Size and Reproduction of Exploited Reef Fishes at Kamiali Wildlife Management Area, Papua New Guinea

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Honolulu, Hawaii
November 2013

COVER

A bird's eye view of the shoreline inhabited by most residents of Kamiali Wildlife Management Area. Photo: Ross Langston.

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Bishop Museum Technical Report 62

Honolulu, Hawaii
November 2013

Bishop Museum Press
1525 Bernice Street
Honolulu, Hawai‘i

ISSN 1085-455X

Contribution No. 2013-008 to the Pacific Biological Survey

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EXECUTIVE SUMMARY

The Kamiali Initiative is a Bishop-Museum-led project to develop a self-sustaining cycle of environmental conservation, scientific research, and economic development in the coastal community of Kamiali, Papua New Guinea. The area includes approximately 120,000 acres of terrestrial and marine habitat, and is larger than most state parks in California. In fact, Kamiali's territory is larger than that of 16 countries. The success of the Kamiali Initiative is contingent upon ~ 600 Kamiali residents preserving the natural environment such that biological field researchers are motivated to work in the area. This project is arguably the most successful and is the only fully sustainable large-scale terrestrial/marine biodiversity conservation project in Papua New Guinea.

The most-challenging conservation issues at Kamiali center on coral-reef fishes. Fish are the source of the overwhelming majority of dietary protein for this coastal village, and coral-reefs are preferred fishing sites. To be successful, conservation practices must balance the conflicting needs of protecting fish populations (to attract researchers) against the cultural value of and dietary need for subsistence fishing.

Here we describe the status of Kamiali's exploited reef-fish populations to help guide and evaluate conservation efforts. We conducted rapid, histology-based reproductive analysis on four species to generate parameters necessary for life-history-based management of fisheries, described catch characteristics of the most common species and evaluate the sustainability of the fishery, used a combination of advanced diving technology and laser videogrammetry to augment our 2009 – 2012 descriptions of the size structure of exploited species (a total 84 species are covered in this report), expanded a literature review of reproductive parameters, estimated the percentage of reproductive individuals in each population (when sufficient information existed), and plotted a time series of average length for the most-consistently abundant species to examine long-term trends in fish size.

Results of reproductive analysis of *Caesio cuning* (*luduŋ mai*) and *Lethrinus erythropterus* (*kada maba*) are presented in Longenecker *et al*. (in review). To summarize, for *C. cuning*, the fork length (FL) at which 50% of individuals are mature (L_{50}) is 12.6 cm for males and 15.3 cm for females. Overall sex ratio of mature individuals is not significantly different from 1:1; however sex-ratio does vary predictably with length. Females dominate size-classes from 17 - 20 cm FL and males are more abundant in smaller and larger size classes. The species is a batch-spawning gonochore (*i.e.*, it does not change sex). Batch fecundity (BF) is an exponential function of length [$BF = 0.1163(FL)^{4.2796}$], but size-specific sex ratios cause per-individual egg production to peak at 19.2 cm FL and rapidly decline toward zero with increasing fish length. Total body weight (W) is an approximately cubic function of length [$W = 0.0208(FL)^{3.0322}$]. For *L. erythropterus*, minimum size-at-maturity (L_m) is 19.2 cm FL for males, and female L_{50} is 20.4 cm FL. Overall sex ratio of mature individuals is not significantly different from 1:1; however sex-ratio does vary predictably with length. Males dominate size classes > 21 cm. The species is a batch-spawning, protogynous hermaphrodite (*i.e.*, changes sex from female to male). $W = 0.0145(FL)^{3.0976}$ for all specimens, but the length-weight relation differs between sexes. L_m of *Myripristis adusta* (*imbilĩ tombo gabo*) is 15.7 cm FL for males and 16.5 cm for females. The species is a batch-spawning gonochore. $W = 0.0123(FL)^{3.2627}$. L_m of *Plectropomus oligacanthus* (*ikula su tatalõ*) is 50.5 cm FL for males and 27.3 cm for females. The species is a batch-spawning protogynous hermaphrodite. $W = 0.0042(FL)^{3.3133}$.

Harvest of *Caesio cuning* (*luduŋ mai*) at KWMA appears biased toward larger individuals. A catch of 137 fish yielded 15.23 kg. The same yield can be obtained by harvesting only 96 fish distributed evenly amongst the 17 – 21 cm size classes. Under the latter scenario, more individuals would grow to reproductive size and promote population growth.

