Life-history and per-recruit assessment of *Lethrinus obsoletus* from Guam

Summitted by

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EXECUTIVE SUMMARY

Age-based demographic data for coral reef fish is scarce for many regions. Such data, however, provides critical baseline information for fishery managers regarding the potential effects of exploitation on the population biology of a species. In this report, specimens confiscated by the Department of Agriculture which were illegally poached from Guam's marine preserves were used to estimate age-based biological parameters of the common orange-striped emperor *Lethrinus obsoletus* for use in future assessments. Using standard otolith technology, the age structure, growth profile, mortality rate and maturation schedule of *L. obsoletus* was estimated. In addition, these parameters were included in a simple per-recruit model to estimate the effects of various management scenarios on the potential yield and reproductive output of future cohorts. Data from this report will be useful for future fishery assessments and add to the growing collection of species on Guam for which age-based life-history parameters are known.

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INTRODUCTION

Age-based life-history data for exploited species are among the most important information available to fishery managers. Without such information, it would be very difficult to predict the response of a species to exploitation. Until recently, age-based studies of tropical reef-fish demography have been rare, largely resulting from the belief that tropical fish do not deposit reliable annual increments in their otoliths (Choat et al. 2009). However, recent studies have demonstrated that while otoliths from tropical fish are more difficult to interpret than those from temperate regions, they consistently provide reliable age estimates across virtually all taxa (Choat & Axe 1996; Choat et al. 1996; Choat & Robertson 2002).

Emperorfish (Family: Lethrinidae) are an important component of many coral reef subsistence, commercial and recreational fisheries (Carpenter & Allen 1989). On Guam, lethrinids are consistently among the top ten targeted families in the nearshore fishery. Two species in particular, *Lethrinus harak* and *L. obsoletus* represent the majority of the reef flat harvest of lethrinids on Guam. Recently, the biology of *L. harak* has been extensively studied on Guam, but little attention has been given to its closely related congener, *L. obsoletus*. Otolith data from Fiji suggest it reaches a maximum age of 14 yrs (Lasi 2003) and in Japan its sexuality has been described as juvenile hermaphroditism, in which sexual transition occurs prior to ovarian maturation (Ebisawa 2006).

In August 2008, over 20 kilograms of reef fish, poached from the Achang Marine Preserve, was confiscated by conservation officers and recorded by the Division of Aquatic and Wildlife Resources (DAWR). These fish were released to the University of Guam Marine Laboratory (UOGML) for use in life-history studies. These specimens supplemented several studies of reef-fish life-history and genetics undertaken by Master's- and PhD-level students at UOGML and James Cook University. This report utilizes the confiscated catch to document life-history parameters of the common orange-striped emperor, *Lethrinus obsoletus* from Guam. Using standard otolith technology, age-based biological parameters were derived and subsequently used in per-recruit analyses to serve as a baseline for future assessment of the species on Guam.

METHODS

Sampling

A total of 35 *L. obsoletus* were confiscated by conservation officers of the Department of Agriculture as part of a large illegally poached catch from the Achang Marine Preserve (Figure 1). These samples were turned over to DAWR and subsequently released to UOGML for scientific study. Samples were collected at night using three pronged spears and underwater flashlights. Specimens were not kept fresh on ice due to the magnitude of the illegal harvest, but were only in an early stage of decomposition when processed so it was still feasible to macroscopically assign sex and maturity stage with high confidence. An additional six specimens were sampled from sites on Guam by the author to fill gaps in the size range. Measurements were taken of fork length (FL) to the nearest millimeter and total weight (TW) to the nearest gram. Sagittal otoliths were removed, cleaned in ethanol, weighed to the nearest 0.001 g, and stored for later sectioning. Gonads were extracted and examined macroscopically to determine sex and development stage. Classification of maturity stages followed that for *L. harak*, a congeneric species with a similar life history. The relationship between FL and TW was estimated using regression analysis.

