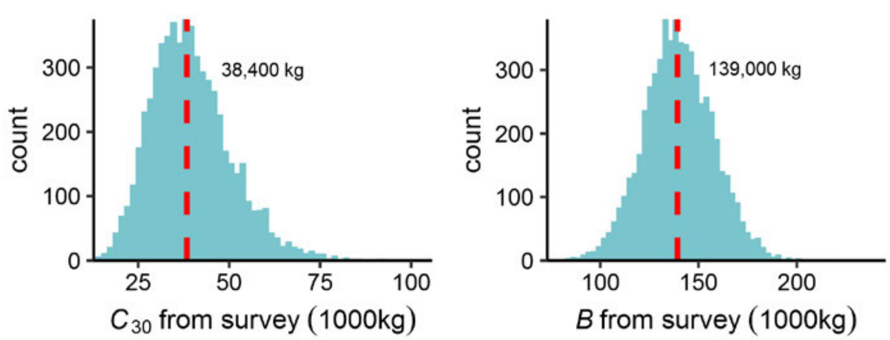


Size structure and average length time series from UVS (±SE).

Chlorurus spilurus

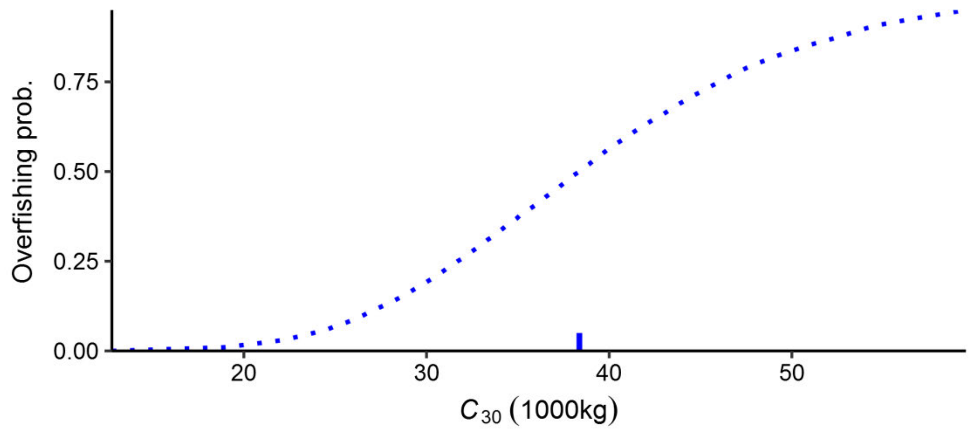


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Chlorurus spilurus



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	26.6	0.31	33.3
0.11	26.9	0.32	33.7
0.12	27.4	0.33	33.9
0.13	27.8	0.34	34.2
0.14	28.2	0.35	34.4
0.15	28.6	0.36	34.7
0.16	29.0	0.37	35.0
0.17	29.3	0.38	35.1
0.18	29.6	0.39	35.4
0.19	29.9	0.40	35.8
0.20	30.3	0.41	36.1
0.21	30.5	0.42	36.3
0.22	30.9	0.43	36.5
0.23	31.1	0.44	36.8
0.24	31.4	0.45	37.1
0.25	31.7	0.46	37.3
0.26	32.0	0.47	37.6
0.27	32.3	0.48	37.8
0.28	32.6	0.49	38.1
0.29	32.8	0.50	38.4
0.30	33.1		

Chlorurus spilurus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	301	0.31	264
0.11	299	0.32	262
0.12	297	0.33	260
0.13	295	0.34	257
0.14	293	0.35	257
0.15	290	0.36	255
0.16	288	0.37	253
0.17	286	0.38	251
0.18	284	0.39	249
0.19	284	0.40	246
0.20	282	0.41	244
0.21	279	0.42	242
0.22	277	0.43	240
0.23	275	0.44	238
0.24	273	0.45	235
0.25	273	0.46	233
0.26	271	0.47	231
0.27	268	0.48	229
0.28	266	0.49	227
0.29	264	0.50	224
0.30	301		

Scarus dubius

Regal parrotfish, *lauia*
Scaridae (parrotfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	335	17	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 375 (2) from NWHI diver survey
K	0.63	0.22	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	232	26	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	13	4.5	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	3.86e-7	-	-	-	Froese (1998)
L-W β	3.75				
L_{S50}	190	-	mm	-	Estimated.
L_{S95}	220				
$\bar{L}$ diver survey	287	5	mm	121	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	-
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	80	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.26	0.09	yr^{-1}
F	0.18	0.18	yr^{-1}
F_{30}	0.31	0.10	yr^{-1}
F/F_{30}	0.6	0.6	-
SPR	0.45	0.23	-
SPR < 0.30 iterations	26	-	%
Lc_{30}	0	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	32,840	7,868	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	7,690	2,660	kg

General comments

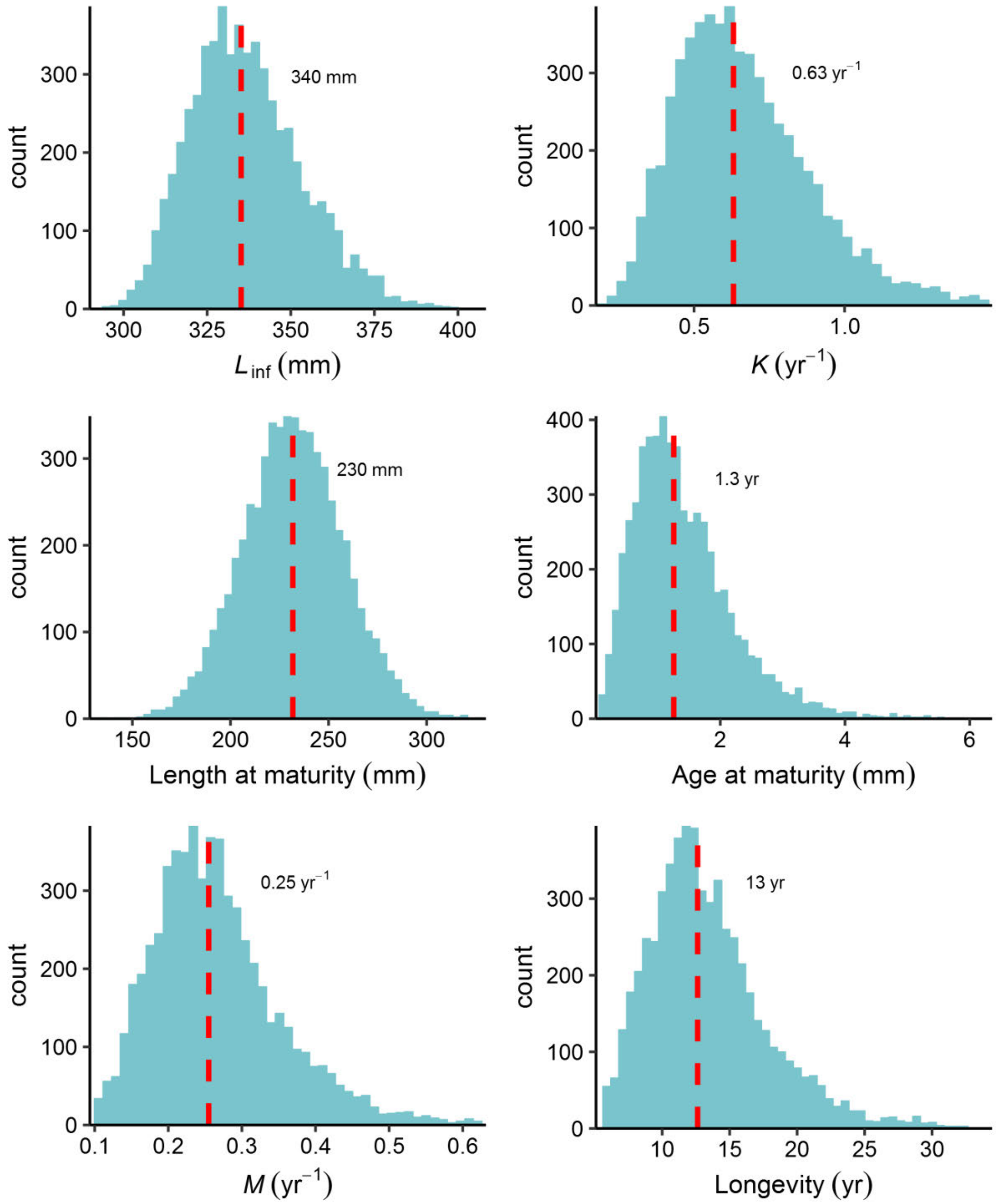
Parrotfish catches are grouped at the family level and therefore there is no species-level commercial data.

Population abundance was fairly variable from year to year for this species, but appeared to be increasing from 2003 to 2015 before falling slightly in 2016. There was not enough yearly observation to generate a proper L_{bar} time series.

There are currently no published life history parameters for this species. We used the stepwise approach to generate these parameters using an L_{max} value (375 mm) from the NWHI. The L_{max} estimate from the MHI was nearly identical (378 mm). Furthermore, selectivity for parrotfishes had to be estimated, given the absence of catch data. A sensitivity run with L_{S50} at 230 mm and L_{S95} at 250 mm had little impact on the results (*F*: 0.21, *SPR*: 0.43).

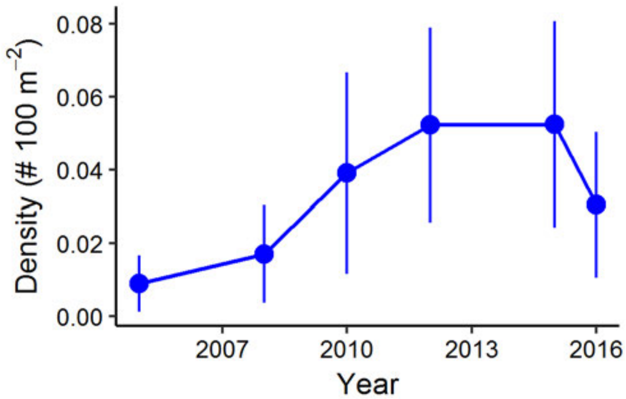
The population biomass estimate may be biased downward given that this species' range extends to 68 m depth, which is beyond the depth of the diver surveys (30 m).

Scarus dubius

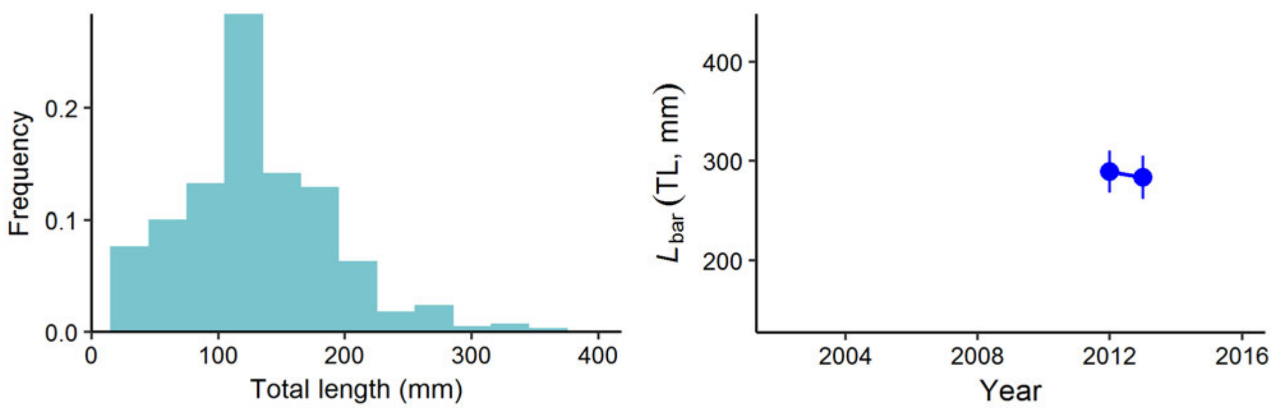


Life history parameter distributions.