A total 666 individuals were captured on video during 2012, yielding a combined total of 3,944 individuals representing 84 reef-associated species from 19 families (inclusive of 2009 – 2012 data). An exploited reef fish swimming in Kamiali Wildlife Management Area is likely to be about 3/5 of its potential maximum length, and 11% shorter than the length at which maximum yield can be obtained. Size-at-maturity is known for 49% of the species studied. Of these, mean individual length was 100% of female L_{50}. Sex-ratios are known for 28 species. Considering only these species, an average 31% of individuals are mature females.

For the five most-consistently abundant species, 3-year moving averages of length suggest size is relatively stable. Average length for all species is near female L_{50}.

Based on the apparent ease with which residents are able to catch fish, overfishing does not currently appear to be a threat to the majority of the exploited reef-fish species we examined. We propose that the population characteristics of species we studied at Kamiali Wildlife Management Area (average size >½ of maximum length and equal to female reproductive length) can be used as indicators of robust populations of exploited fishes.

These aspects of exploited fish populations are apparently maintained by several characteristics of the village and its fishery, such as: customary tenure, distance (and relatively high cost of transport) to commercial markets, a subsistence economy, lack of refrigeration, and environmental cycles. Ongoing and anticipated changes related to economic modernization may threaten these aspects of village life. The Kamiali Initiative, by establishing a pathway to economic development that starts with environmental conservation, should help reduce the environmental impact of socioeconomic transformation.

INTRODUCTION

Kala Pronunciation Guide

To help our target audience (coastal residents of the Huon Coast, Papua New Guinea) better understand the information presented in this report, we present the Kala fish names used by residents of the Kamiali Wildlife Management Area (including 17 names not previously recorded). Kala is the vernacular (or native) language of approximately 2,000 people from six villages along the Huon Coast.

English speakers will recognize most Kala letters. Shared consonants are pronounced the same in both languages; however English speakers may hear the Kala "l" as an English "r". The Kala language has ten vowels. It also has a consonant not used in English. The following pronunciation guide is paraphrased from DeVolder *et al*. 2012:

- a is pronounced "a" as in apple.
- e is pronounced "ay" as in way.
- i is pronounced "ee" as in see.
- o is pronounced "oa" as in boat.
- u is pronounced "oo" as in boot.
- The diacritical mark ~, called a *titi* (meaning wave) in Kala, may appear with any vowel (ã, ẽ, ĩ, õ, ũ) and indicates the vowel is nasalized. That is, air is let into the nasal cavity during pronunciation.
- ŋ is pronounced "ng" as in song.

General Background

This report presents the results of research focused on exploited reef fishes at Kamiali Wildlife Management Area, Morobe Province, Papua New Guinea in 2013, and discusses the most current research in the context of previous, related work in the area (Longenecker *et al*. 2009, 2010, 2011, 2012). Our descriptions of the reproductive and population-level characteristics of these fishes are crucial for the success of the Kamiali Initiative, a project to develop a self-sustaining cycle of environmental conservation, economic development, and scientific research. The foundation of this initiative is the residents of Kamiali, who hold title to their territory and traditional tenure over their natural resources.

Kamiali residents established the Kamiali Wildlife Management Area (KWMA) in 1996. It contains 32,000 hectares of terrestrial habitat and 15,000 hectares of adjacent marine habitat. KWMA is remote, located about 65 kilometers south of the port town of Lae. There are no roads to (or in) the village. Its approximately 600 residents obtain most of life's needs from the surrounding environment.

Gardening and subsistence fishing are the economic basis throughout much of Papua New Guinea (PNG) and are a focus of life in many villages; however, residents need money for basic supplies and services (*e.g.*, medicine, education, and clothing). These needs, combined with a lack of income, have made exploitation of natural resources (*e.g.*, logging, mining) a tempting short-term source of money elsewhere in PNG. However, logging and mining in PNG often result in disastrous long-term environmental and social impacts. In the interest of conserving their natural resources, and thus preserving their traditional lifestyle, Kamiali leaders signed, in 2006, a Memorandum of Understanding with Bishop Museum outlining the development of a world-class remote scientific research station at KWMA. Visiting researchers pay fees for research permits, field assistance, lodging, and meals. This revenue helps fund educational costs and community-development projects. The Kamiali Initiative thus creates a link between economic benefit and environmental conservation, and provides a strong incentive for villagers to protect their land and water in perpetuity (Figure 1).

Fishing for coral-reef species may be the biggest challenge to the Kamiali Initiative; the vast majority of dietary protein for this coastal village is fish, and coral reefs are preferred fishing sites. For the conservation-research-income cycle to work in Kamiali waters, the village must balance marine conservation with the need for and cultural value of exploiting the marine habitat.