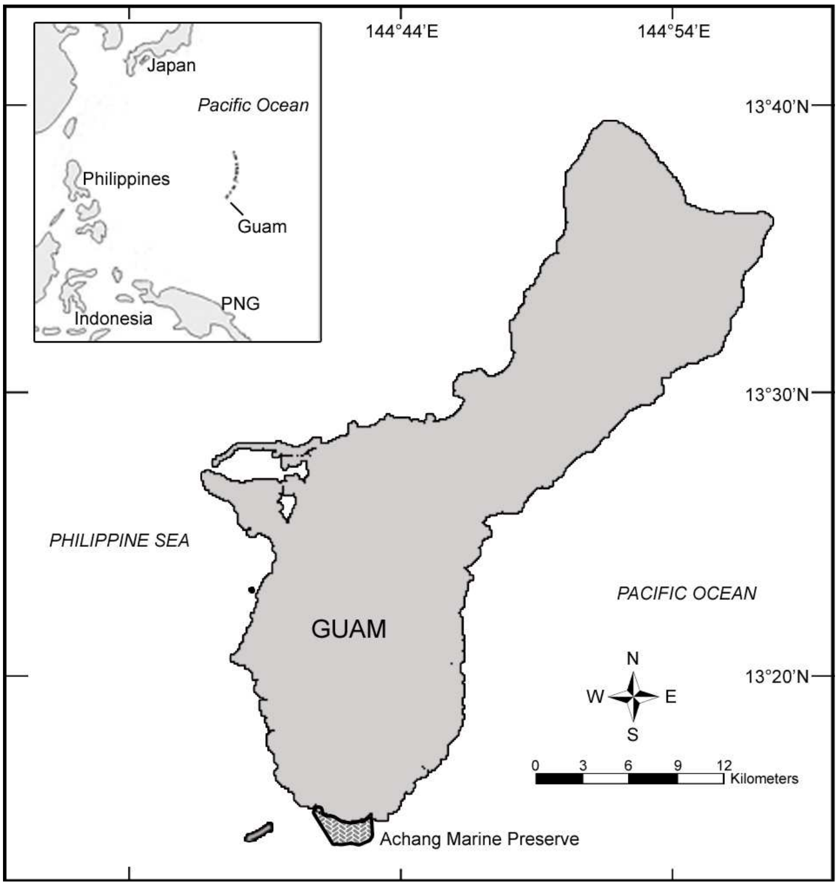

Figure 1. Map of Guam indicating the Achang Marine Preserve, where samples of *Lethrinus obsoletus* were obtained.

Age determination

Sagittal otoliths were mounted in thermoplastic (Crystalbond 509) adhesive on the edge of a microscope slide and ground to the nucleus using 600-grit wet/dry paper fitted to a GEMMASTA GFL8 lapping wheel. The ground face of the otolith was fixed on the slide and the opposite side ground to produce a thin transverse section approximately 300 μm thick. Each section was covered in adhesive and placed on a hotplate (230℃) for approximately 30 minutes to im prove the readability of the opaque bands. These were examined under transmitted light with a low power microscope (20 - 40x). Annuli (represented by alternating translucent and opaque bands) were counted along a consistent axis on the ventral face of the section (Figure 2). Blind readings were made on three separate occasions 1 – 2 days apart. The final age (in years) of an individual was determined when two or more counts agreed (Choat & Axe 1996). The relationship between age and otolith weight was assessed using regression analysis.

The assumption that otolith increments represented annual marks is a safe assumption in the absence of validation procedures (Choat et al. 2009) as this has been validated for this species in Japan (Ebisawa & Ozawa 2009). In addition, otoliths and increment patterns of *L. obsoletus* were very similar to those of other lethrinids which have been previously validated, including on Guam (Brown & Sumpton 1998; Pilling et al. 2000; Grandcourt 2002; Grandcourt et al. 2006; Ebisawa & Ozawa 2009; Taylor & McIlwain 2010).