Scarus dubius

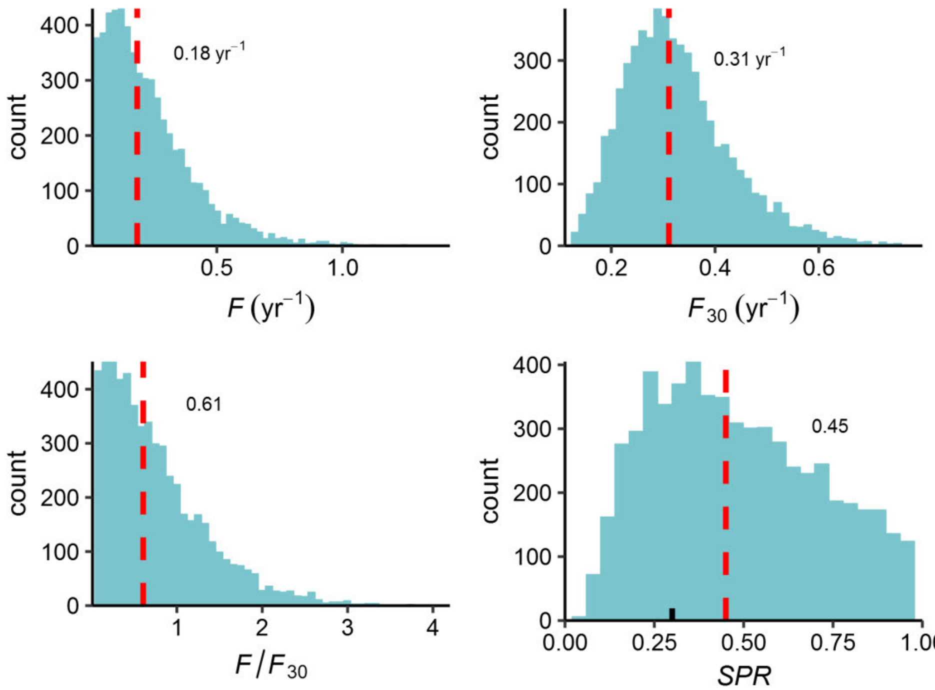


Abundance index from UVS (blue circles.

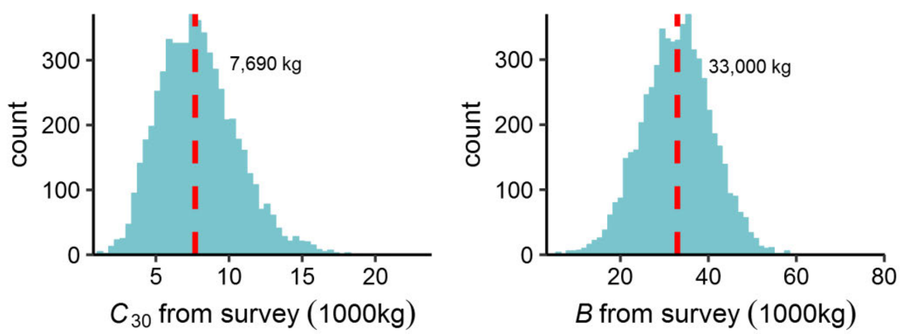


Size structure and average length time series from UVS (±SE).

Scarus dubius

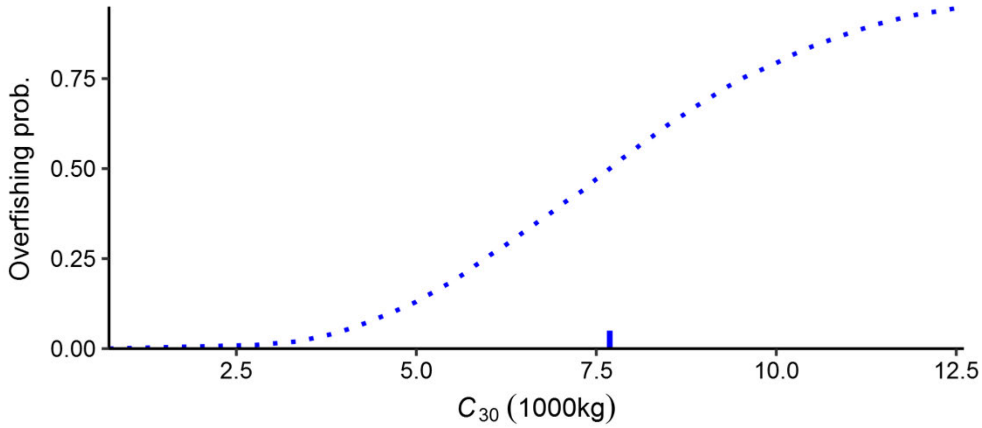


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Scarus dubius



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	4.7	0.31	6.4
0.11	4.8	0.32	6.5
0.12	4.9	0.33	6.5
0.13	5.0	0.34	6.6
0.14	5.1	0.35	6.7
0.15	5.2	0.36	6.7
0.16	5.3	0.37	6.8
0.17	5.4	0.38	6.9
0.18	5.4	0.39	7.0
0.19	5.5	0.40	7.0
0.20	5.6	0.41	7.1
0.21	5.7	0.42	7.2
0.22	5.8	0.43	7.2
0.23	5.8	0.44	7.3
0.24	5.9	0.45	7.4
0.25	6.0	0.46	7.4
0.26	6.0	0.47	7.5
0.27	6.1	0.48	7.6
0.28	6.2	0.49	7.6
0.29	6.3	0.50	7.7
0.30	6.3		

Scarus dubius

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	260	0.31	136
0.11	256	0.32	125
0.12	253	0.33	108
0.13	249	0.34	0
0.14	243	0.35	0
0.15	239	0.36	0
0.16	236	0.37	0
0.17	232	0.38	0
0.18	226	0.39	0
0.19	222	0.40	0
0.20	217	0.41	0
0.21	211	0.42	0
0.22	203	0.43	0
0.23	198	0.44	0
0.24	190	0.45	0
0.25	185	0.46	0
0.26	179	0.47	0
0.27	173	0.48	0
0.28	165	0.49	0
0.29	158	0.50	0
0.30	148		

Scarus psittacus

Palenose parrotfish, *uhu*
Scaridae (parrotfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	291	16	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 326 (2) from NWHI diver survey
K	0.72	0.25	yr^{-1}		
a_0	-0.6	-	yr		
L_{mat}	201	25	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	11	3	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	5.02e-6	-	-	-	Kulbicki (2005)
L-W β	3.32				
L_{S50}	200	-	mm	-	Estimated
L_{S95}	210				
$\overline{L}$ diver survey	254	2	mm	344	NOAA-CREP diver survey
$\overline{L}$ commercial	-	-	mm	-	-
$\overline{L}$ combined	-	-	mm	-	-
Max. depth	48	-	m	-	NOAA-CREP BRUV survey
Federal waters	10	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.29	0.10	yr^{-1}
F	0.31	0.29	yr^{-1}
F_{30}	0.45	0.16	yr^{-1}
F/F_{30}	0.7	0.7	-
SPR	0.41	0.23	-
SPR < 0.30 iterations	32	-	%
Lc_{30}	0	-	Mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	130,295	41,926	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	39,900	16,300	kg

General comments

Parrotfish catches are grouped at the family level and therefore there is no species-level commercial data.

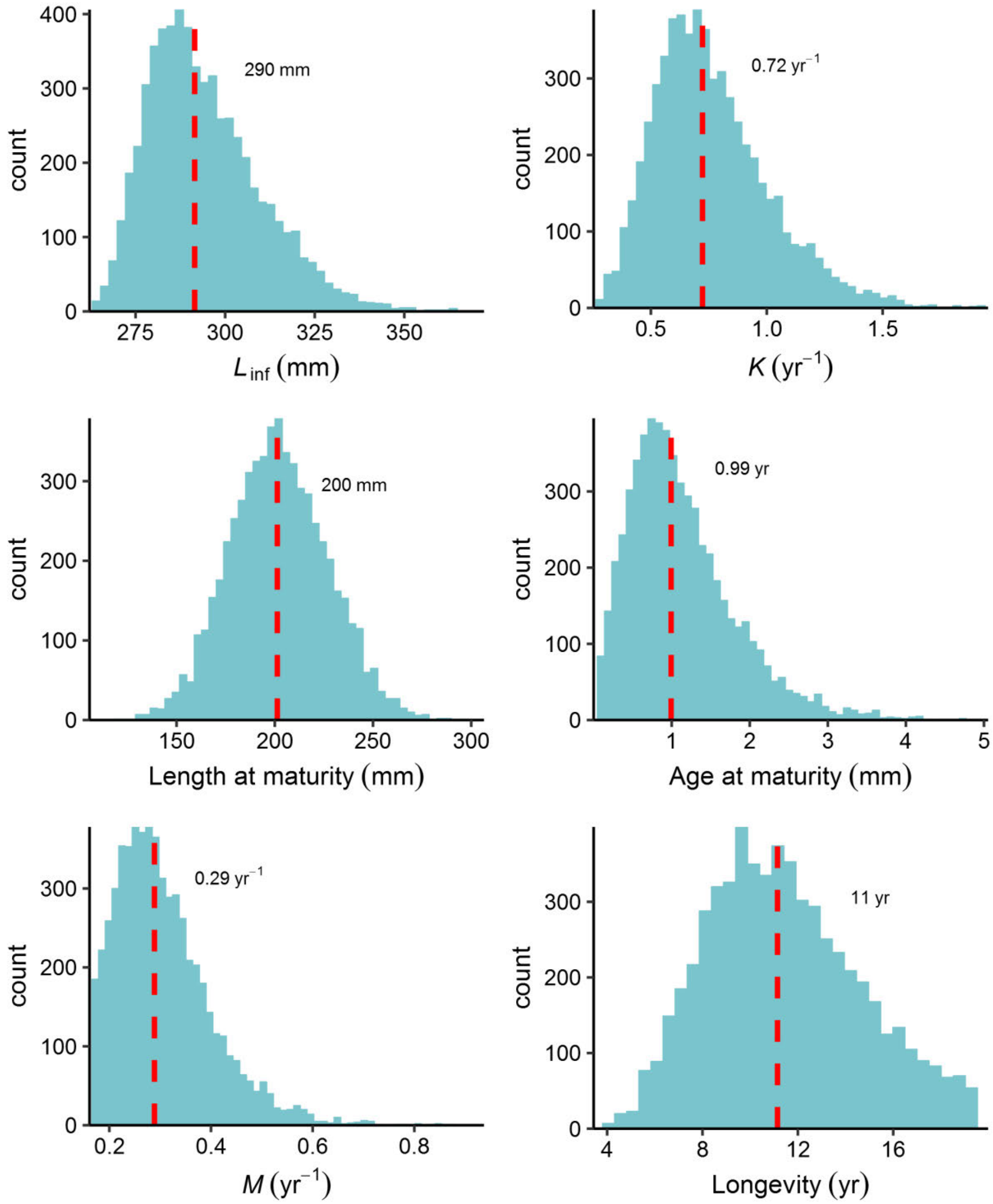
Population abundance has been increasing since 2003, with a potential small decrease in 2016. L_{bar} has remained stable from 2008 to 2016. Selectivity had to be estimated given the lack of catch data.

The life history parameters were available from a study conducted in American Samoa, but the L_{inf} for this study was deemed too small compared to L_{max} values in the NWHI (278 mm vs. 326 mm). This study also estimated a *K* parameter that seemed extreme for parrotfishes (1.65). The American Samoa LH parameters would have generated the following estimates: L_{inf}: 278 mm, *K*: 1.65, L_{mat}: 196 mm, *M*: 0.50, F_{30}: 0.82, *F*: 0.87, *SPR*: 0.30, C_{30} survey: 57,913 kg.

A sensitivity run with L_{S50} at 220 mm and L_{S95} at 240 mm had a slight impact on the results (*F*: 0.51, *SPR*: 0.31).

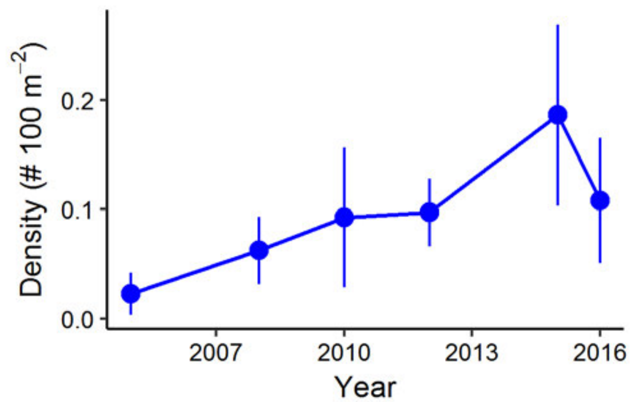
The population biomass estimate should be reasonably accurate given that this species extends only slightly beyond the maximum diver survey depth (30 m).

Scarus psittacus

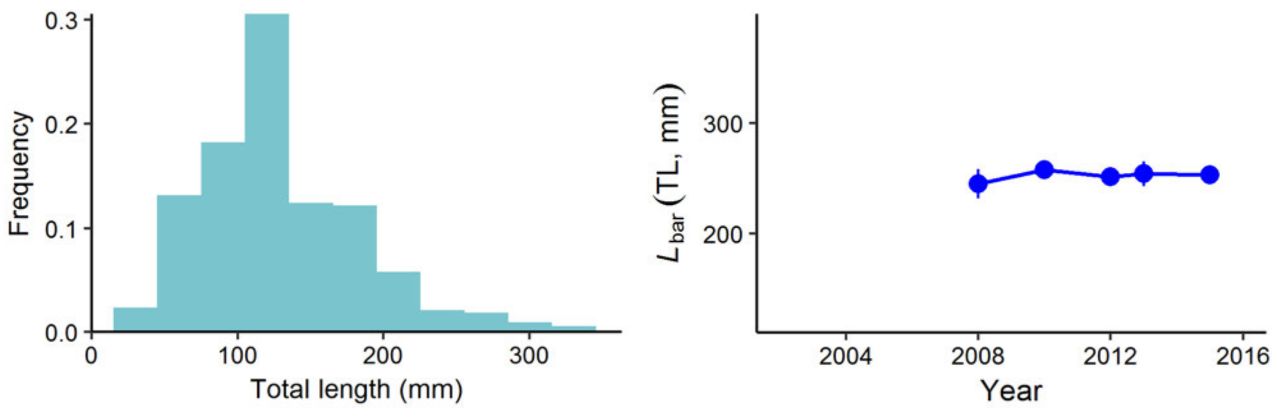


Life history parameter distributions.