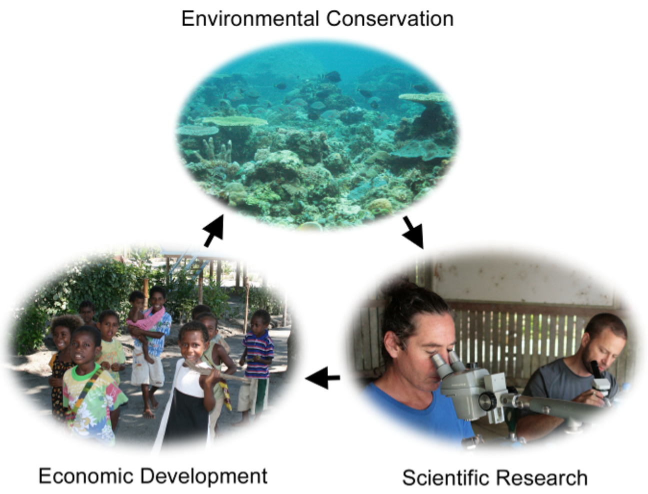


Figure 1. Conceptual model of the Kamiali Initiative: A well-managed environment attracts biological research, providing a means of economic development to pay for school and medicine, thus providing incentive for continued environmental conservation.

Fishery Surveys

The most productive starting point to help the village balance reef-fish conservation and exploitation is a robust, baseline description of population size structure (*i.e.*, length-frequency data, or the number of fish that have reached a given length). This information has intuitive appeal; Kamiali residents understand that shrinking average fish size may indicate unsustainable fishing practices. Length-frequency information is also the basis for science-based fishery management and conservation; when combined with life-history information, a description of population size structure permits predictions about the outcome of various management and conservation actions.

We now have size-structure data covering a span of five years. These data enable us to plot a time-series of average fish length for some of the more-abundant species. The time-series plots will help identify long-term trends in exploited fish populations (*e.g.*, whether average is length shrinking, stable, or increasing). This long-term baseline information will permit evaluation of management and conservation efforts enacted at KWMA.

Reproductive Analysis

Size-at-maturity

Although detailed descriptions of size structure are the foundation of fishery management and conservation, one of the biggest challenges to converting those data into resource management and conservation action is a lack of basic life-history information about the majority of exploited fish species. Remarkably little is known about reproductive parameters for Kamiali's exploited reef fishes. Size-at-maturity is unknown for more than half of the 74 species examined by Longenecker *et al*. (2012). This problem is not restricted to Papua New Guinea; Longenecker *et al*. (2008a) report that size-at-maturity is unknown for 38% of the 13 most heavily exploited reef fishes in Hawaii. Worldwide, this information is missing for ~83% of exploited species (Froese & Binohlan 2000). Without this information, it is impossible to evaluate whether fishing practices give fish the chance to reproduce (and thus "seed" the next generation) before they are harvested.

The sheer diversity of coral-reef fishes, and the supposed cost associated with the reproductive analysis of each species are often cited as barriers to obtaining this important information (Roberts & Polunin 1993, Johannes 1998). Further, most Pacific Island nations, where most of the world's coral reefs are located, have little or no capacity to conduct the reproductive research needed to support fishery management and conservation (Dalzell 1998). The reason for the latter problem may be as simple as a lack of basic infrastructure (*e.g.*, electrical service needed to operate laboratory equipment) in many parts of these developing countries.

Given the scarcity of reproductive information, Froese & Binohlan (2000) developed empirically derived equations to estimate reproductive size. The equation for minimum female size-at-maturity (L_m) is highly predictive ($r^2 = 0.905$) for the subset of species used to develop the regression. However, Longenecker *et al*. (2011) demonstrated that the relationship overestimated female L_m for exploited fishes at KWMA. Further, the degree of overestimation increased with increasing maximum length (*i.e.*, the error was greater for larger-bodied species). We fully recognize the value of Froese & Binohlan's equations; it is far better to have an approximate reproductive size, based on empirical evidence, than to devise fishery management and conservation plans without reference to reproductive biology. However, the results of Longenecker *et al*. (2011) highlight the need for continued life-history work, especially where conservation actions must be balanced with the need to obtain food. If size-at-maturity is used as the basis for harvestable size, detailed reproductive information reduces the possibility that conservation actions would unnecessarily hamper the ability of subsistence fishing communities to obtain food. Marine-resource management and conservation outcomes are more likely to match expectations when the latter are based on accurate information rather than approximations with known biases.