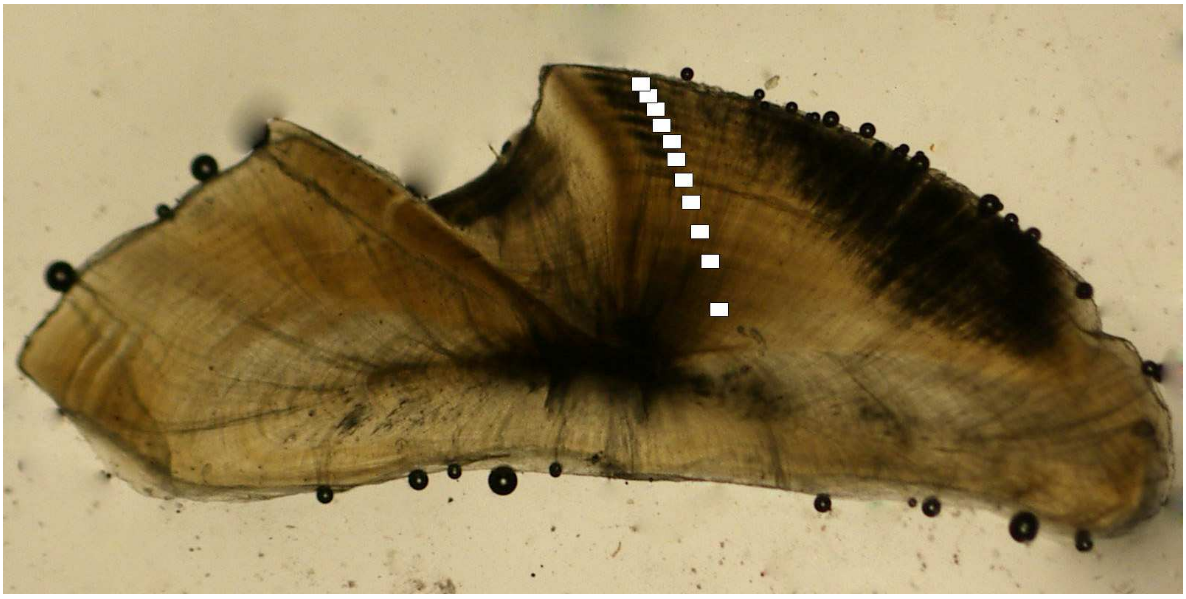

Figure 2. Transverse section of an otolith from an 11 year-old *Lethrinus obsoletus* from Guam.

Age, growth, mortality and maturity

The von Bertalanffy growth function (VBGF) was fitted to length-at-age estimates using non-linear least squares estimation. The VBGF is represented by,

$$L_t = L_\infty \{1 - \exp[-K\ (t - t_0)]\},$$

where L_t is the FL of a fish at age t, L_∞ is the mean asymptotic FL, K is the growth coefficient which describes the rate at which fish grow towards L_∞, t is the age of the fish, and t_0 is the theoretical age at which FL is equal to zero, as described by the growth rate. To promote a better fit to the size-at-age data, no constraint for size at settlement was placed upon the y-intercept.

Mortality was estimated using an age-based catch curve. The natural logarithm of the number of fish in each age class was plotted against its corresponding age, and total mortality (Z) was estimated as the absolute value of the slope from a fitted line (Ricker 1975). Age classes not fully recruited to the fishery were excluded for this analysis. Natural mortality (M) was tenuously assumed to be equal to Z from catch curves as samples were obtained from a marine protected area where fishing mortality (F) theoretically equals zero.

The size and age at 50% maturity were estimated by plotting the proportion of mature individuals against the length and age classes and fitting a logistic equation to the data.