Scarus psittacus

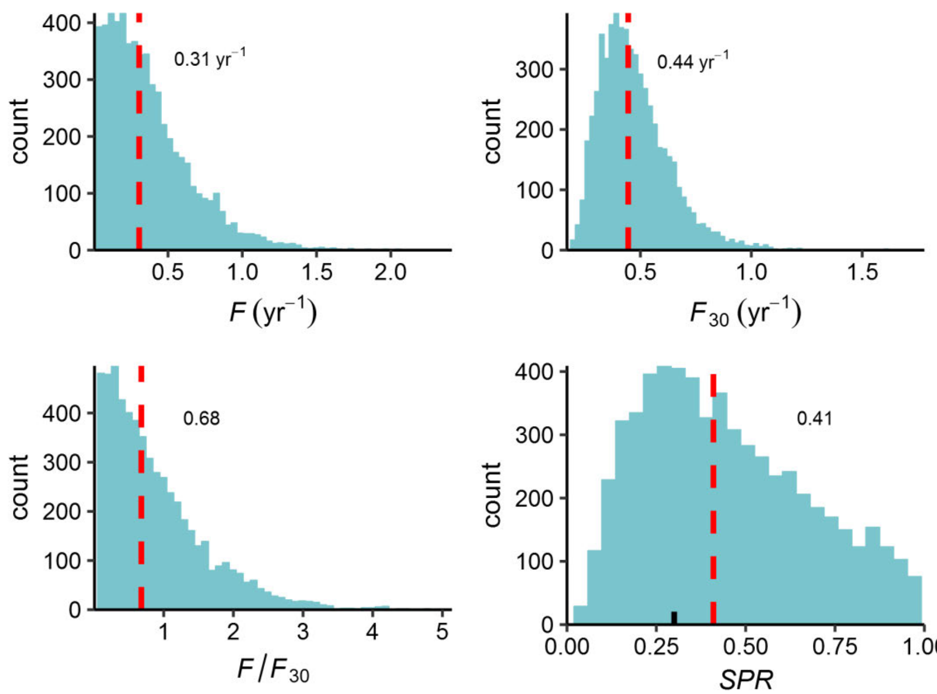


Abundance index from UVS (blue circles).

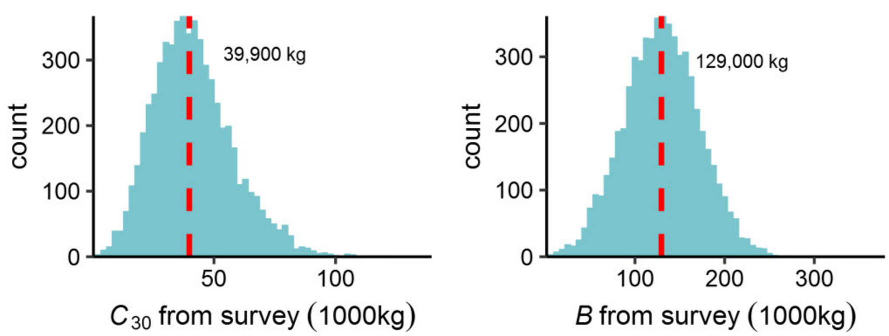


Size structure and average length time series from UVS (±SE).

Scarus psittacus

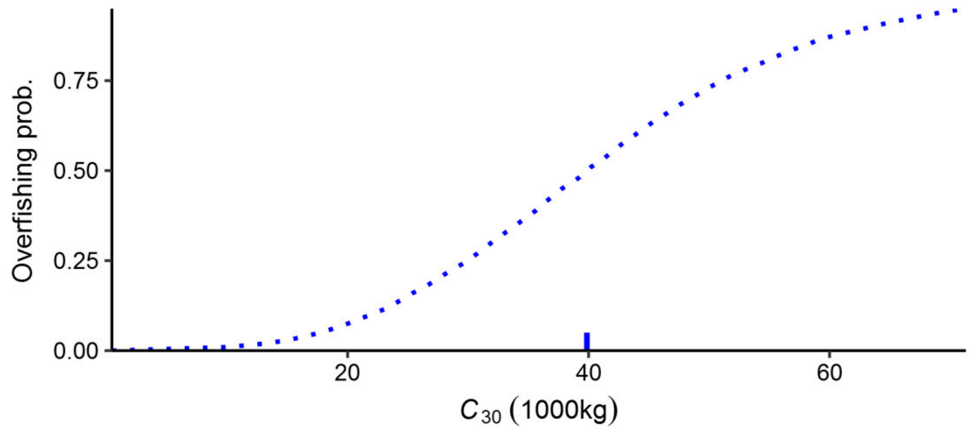


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Scarus psittacus



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	22.0	0.31	32.4
0.11	22.7	0.32	32.8
0.12	23.4	0.33	33.2
0.13	23.9	0.34	33.6
0.14	24.4	0.35	34.0
0.15	24.9	0.36	34.4
0.16	25.4	0.37	34.8
0.17	26.0	0.38	35.2
0.18	26.5	0.39	35.7
0.19	27.0	0.40	36.0
0.20	27.5	0.41	36.3
0.21	28.0	0.42	36.7
0.22	28.4	0.43	37.0
0.23	28.9	0.44	37.4
0.24	29.5	0.45	37.8
0.25	29.9	0.46	38.3
0.26	30.4	0.47	38.7
0.27	30.8	0.48	39.2
0.28	31.1	0.49	39.5
0.29	31.6	0.50	39.9
0.30	31.9		

Scarus psittacus

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	240	0.31	180
0.11	236	0.32	174
0.12	234	0.33	170
0.13	230	0.34	168
0.14	228	0.35	162
0.15	226	0.36	158
0.16	222	0.37	154
0.17	220	0.38	146
0.18	218	0.39	140
0.19	214	0.40	132
0.20	212	0.41	124
0.21	208	0.42	118
0.22	206	0.43	106
0.23	204	0.44	88
0.24	200	0.45	0
0.25	198	0.46	0
0.26	196	0.47	0
0.27	194	0.48	0
0.28	190	0.49	0
0.29	186	0.50	0
0.30	182		

Scarus rubroviolaceus

Redlip parrotfish, *uhu ‘ele’ele*
Scaridae (parrotfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	563	23	mm	182	Mean and SD: Howard (2008)
K	0.288	0.041	yr^{-1}		
a_0	-0.809	-	yr		
L_{mat}	374	9	mm	182	Mean and SD: Howard (2008)
Longevity	22	2	yr	182	Mean and SD: Howard (2008)
L-W α	7.89e-6	-	-	-	Smith & Dalzell (1993)
L-W β	3.11				
L_{S50}	240	-	mm	-	Estimated.
L_{S95}	260				
$\bar{L}$ diver survey	401	8	mm	1054	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	-
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	68	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.15	0.01	yr^{-1}
F	0.18	0.04	yr^{-1}
F_{30}	0.15	0.01	yr^{-1}
F/F_{30}	1.2	0.3	-
SPR	0.26	0.08	-
SPR < 0.30 iterations	68	-	%
Lc_{30}	302	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	623,532	80,385	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	82,500	11,900	kg

General comments

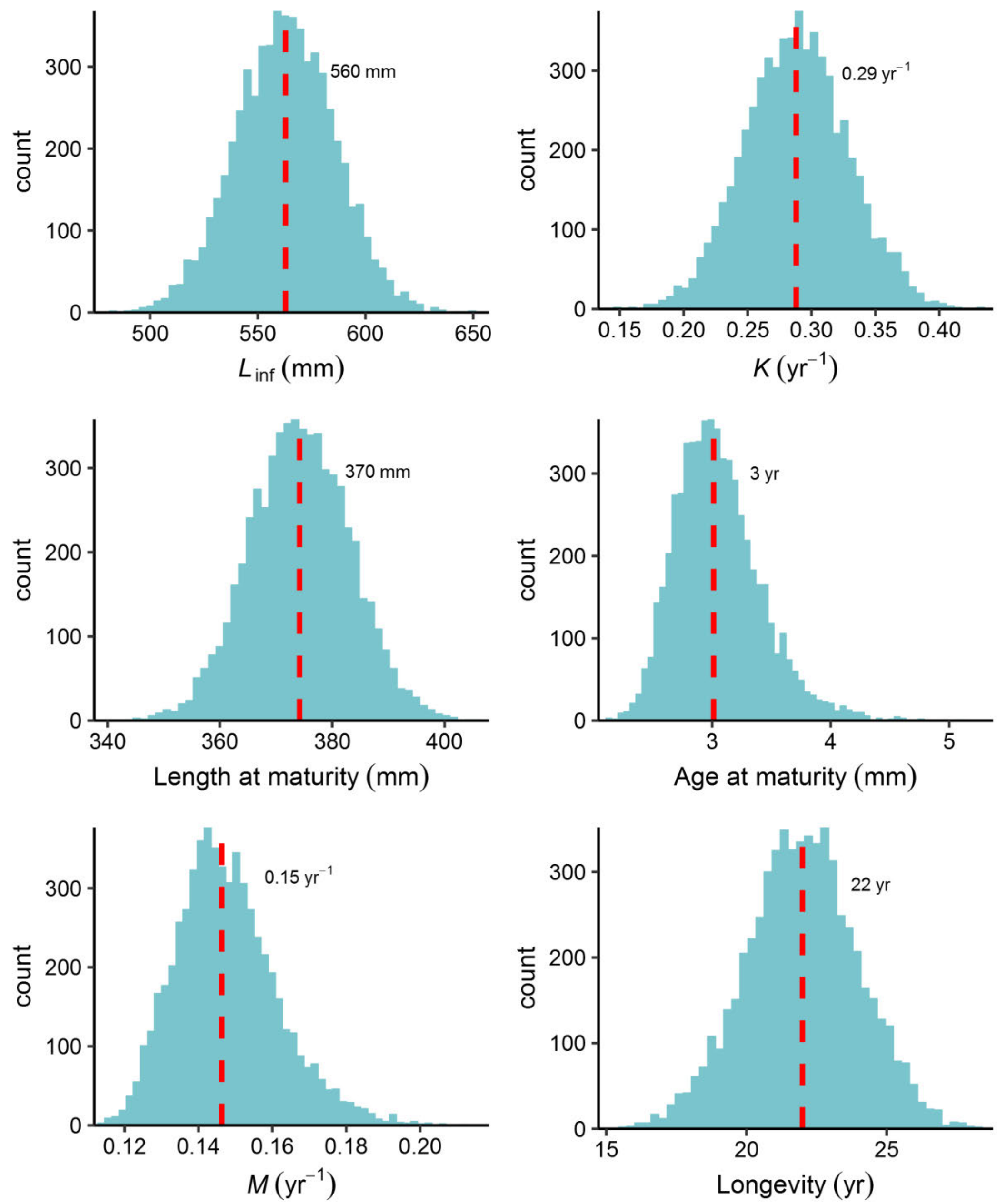
Parrotfish catches are grouped at the family level and therefore there is no species-level commercial data.

Population abundance has been fluctuating between 2005 and 2016, with no clear temporal pattern. L_{bar} from UVS has also been fluctuating but has remained stable overall. As with other parrotfishes, selectivity had to be estimated given the lack of catch data. A sensitivity run with L_{S50} at 260 mm and L_{S95} at 300 mm had little impact on the results (*F*: 0.19, *SPR*: 0.25).

The life history parameters for this species came from an in-depth local study and there was little reasons to doubt the validity of these parameters. As an exercise, the stepwise approach was used to generate alternate numbers (using an L_{max} of 681 mm from the NWHI) and generated the following values: L_{inf}: 580 mm, *K*: 0.26, *M*: 0.15, L_{mat}: 403 mm, *F*: 0.17, *SPR*: 0.24. C_{30} survey: 75,920 kg. These values are fairly close to the original analyses.