Per-recruit assessment

Per-recruit analysis was used to model the potential yield and reproductive potential per recruit for *L. obsoletus* on Guam. Spawner biomass per-recruit (SBR) and yield per-recruit (YPR) were calculated for fishing mortalities ranging from 0 to 1 yr^{-1} to evaluate the effects of modifying the instantaneous fishing mortality and the size or age at first capture. The SBR was calculated as follows:

SBR = SB / R

$$= \sum_{t=0}^{t_{max}} \exp\ (-((F\ \cdot\ S_t) - M)\ t)\ W_t\ \mathrm{G_t}$$

where SB is the total spawner biomass (in g), R is the number of recruits (set to 1), F and M are the fishing and natural mortality rates, respectively, W_t is the weight at age *t*, t_{max} is the maximum observed age in the fishery (calculated in months), and $\mathrm{G_t}$ and S_t are the fraction of mature fish and the gear selectivity at age *t*, respectively. Maturity and selectivity were logistic equations calculated as the proportion of mature individuals and the probability of capture by age.

Growth parameters from the unconstrained VBGF fitted to weight-at-age data and the natural mortality rate (M) were used to construct the YPR stock assessment model as follows:

YPR = Y / R

$$= \sum_{t_c}^{t_{max}} \mathrm{F}\ \ N_t\ W_t$$

where Y is yield, t_c is the age at first capture, t_{max} is the maximum age in the fishery, N_t is the number of individuals alive at age t. I employed a modified version of the classic Beverton & Holt (1957) YPR model (taken from Sparre et al. (1989)) to estimate yield for various sizes or ages at first capture across a range of fishing mortalities.

RESULTS

A total of 42 *L. obsoletus* were obtained, ranging in size from 132 – 295 mm FL. Of these, 33 were identified as female and 5 were identified as male, while 3 individuals remained unsexed. Individuals ranged in age from 1 to 11 years. Males on average were larger (213 vs 190 mm FL) and older (4.6 vs 3.6 yrs) than females, although the largest and oldest individuals were female.

Age (in years) was assigned to 41 of the 42 individuals. There was a very strong relationship between otolith weight and age (r^2 = 0.97, $F_{1,38}$ = 1397, $p < 0.0001$;

Figure 3). The species is relatively slow-growing with VBGF parameters as follows: L_∞ = 305.6 mm FL, K = 0.176 yr^{-1}, t_0 = -2.52 yrs (Figure 4).

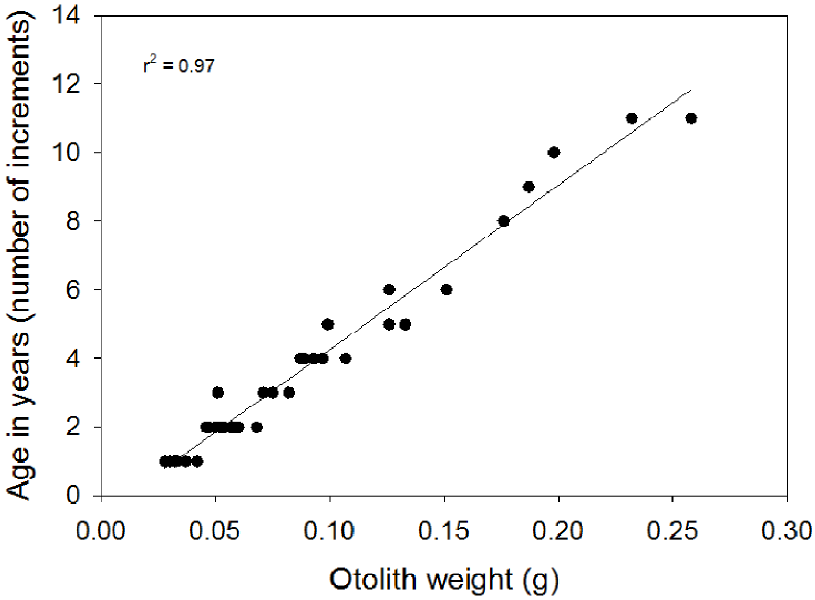

Figure 3. Regression of otolith weight and age for *Lethrinus obsoletus* on Guam.