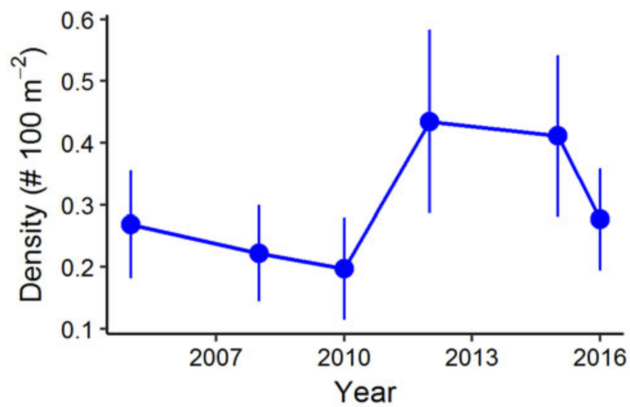
The population biomass estimate may be biased downward given that this species’ range extends to 68 m depth, which is beyond the depth of the diver surveys (30 m).

Scarus rubroviolaceus

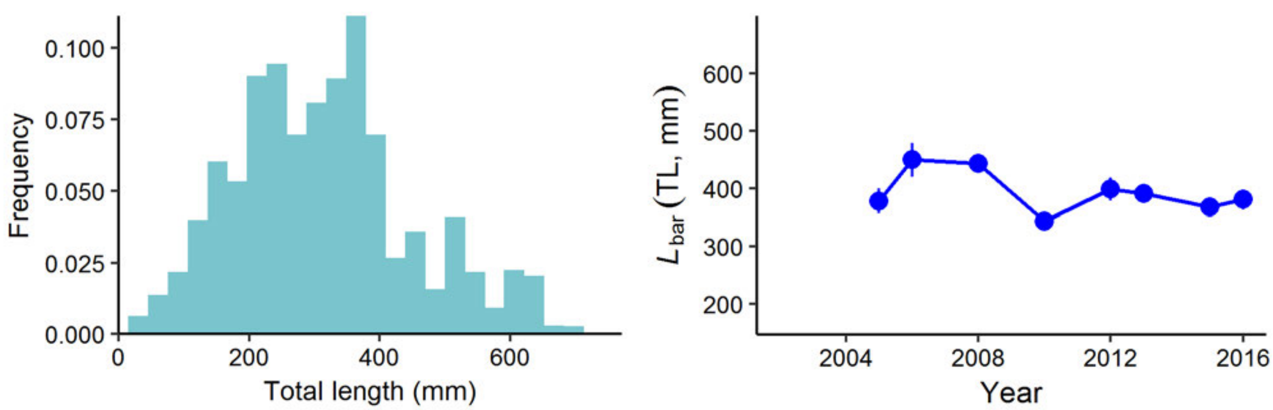


Life history parameter distributions.

Scarus rubroviolaceus

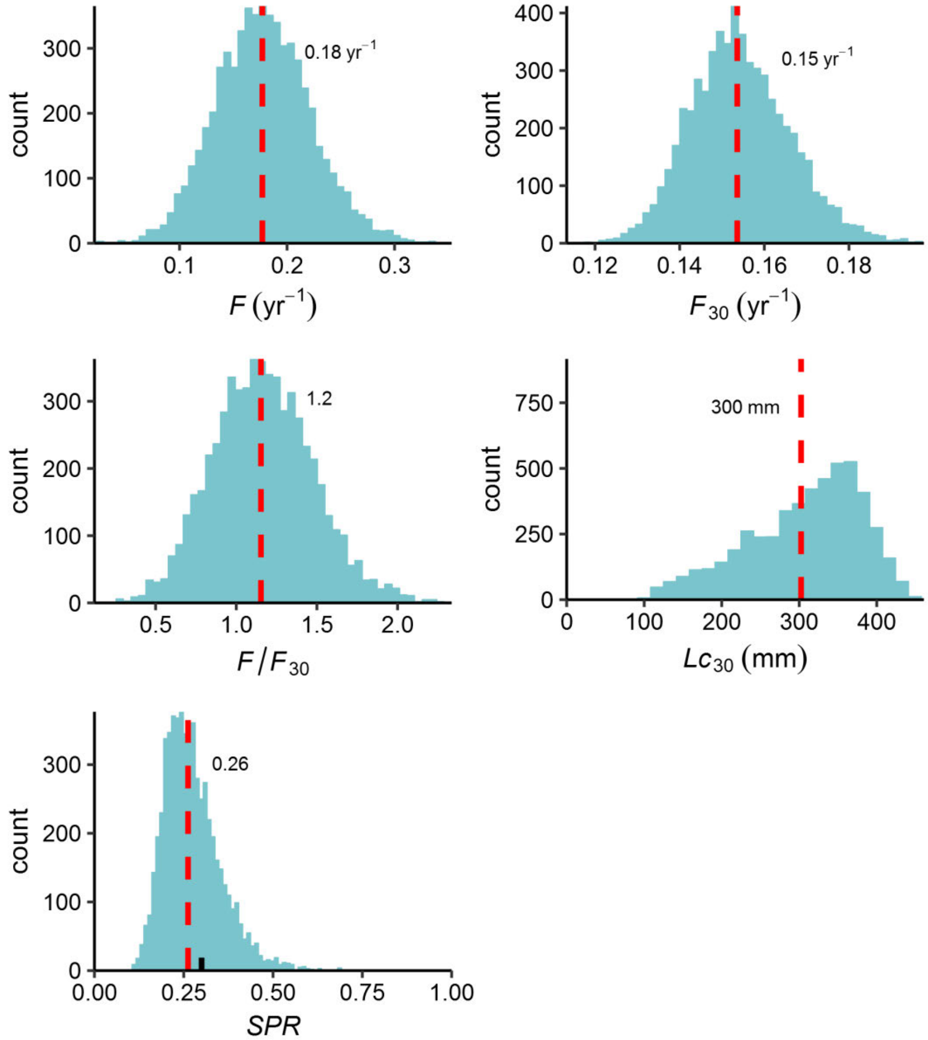


Abundance index from UVS (blue circles, ±SE).

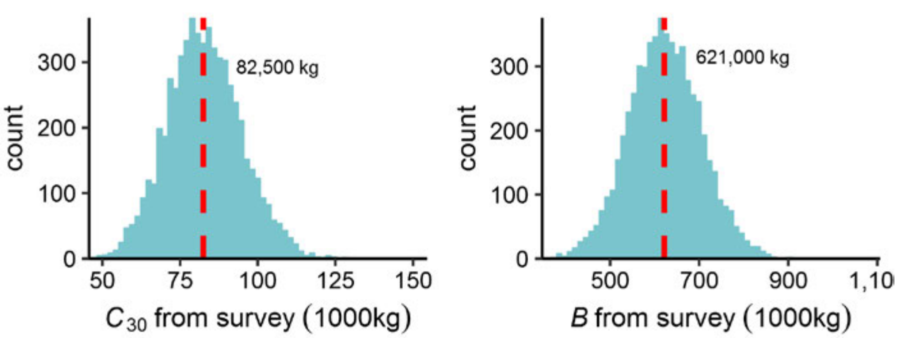


Size structure and average length time series from UVS (±SE).

Scarus rubroviolaceus

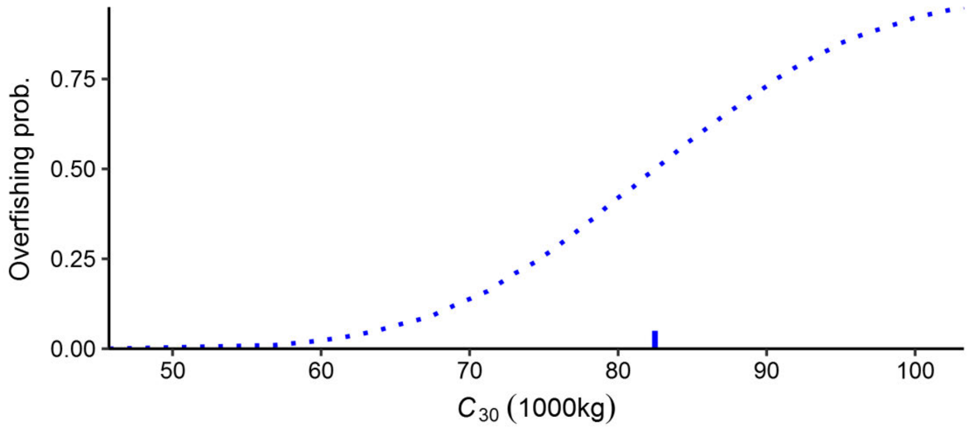


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Scarus rubroviolaceus



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	67.9	0.31	76.7
0.11	68.5	0.32	77.0
0.12	68.9	0.33	77.3
0.13	69.5	0.34	77.6
0.14	70.1	0.35	77.9
0.15	70.6	0.36	78.3
0.16	71.2	0.37	78.6
0.17	71.6	0.38	78.9
0.18	72.0	0.39	79.1
0.19	72.3	0.40	79.4
0.20	72.7	0.41	79.7
0.21	73.1	0.42	80.0
0.22	73.6	0.43	80.3
0.23	73.9	0.44	80.7
0.24	74.4	0.45	81.0
0.25	74.7	0.46	81.3
0.26	75.0	0.47	81.5
0.27	75.4	0.48	81.8
0.28	75.7	0.49	82.2
0.29	76.1	0.50	82.5
0.30	76.4		

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	386	0.31	355
0.11	384	0.32	353
0.12	382	0.33	353
0.13	379	0.34	350
0.14	379	0.35	348
0.15	377	0.36	348
0.16	374	0.37	346
0.17	372	0.38	343
0.18	370	0.39	341
0.19	370	0.40	338
0.20	367	0.41	338
0.21	365	0.42	336
0.22	362	0.43	334
0.23	360	0.44	334
0.24	360	0.45	331
0.25	358	0.46	329
0.26	355	0.47	326
0.27	353	0.48	324
0.28	350	0.49	324
0.29	350	0.50	322
0.30	348		

Cephalopholis argus

Peacock grouper, *roi*
Serranidae (groupers)

Life history and other input parameters

Parameter	Value	SD	Unit	N	Source
L_{inf}	506	11	mm	590	Mean: Donovan (2013), SD: Kritzer (2001)
K	0.075	0.007	yr^{-1}		
a_0	-6.5	-	yr		
L_{mat}	268	8	mm	100?	Mean: Myers (1999), SD: Nadon (unpublished)
Longevity	25	1.4	yr	590	Mean: Donovan (2013), SD: Kritzer (2001)
L-W α	2.05e-5	-	-	-	Kulbicki (2005)
L-W β	2.99				
L_{S50}	270	-	mm	-	DAR commercial data
L_{S95}	310				
$\bar{L}$ diver survey	373	4	mm	614	NOAA-CREP diver survey
$\bar{L}$ commercial	374	4	mm	2234	DAR commercial data
$\bar{L}$ combined	374	4	mm	-	-
Max. depth	80	-	m	-	Pyle et al. (2016)
Federal waters	21	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.13	0.01	yr^{-1}
F	0.02	0.02	yr^{-1}
F_{30}	0.16	0.01	yr^{-1}
F/F_{30}	0.1	0.1	-
SPR	0.80	0.11	-
SPR < 0.30 iterations	0	-	%
Lc_{30}	-	-	mm

Parameter	Median	SD	Unit
B from catch	232,000	494,000	kg
B from survey	777,397	56,961	kg
Commercial catch	830	980	kg
Recreational catch	3,192	6,708	kg
Total catch	4,552	5,594	kg
C_{30} from catch	33,300	72,200	kg
C_{30} from survey	111,000	11,300	kg

General comments

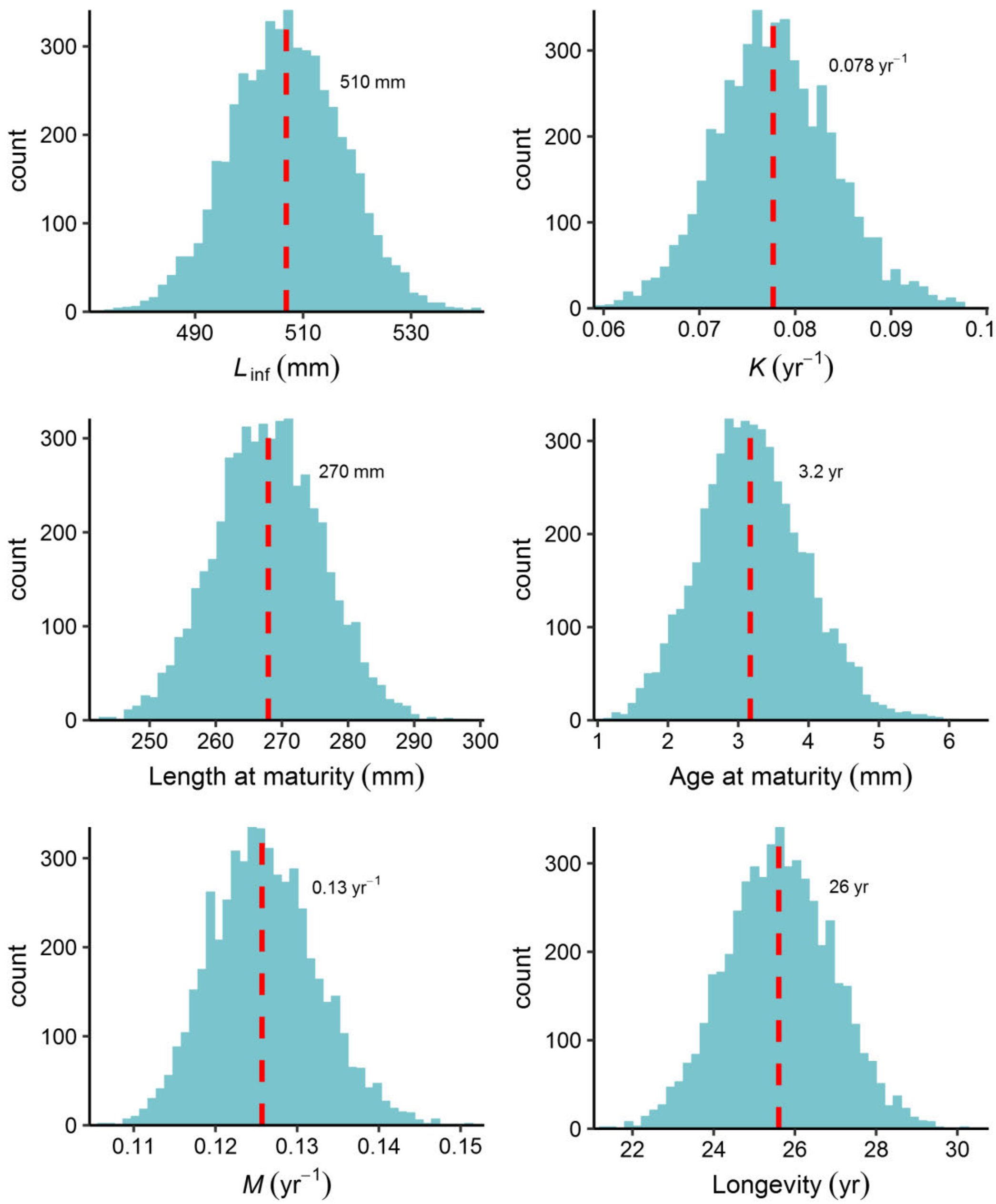
Note: this species is non-native and considered invasive. It was introduced in 1956 from Tahiti.

Population abundance has been stable for the last 10 years, except for a higher estimate in the first year. The commercial catch increased steadily from 2003 to 2011 before going back down. The recreational catch was too variable to infer on any temporal trends. The L_{bar} from the commercial and recreational sector were identical and stable.

The growth parameters for this species came from an in-depth local study. However, the maturity parameter came from a less reliable source. Furthermore, the growth curve did not have juvenile age estimates which explains the highly negative a_0 and the resulting low K value. We could not run the stepwise approach for this species given that the grouper family is not currently available for this method.

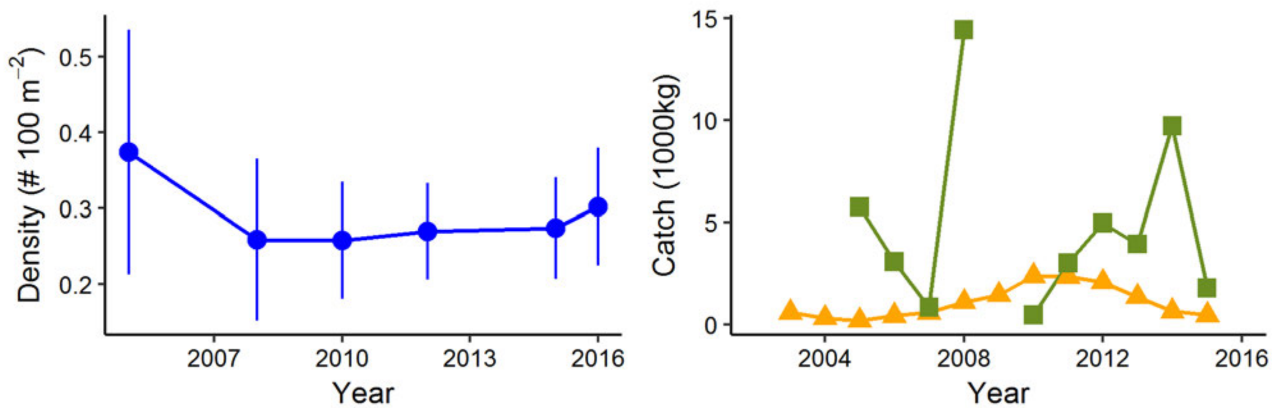
Population estimate from the catch was about a third the size of the population estimate from diver surveys. This is not entirely surprising given that the catch estimate seemed low. For example, the average weight of this species is around 1 kg, which would suggest that only 3000 individuals are caught recreationally every year. This would mean only 8 individuals are caught on a daily basis across the entire island chain, which seems unlikely. The diver survey population should be fairly representative given that this is a commonly encountered species that is easily identified, although it is likely biased downward given that this species' range extends beyond diver depths, to 80 m. Note: no Lc_{30} could be generated given the very low fishing mortality rates.

Cephalopholis argus

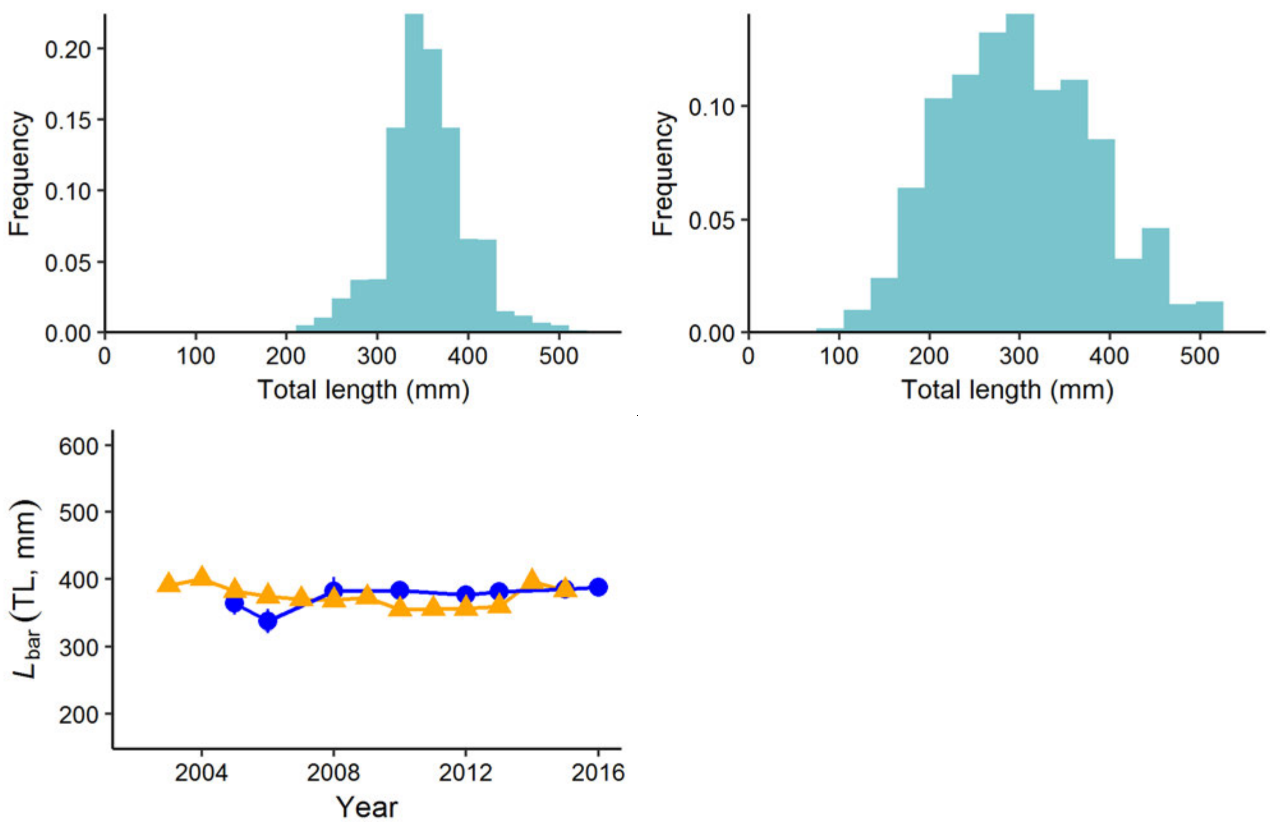


Life history parameter distributions.

Cephalopholis argus

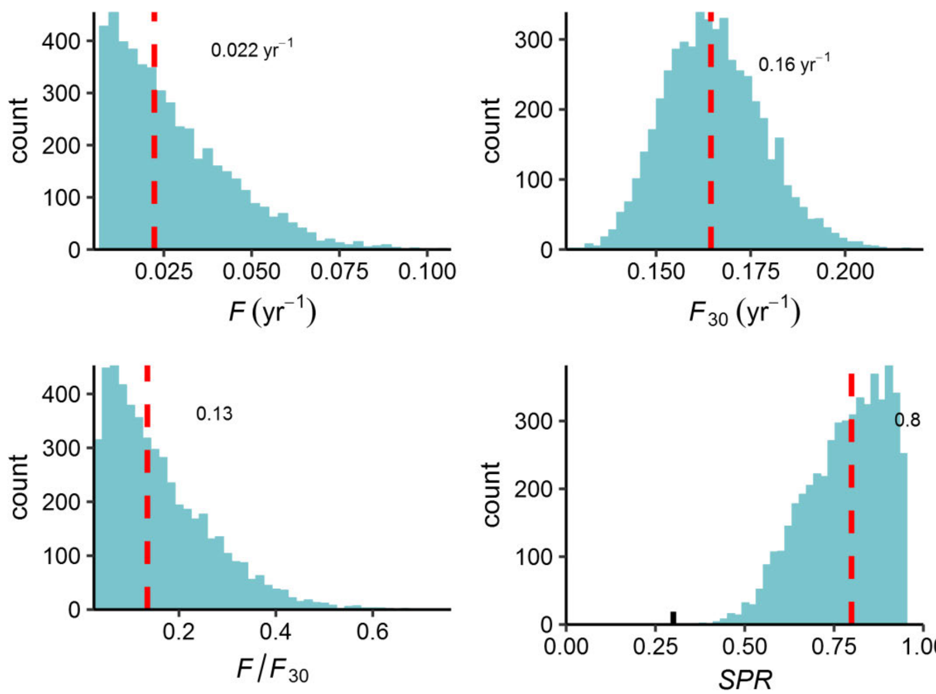


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



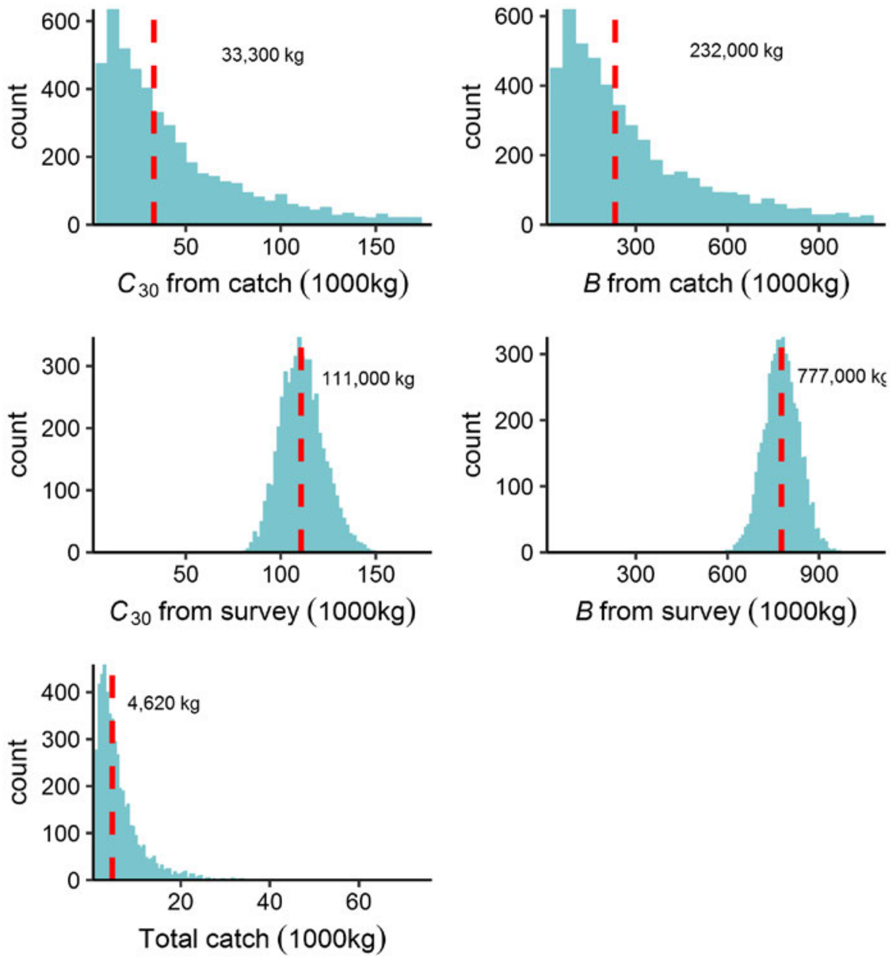
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Cephalopholis argus



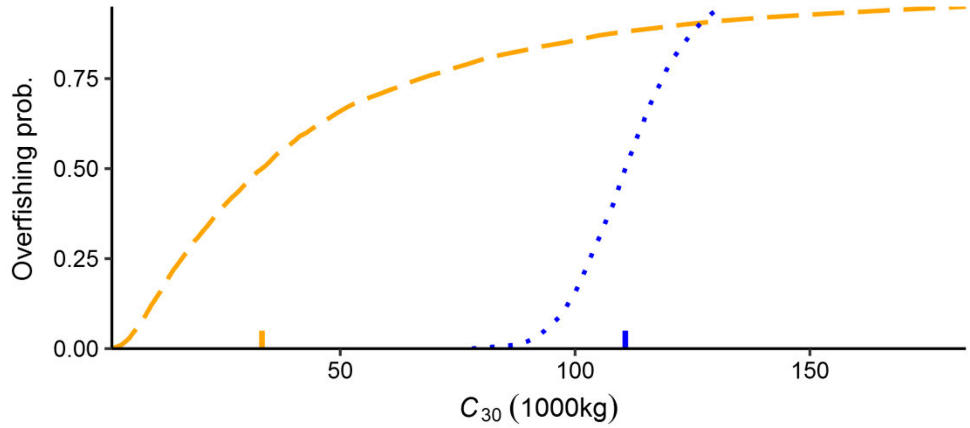
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Cephalopholis argus



C_{30} and current total catch (left) and population size (right) distributions.