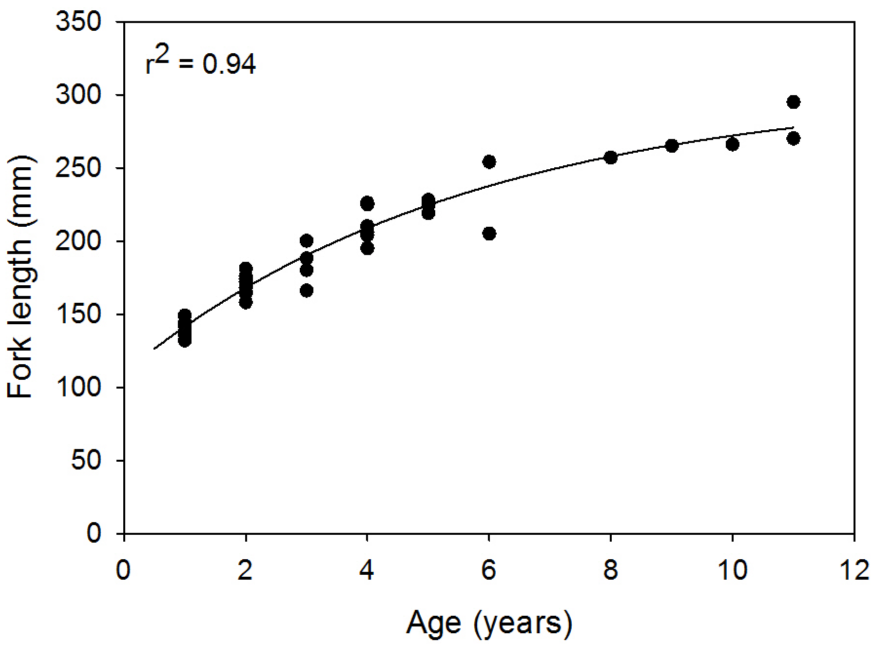

Figure 4. Von Bertalanffy growth function (VBGF) fitted to length-at-age data for males and females combined.

The modal age group in the derived age-frequency distribution was 2 years, indicating that 0+ and year 1 individuals were not fully selected for by the sampling technique (Figure 5). The total mortality estimate from the age-based catch curve was 0.235 yr-1 (Figure 6).

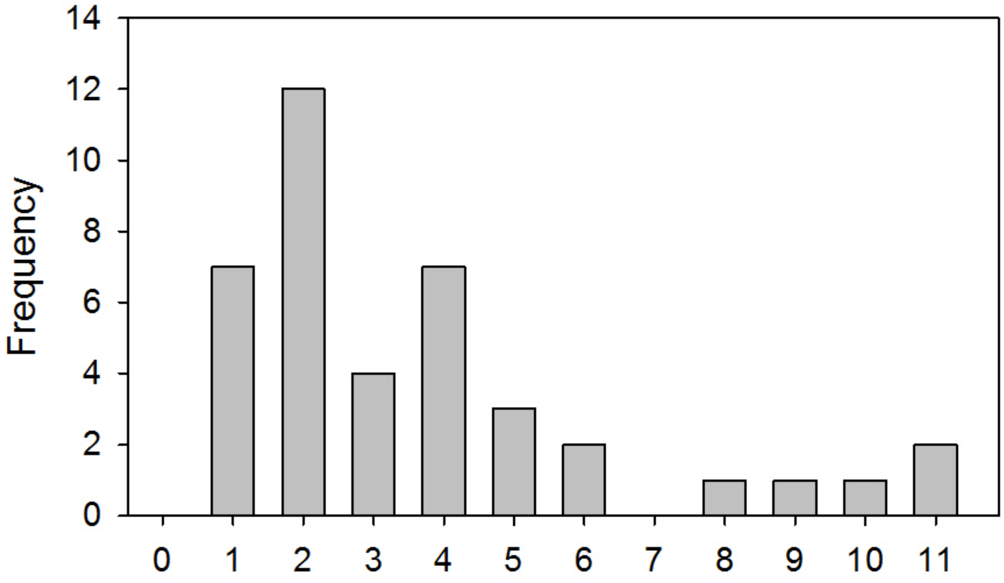

Figure 5. Age-frequency distribution for *Lethrinus obsoletus*.