Cephalopholis argus



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	8.9	97.1	0.31	19.8	105.4
0.11	9.3	97.6	0.32	20.4	105.7
0.12	9.7	98.1	0.33	21.0	106.0
0.13	10.3	98.6	0.34	21.7	106.2
0.14	10.8	99.2	0.35	22.3	106.5
0.15	11.3	99.7	0.36	22.9	106.8
0.16	11.8	100.1	0.37	23.5	107.1
0.17	12.2	100.4	0.38	24.2	107.4
0.18	12.7	100.9	0.39	24.8	107.7
0.19	13.2	101.2	0.40	25.5	108.0
0.20	13.6	101.6	0.41	26.2	108.3
0.21	14.1	101.9	0.42	26.9	108.6
0.22	14.5	102.4	0.43	27.8	108.9
0.23	15.2	102.7	0.44	28.6	109.2
0.24	15.7	103.2	0.45	29.3	109.4
0.25	16.3	103.5	0.46	30.0	109.7
0.26	16.8	103.9	0.47	30.7	110.0
0.27	17.4	104.1	0.48	31.4	110.4
0.28	17.9	104.5	0.49	32.3	110.7
0.29	18.6	104.8	0.50	33.3	110.9
0.30	19.0	105.1			

Monotaxis grandoculis

Bigeye bream, *mu*
Lethrinidae (emperors)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	527	22	mm	-	Mean and SD: Nadon & Ault (2016) L_{max}: 597 (19) from NWHI diver survey
K	0.37	0.18	yr^{-1}		
a_0	-0.5	-	yr		
L_{mat}	389	28	mm	-	Mean and SD: Nadon & Ault (2016)
Longevity	21	9	yr	-	Mean and SD: Nadon & Ault (2016)
L-W α	1.93e-5	-	-	-	Smith & Dalzell (1993)
L-W β	3.02				
L_{S50}	250	-	mm	-	DAR commercial data
L_{S95}	300				
$\overline{L}$ diver survey	359	7	mm	278	NOAA-CREP diver survey
$\overline{L}$ commercial	448	4	mm	1951	DAR commercial data
$\overline{L}$ combined	425	5	mm	-	-
Max. depth	101	-	m	-	Pyle et al. (2016)
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.15	0.06	yr^{-1}
F	0.12	0.12	yr^{-1}
F_{30}	0.16	0.07	yr^{-1}
F/F_{30}	0.8	0.6	-
SPR	0.38	0.22	-
SPR < 0.30 iterations	36	-	%
Lc_{30}	0	-	Mm

Management information

Parameter	Median	SD	Unit
B from catch	28,600	82,200	kg
B from survey	231,797	49,031	kg
Commercial catch	1,346	1,270	kg
Recreational catch	1,381	1,129	kg
Total catch	2,998	1,668	kg
C_{30} from catch	3,950	11,700	kg
C_{30} from survey	31,700	12,800	kg

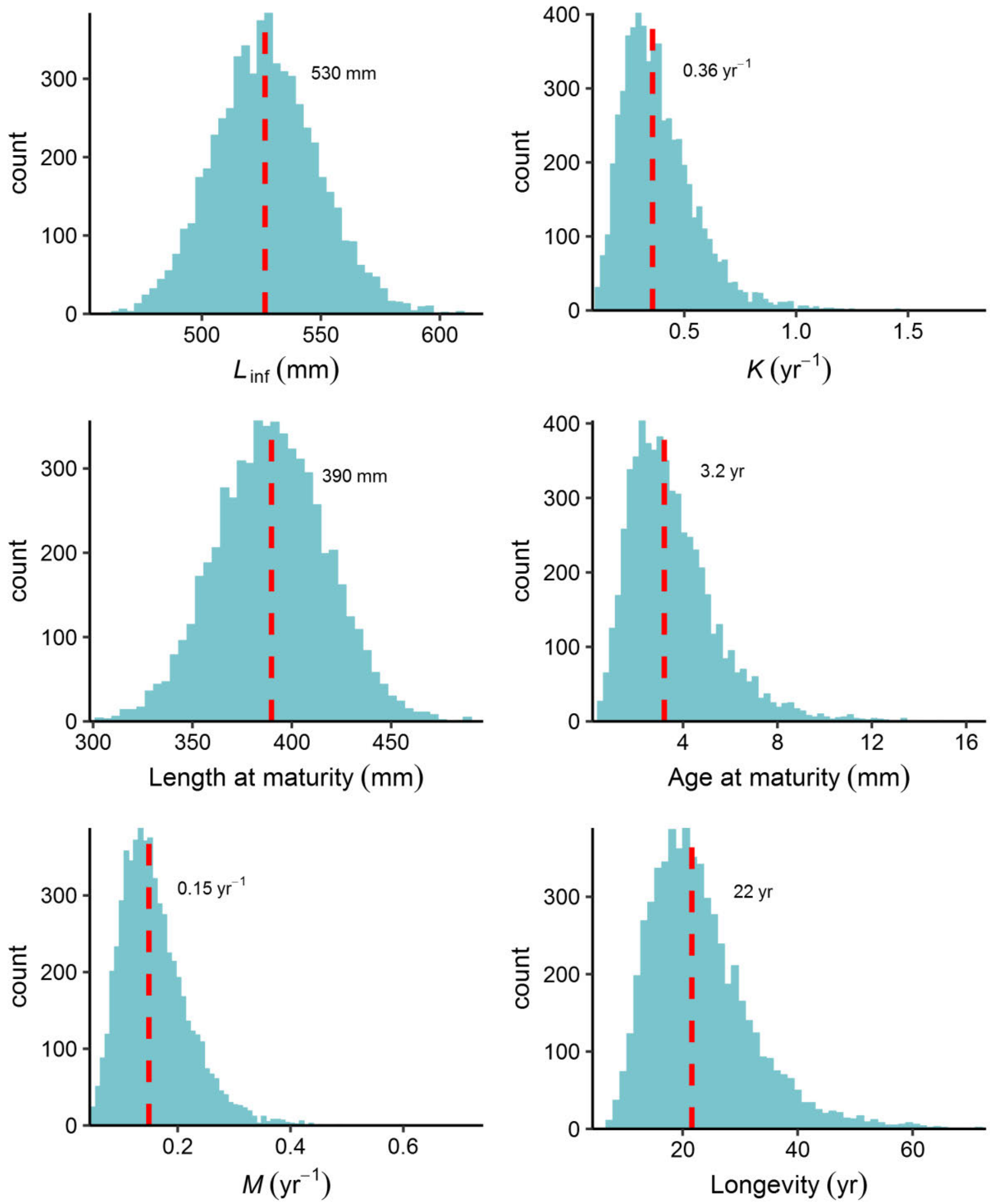
General comments

The population abundance has been stable except for a drastic jump in the last survey year which was likely a statistical outlier. Commercial L_{bar} have been generally steady and higher than the UVS L_{bar}. It is not entirely clear why there is such a discrepancy between L_{bar} sources. The commercial catch increased drastically between 2008 and 2011 before falling quickly again to its original level. The recreational catch was too variable to infer on temporal trends.

There are currently no published life history parameters for this species. We used the stepwise approach to generate LH parameters, using an L_{max} value from NWHI diver surveys. A sensitivity run using an alternate L_{max} value from the MHI UVS (556 mm) generated the following results: L_{inf}: 493 mm, K: 0.45, M: 0.16, F_{30}: 0.18, F: 0.07, *SPR*: 0.59, C_{30} catch: 6,828 kg, C_{30} survey: 35,538 kg.

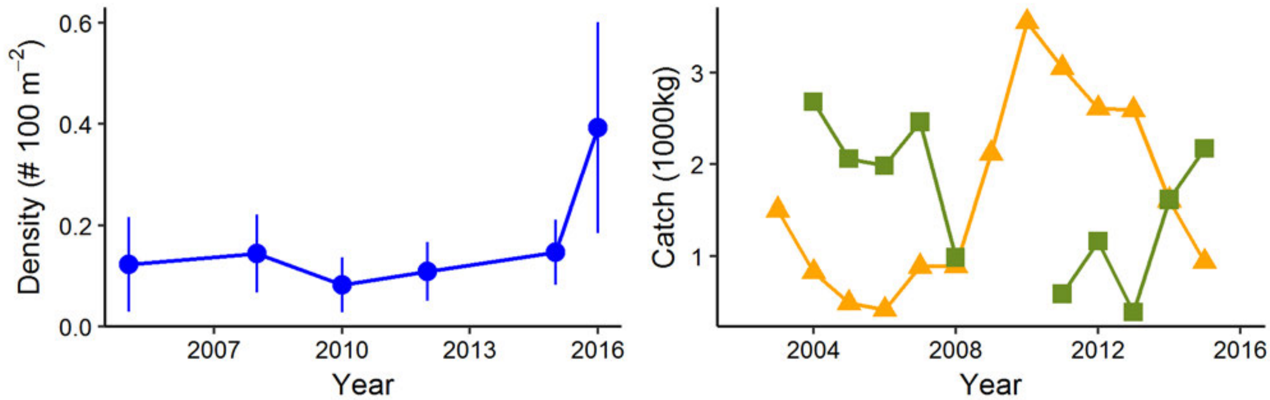
The total catch estimate seemed fairly low for a relatively common and prized species. The population biomass estimate from diver surveys was much high than the catch-derived estimate. The diver survey biomass estimate, and the C_{30} generated from it, is likely more reliable than the catch data for this species.