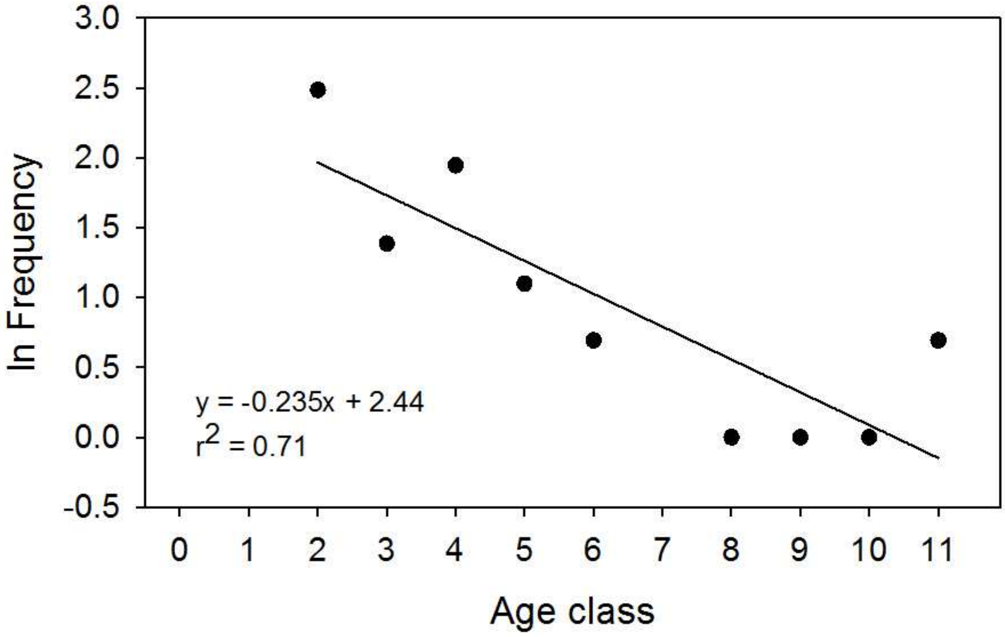

Figure 6. Age-based catch curve for *Lethrinus obsoletus*.

Length and age at maturity is plotted in Figure 7 (A and B, respectively). Length at 50% maturity L_{50} was approximately 210 mm FL (Figure 7A). Age at 50% maturity was approximately 3.9 years (Figure 7B). There was a very strong relationship between FL and TW (r^2 = 0.99), which was described by the power function TW = $(2.13*10^{-5})\ FL^{2.978}$ (Figure 8).

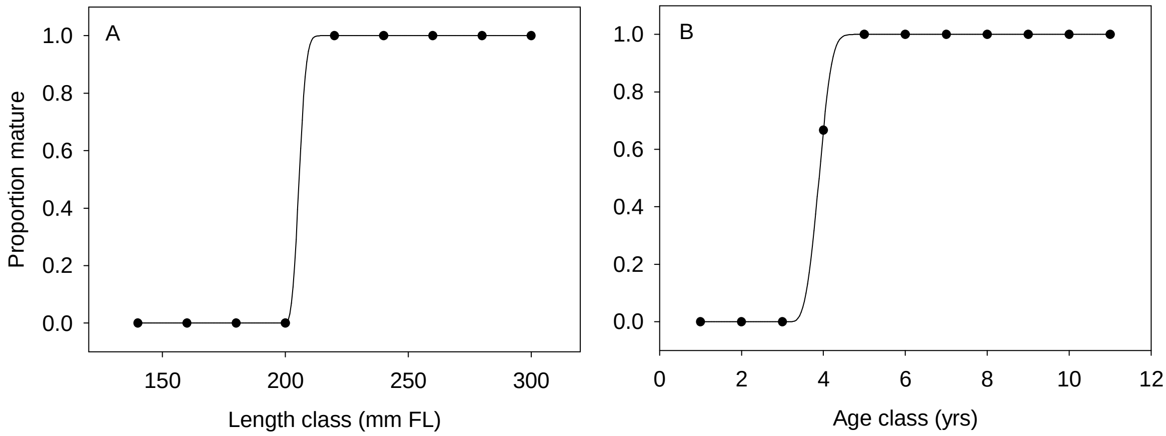

Figure 7. Proportion of mature individuals regressed by (A) length and (B) age class for *Lethrinus obsoletus* on Guam.

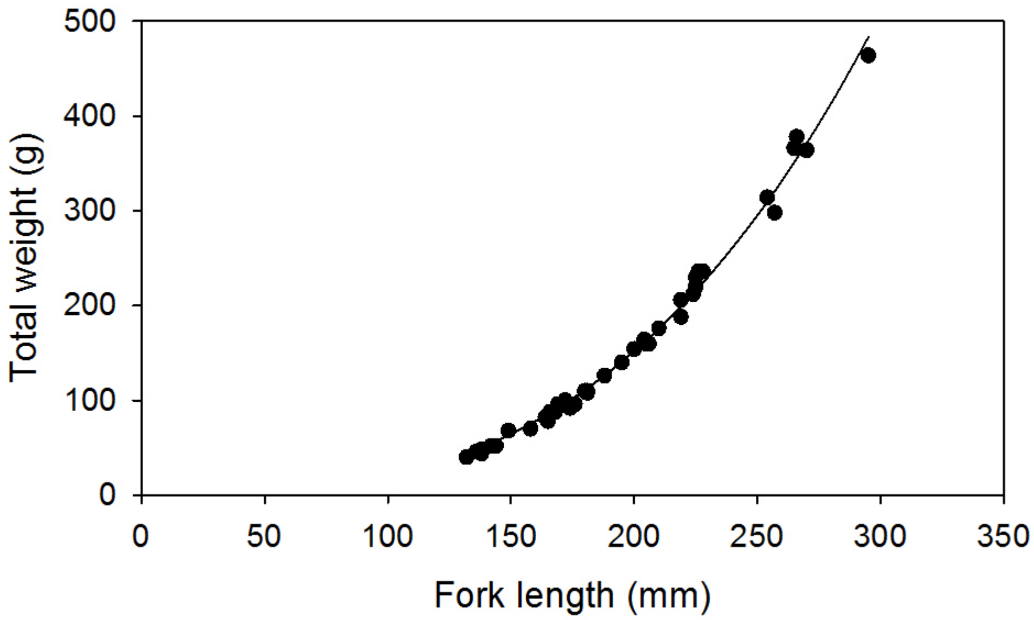

Figure 8. Relationship between fork length and total weight for *Lethrinus obsoletus* on Guam.

The yield per-recruit model (YPR) revealed that highest yields are achieved with no size limit at lower fishing mortalities and with a size limit of 19 cm (3 yrs) at higher fishing mortalities (Figure 9 A). However, these scenarios result in a subsequent low spawner biomass per-recruit estimate (Figure 9B). Increased limits to 22.5 cm (5 yrs) and 25 cm (7 yrs) FL would increase spawner biomass considerably at levels of fishing mortality, with a tradeoff of ~22% and ~48% of the potential yield, respectively.