Monotaxis grandoculis

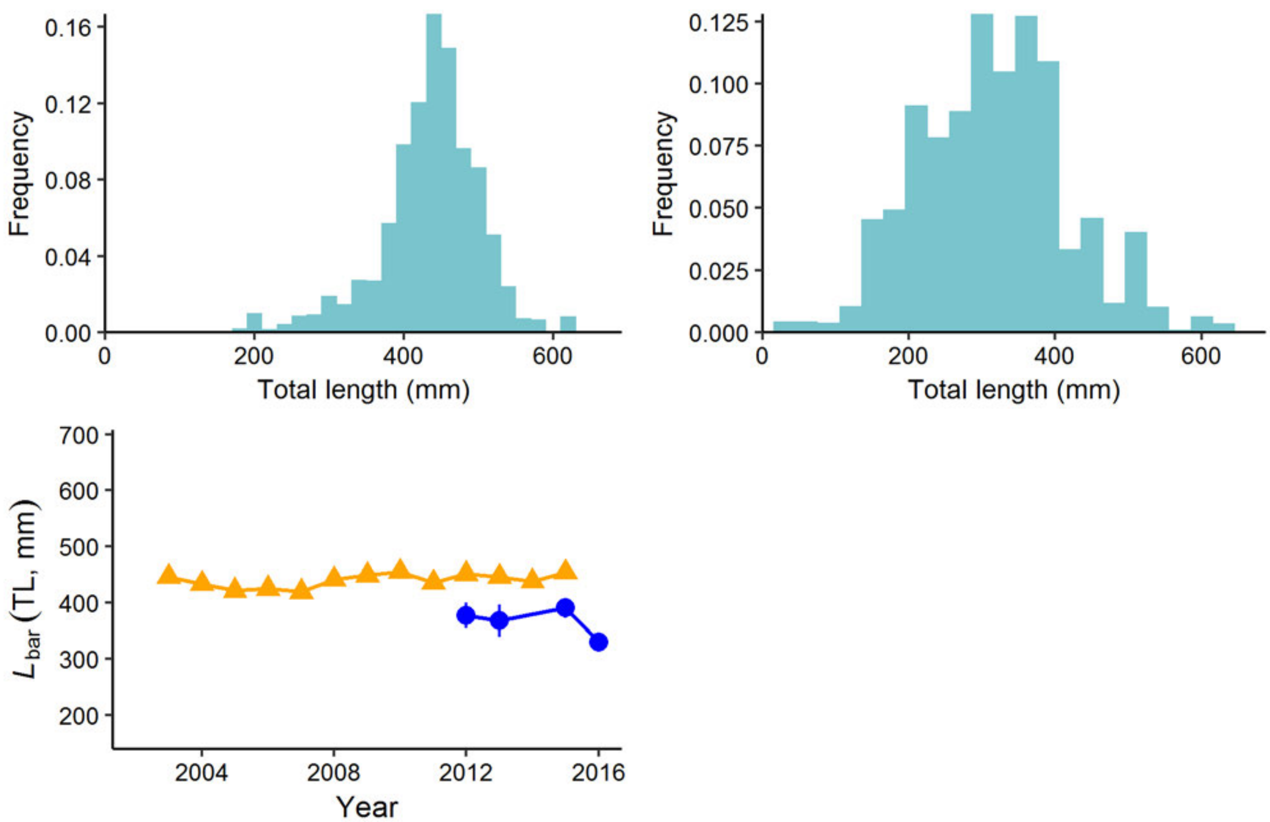


Life history parameter distributions.

Monotaxis grandoculis

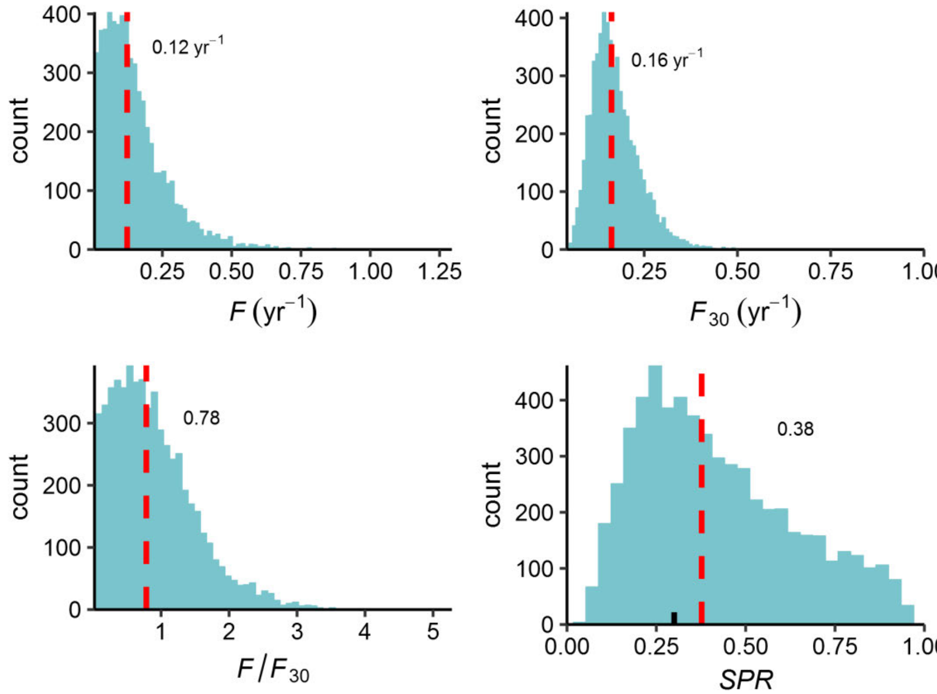


Abundance index from UVS (blue circles, ±SE) and total catch time series from recreational (green squares) and commercial (orange triangles) sectors.



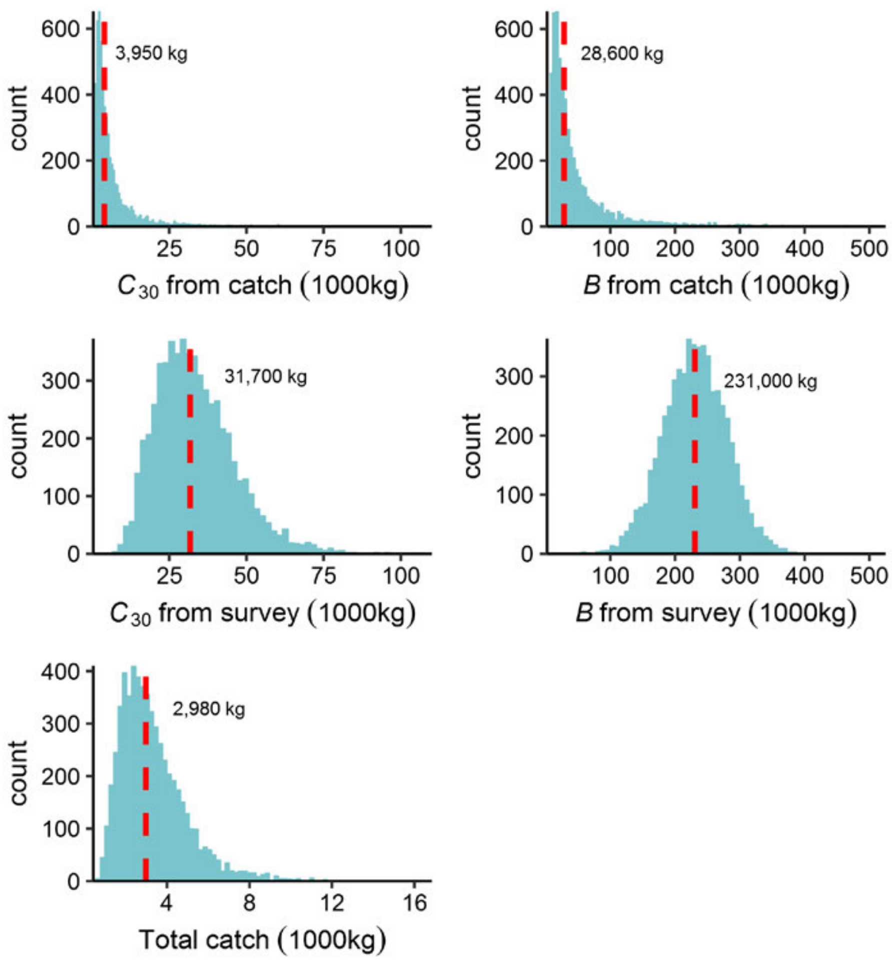
Size structure from commercial catch (top left) and UVS (top right). Average length time series (blue circles – UVS, orange triangles – commercial data, ±SE).

Monotaxis grandoculis



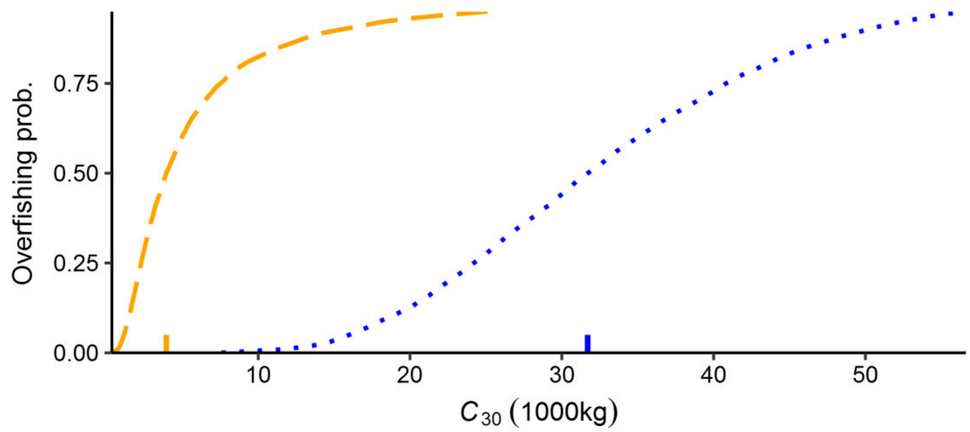
Stock status parameter distributions (*SPR*: small bar shows 0.30 level).

Monotaxis grandoculis



C_{30} and current total catch (left) and population size (right) distributions.

Monotaxis grandoculis



Overfishing probability for a range of C_{30} levels (catch - orange dashed line, UVS – blue dotted line). *OFLs* are represented by small vertical bars.

Probability of overfishing for various C_{30} levels.

Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)	Overfish. probability	C_{30} from catch (1000 kg)	C_{30} from survey (1000 kg)
0.10	1.50	18.7	0.31	2.62	26.0
0.11	1.55	19.2	0.32	2.67	26.3
0.12	1.60	19.7	0.33	2.72	26.6
0.13	1.65	20.2	0.34	2.79	26.9
0.14	1.71	20.5	0.35	2.85	27.2
0.15	1.76	20.9	0.36	2.90	27.5
0.16	1.82	21.3	0.37	2.98	27.8
0.17	1.87	21.6	0.38	3.05	28.2
0.18	1.92	21.9	0.39	3.11	28.5
0.19	1.97	22.2	0.40	3.16	28.7
0.20	2.04	22.6	0.41	3.23	29.1
0.21	2.09	22.9	0.42	3.32	29.4
0.22	2.14	23.3	0.43	3.39	29.7
0.23	2.18	23.6	0.44	3.49	30.0
0.24	2.24	23.9	0.45	3.58	30.2
0.25	2.28	24.2	0.46	3.64	30.5
0.26	2.34	24.5	0.47	3.72	30.8
0.27	2.39	24.9	0.48	3.79	31.0
0.28	2.45	25.1	0.49	3.86	31.3
0.29	2.51	25.4	0.50	3.95	31.7
0.30	2.56	25.7			

Monotaxis grandoculis

Probability of overfishing at various minimum sizes.

Overfishing probability	Lc_{30} (mm)	Overfishing probability	Lc_{30} (mm)
0.10	415	0.31	288
0.11	410	0.32	278
0.12	405	0.33	265
0.13	400	0.34	255
0.14	398	0.35	250
0.15	390	0.36	238
0.16	385	0.37	225
0.17	380	0.38	215
0.18	372	0.39	205
0.19	368	0.40	190
0.20	360	0.41	175
0.21	355	0.42	160
0.22	350	0.43	140
0.23	345	0.44	122
0.24	340	0.45	85
0.25	332	0.46	0
0.26	325	0.47	0
0.27	320	0.48	0
0.28	312	0.49	0
0.29	302	0.50	0
0.30	295		

Myripristis berndti

Bigscale soldierfish, *’u’u*
Holocenridae (soldierfishes)

Life history and other input parameters

Parameter	Value	SD	Unit	n	Source
L_{inf}	271	14	mm	126	Mean: Craig & Franklin (2008), SD: Kritzer (2001)
K	0.148	0.028	yr^{-1}		
a_0	-4.48	-	yr		
L_{mat}	175	5	mm	100?	Mean: Murty (2002) , SD: Nadon (unpublished)
Longevity	27	3.2	yr	126	Mean: Craig & Franklin (2008), SD: Kritzer (2001)
L-W α	2.14e-5	-	-	-	Kulbicki (2005)
L-W β	3.00				
L_{S50}	170	-	mm	-	Estimated with some HMRFS data.
L_{S95}	180				
$\bar{L}$ diver survey	224	4	mm	824	NOAA-CREP diver survey
$\bar{L}$ commercial	-	-	mm	-	-
$\bar{L}$ combined	-	-	mm	-	-
Max. depth	159	-	m	-	Pyle et al. (2016)
Federal waters	22	-	%	-	-

Stock status and other output parameters

Parameter	Median	SD	Unit
M	0.12	0.01	yr^{-1}
F	0.06	0.04	yr^{-1}
F_{30}	0.16	0.02	yr^{-1}
F/F_{30}	0.4	0.3	-
SPR	0.59	0.17	-
SPR < 0.30 iterations	3	-	%
Lc_{30}	-	-	mm

Parameter	Median	SD	Unit
B from catch	-	-	kg
B from survey	260,111	47,848	kg
Commercial catch	-	-	kg
Recreational catch	-	-	kg
Total catch	-	-	kg
C_{30} from catch	-	-	kg
C_{30} from survey	36,100	7,700	kg