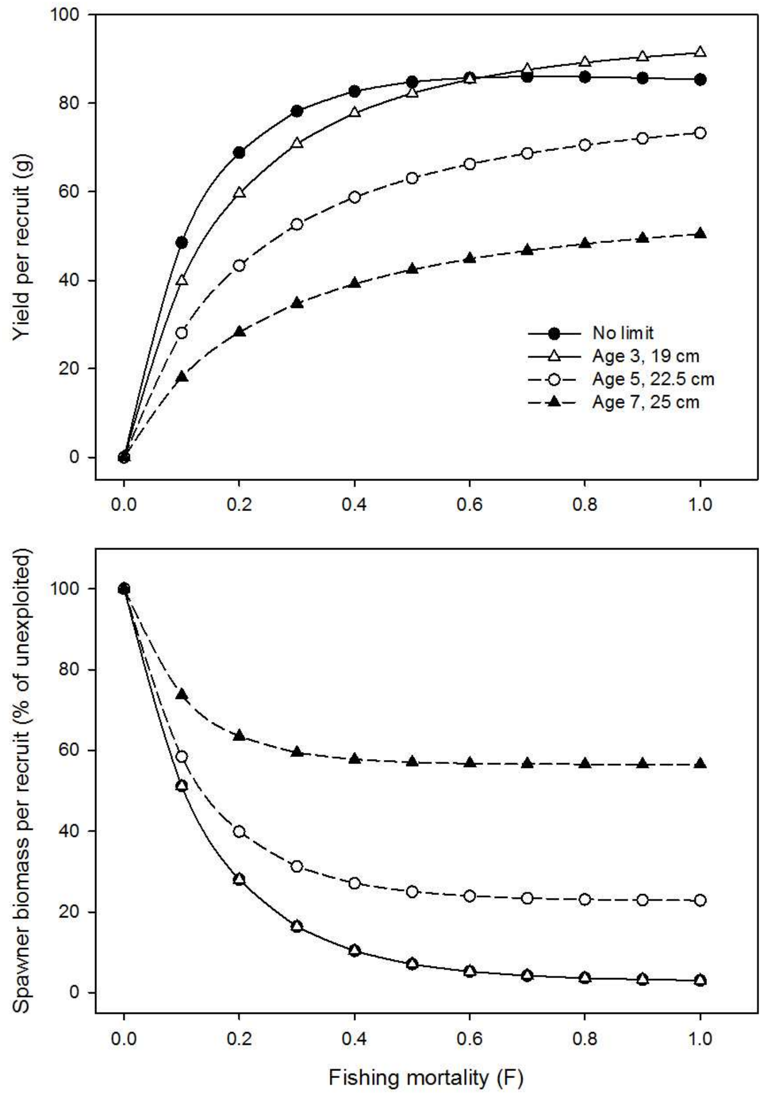

Figure 9. (A) Yield per-recruit and (B) spawner biomass per-recruit model trajectories for various ages and sizes at first-capture scenarios.

DISCUSSION

Lethrinus obsoletus on Guam is relatively slow-growing and late maturing, suggesting a high vulnerability to overexploitation. Age and growth parameters were very similar to those of its congener *L. harak* on Guam, and the species exhibits patterns of growth common among other tropical lethrinids. Evidence suggests that the VBGF provides a poor fit to length-at-age data of many lethrinids when the growth curve is constrained to a given size-at-settlement (Grandcourt 2002; Grandcourt et al. 2006; Taylor & McIlwain 2010; present study).

Model predictions in the present study indicate that an increased size at initial fishery selectivity would greatly benefit the reproductive capacity of *L. obsoletus* on Guam. Instituting size limits would be an obvious approach, although such specific management action is difficult to effectively implement in such a complex multi-species fishery. Recent efforts have been made by local managers to improve awareness regarding size-selectivity and species-specific maturation size in an endeavor to reduce growth overfishing on Guam. Future management may benefit from implementing individual bag limits for species groupings.

The primary purpose of this report was to document age-based life-history parameters of *L. obsoletus* on Guam. Acquiring life-history data from illegally poached specimens is beneficial for a number of reasons: 1) it supplements scientific collections, 2) it reduces the impact of scientists who require samples from protected areas, and 3) it takes a potentially harmful and negative act (poaching) and yields data which can be used to further improve management of coral reef resources. In fact, using such a technique may potentially yield accurate estimates of natural mortality, a parameter which is extremely important in fisheries biology yet rarely measured with high confidence. Because fishing pressure theoretically does not exist in well-protected MPAs, age structures sampled from MPAs have been considered a good predictor of natural mortality (assuming the duration of protection equals or exceeds the maximum lifespan of the species in question) (Bohnsack 1990; Russ et al. 1998; Taylor & McIlwain 2010). Due to the low sample size in the present study, the natural mortality estimate did not yield high confidence. However, further work such as combining age-length keys with visual survey data is an ideal method for estimating population age structure and mortality.

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