General comments

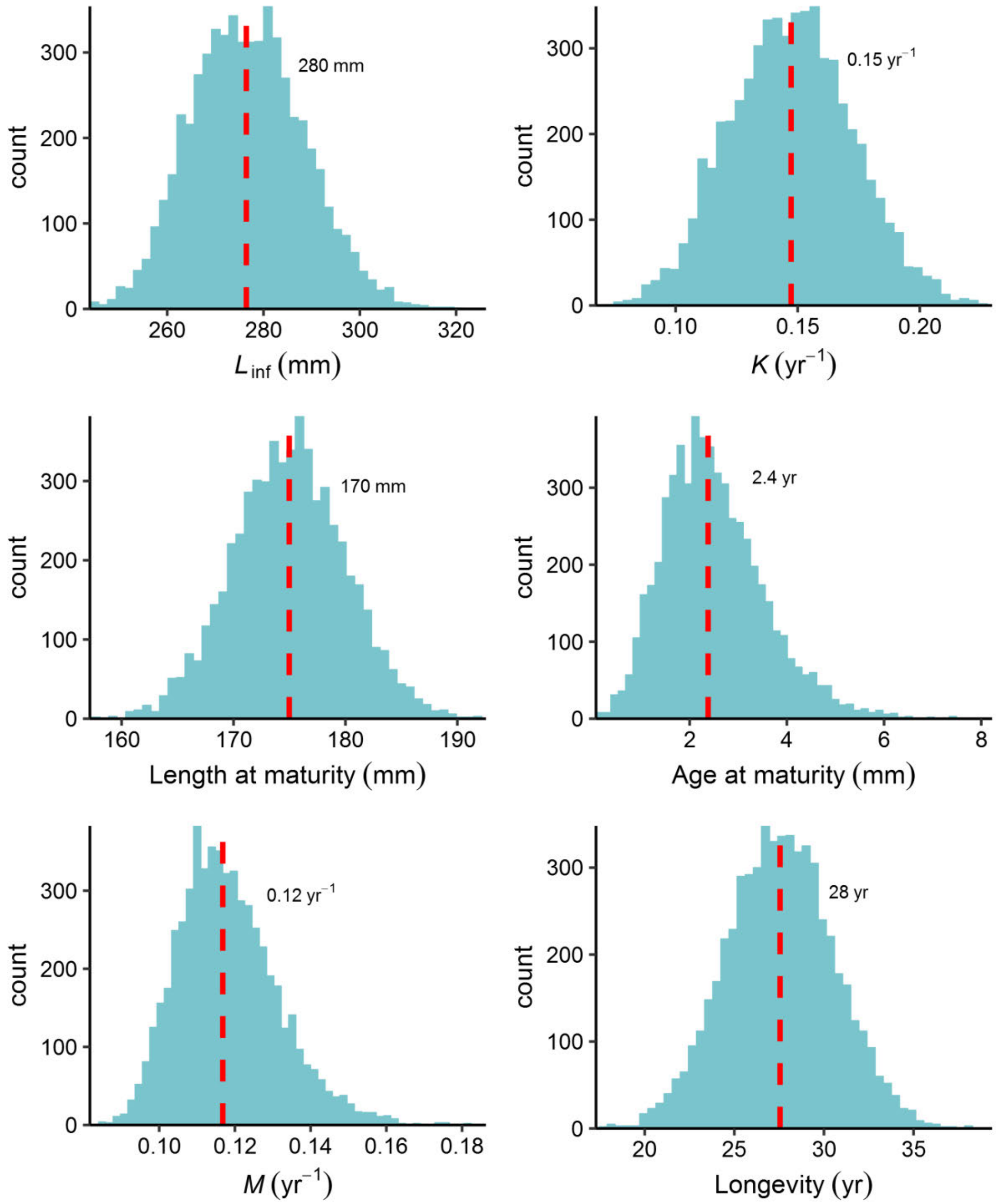
This species is reported with other soldierfishes in the commercial data set, preventing the use of catch data for the current analyses.

Population abundance for this species appear to have been relatively stable. L_{bar} were higher in the earlier survey years (2005–2008) but appear to have declined in 2009, staying relatively stable since then. Selectivity had to be estimated given the lack of catch data. However, there were some length estimates in the HMRFS recreational data set (n = 15) which provided some basis for our estimate. A sensitivity run with L_{S50} at 200 mm and L_{S95} at 220 mm generated similar values (F: 0.07 and SPR: 0.63).

The growth parameters came from a local study. However, the maturity parameter came from a study in India for a different species (*M. murdjan*). Further, the growth study lacked age estimates for juveniles resulting in a fairly negative a0 parameter and low K estimate. We could not run the stepwise approach for this species given that the soldierfish family is not currently available for this method.

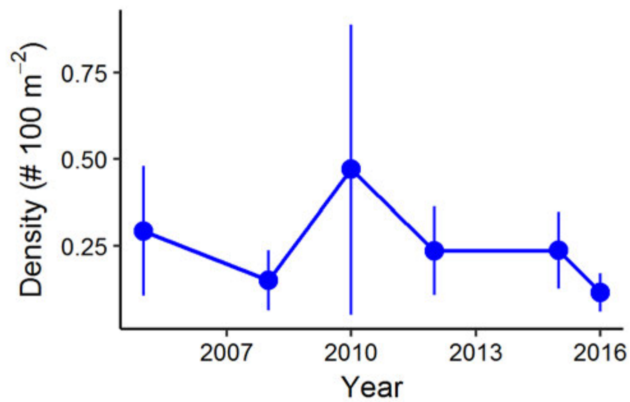
This species occurs at depths much greater than the maximum diver survey depth (159 m vs. 30 m) and it is likely that the population size estimate is bias downward.

Myripristis berndti

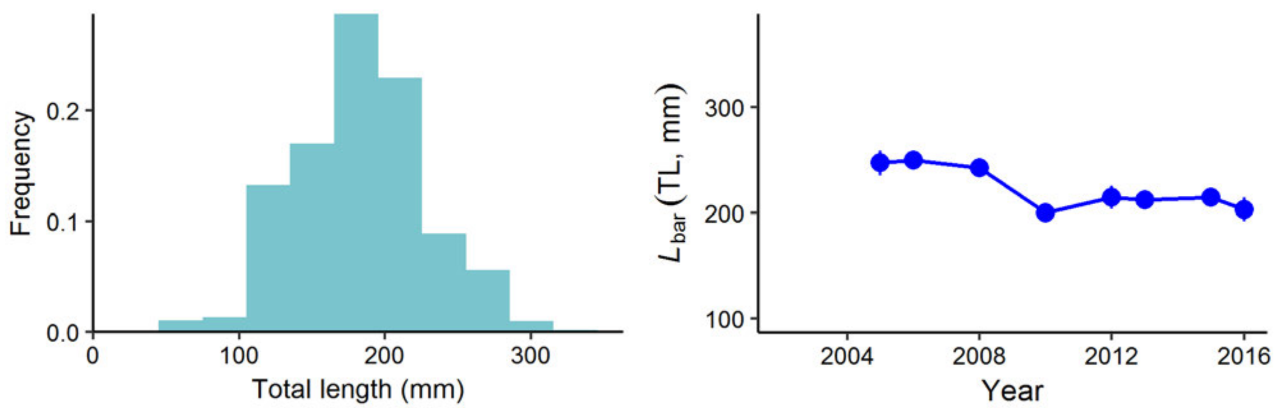


Life history parameter distributions.

Myripristis berndti

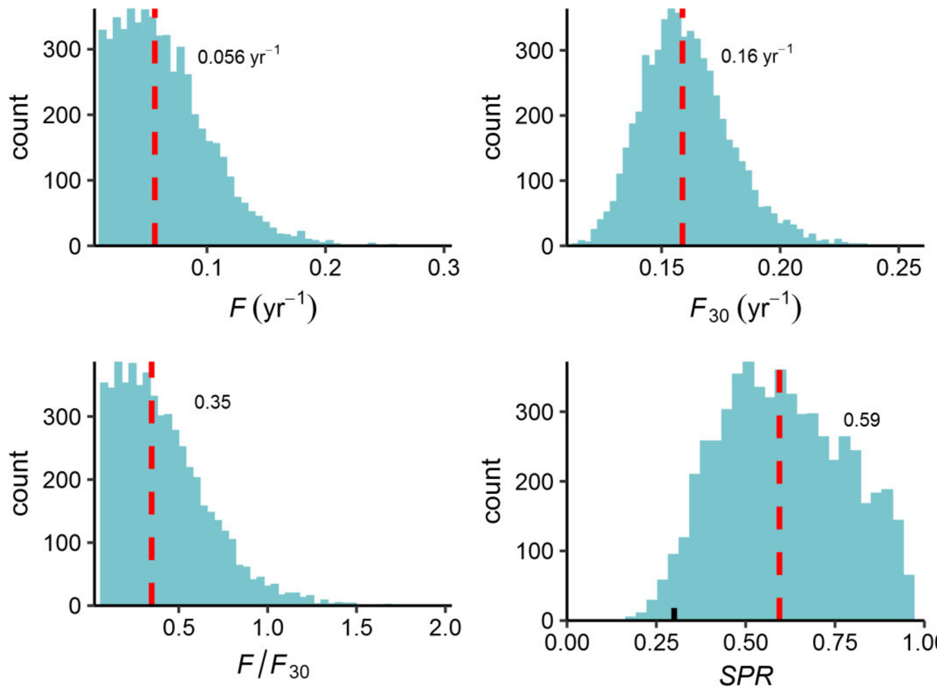


Abundance index from UVS (blue circles, ±SE).

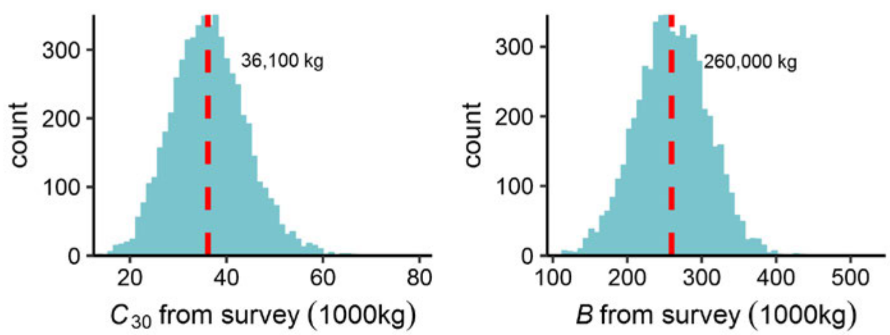


Size structure and average length time series from UVS (±SE).

Myripristis berndti

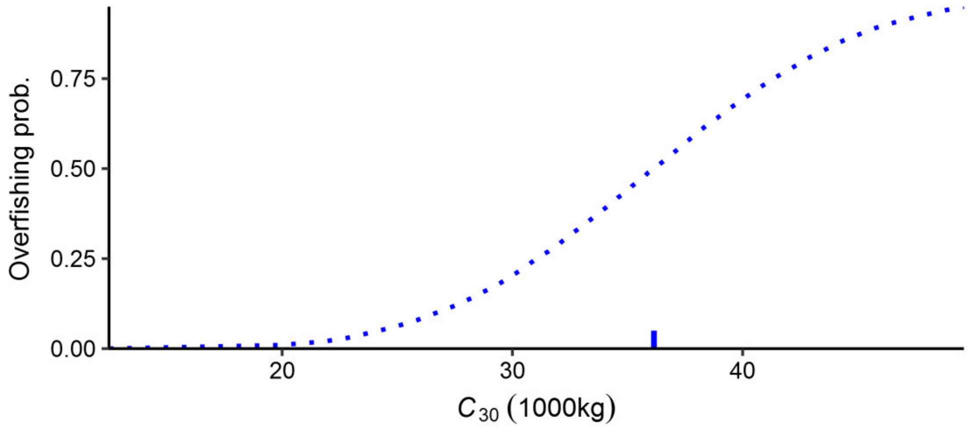


Stock status parameter distributions (*SPR*: small bar shows 0.30 level).



C_{30} (left) and population size (right) distributions.

Myripristis berndti



Overfishing probability for a range of C_{30} levels (UVS – blue dotted line). *OFL* is represented by a small vertical bar.

Probability of overfishing for various C_{30} levels.

Overfishing probability	C_{30} from survey (1000 kg)	Overfishing probability	C_{30} from survey (1000 kg)
0.10	26.7	0.31	32.4
0.11	27.1	0.32	32.6
0.12	27.5	0.33	32.8
0.13	27.9	0.34	33.0
0.14	28.2	0.35	33.2
0.15	28.5	0.36	33.4
0.16	28.8	0.37	33.6
0.17	29.1	0.38	33.8
0.18	29.4	0.39	34.0
0.19	29.7	0.40	34.2
0.20	29.9	0.41	34.4
0.21	30.2	0.42	34.6
0.22	30.4	0.43	34.8
0.23	30.6	0.44	35.1
0.24	30.8	0.45	35.2
0.25	31.1	0.46	35.4
0.26	31.3	0.47	35.5
0.27	31.6	0.48	35.8
0.28	31.8	0.49	35.9
0.29	32.0	0.50	36.1
0.30	32.2		