To address the above problems, we developed a method for rapid, low-cost, on-site, histology-based reproductive analysis that does not require electrical service (Longenecker *et al*. 2013a). With this method, reproductive information can be generated quickly (making coral-reef-fish diversity a less-overwhelming problem), and its low cost eliminates one of the arguments against broad-scale reproductive analysis.

The Longenecker *et al*. (2013a) method focuses on histological examination because gross (macroscopic) examination of gonads is known to introduce excessive error when describing reproductive parameters (Vitale *et al*. 2006). Longenecker *et al*. (2013a) compared results from macroscopic and histological reproductive analysis and found that reproductive status and/or sex was misclassified in 47% of specimens examined. This level of error appears consistent; in a later study, 43% of specimens were misclassified (Longenecker *et al*. 2013b). Importantly, in both studies gross (macroscopic) examinations led to overestimates of the number of mature females and underestimates of the number of mature males. These systematic errors underestimate female and overestimate male size-at-maturity. For instance, macroscopic examination of *godobo manibarã* and *godobo tarõ* (*Diagramma pictum*) gonads (Grandcourt *et al.* 2006) underestimated female size-at-maturity by 11% compared to results of histological examination of the same population (Grandcourt *et al*. 2011). If size-at-maturity is used as the basis for establishing a minimum-size limit, macroscopic gonad examination can underestimate female size-at-maturity and lead to potentially unsustainable fisheries.

Providing accurate reproductive information will allow resource owners in developing countries (*i.e.*, Kamiali residents) to determine how their fishing practices may be impacting their marine environment. For instance, villagers can evaluate whether fish on the dinner table have had the chance to reproduce. Combining reproductive information with descriptions of size structure will allow communities to judge whether there are enough adult (*i.e.*, reproductively active) fish to insure an adequate food supply for future generations.

Batch Fecundity and Sex-ratios

Helping village residents understand the value of targeting mature fish may be most simply done by generating estimates of reproductive output. One approach is to describe batch fecundity: the number of eggs shed in a single spawning event. Typically, there is an exponential (approximately cubic) relationship between fish length and batch fecundity, and females are generally expected to attain larger size than males (Pauly 1994, Webb & Freckleton 2007). Thus, it is commonly thought that an increase in average fish size will result in vast increases in egg production and the number of young fish available to replace those harvested (*i.e.*, "seed" the next generation). For instance, Roberts & Polunin (1993), Allison *et al*. (1998), Halpern (2003), Froese (2004), Birkeland & Dayton (2005), and Sale *et al*. (2005) argue that that large fish play a disproportionately important role in the reproductive output of a population because large females produce many more eggs than small females. However, this argument may not hold if the sex ratios change with size.

Longenecker *et al*. (in review) show that egg production by the largest individuals can drop or completely stop when larger size-classes are male dominated. This phenomenon is not unusual; Longenecker *et al*. (2012) report that for 62% of the 13 species at KWMA for which size-specific sex ratios are known, the proportion of males in a population increases with length. In Hawai‘i, the same pattern was found in three additional species: a damselfish, an angelfish and a surgeonfish (Longenecker & Langston 2008, Langston *et al*. 2009). Loubens (1980) found that 12 species from New Caledonia (a triggerfish, a monocle bream, a wrasse, groupers, emperors, and snappers) reach a size where only males are present, and nine additional species (groupers and emperors) become increasingly male-biased with length. The same trend would be expected for protogynous fishes (those that change sex from female to male) such as the Scaridae (parrotfishes), Serranidae (groupers and coral trouts), and Labridae (wrasses). Some species from the above locations (KWMA, Hawai‘i, and New Caledonia) have stable or increasingly female-biased sex ratios (see Loubens 1980, Longenecker *et al*. 2008b, Longenecker *et al*. 2011); however, the majority of species studied (71%) become male-biased as size increases. Further, those species that become male-biased represent a broad range (9 families) of reef fishes.

If the goal of fishery management and conservation is to ensure an adequate supply of offspring, then size-specific sex ratios must be known before useful management policies can be formulated. This information is necessary to evaluate whether conservation and management actions designed to increase average fish length will result in more population-level egg production (*i.e.*, the number of offspring available to "seed" the next generation). Given the results summarized above, increases in average length do not necessarily lead to increases in mature individuals of both sexes. Thus, a combination of reproductive parameters must be considered so that subsistence fishers are not unnecessarily burdened by conservation and management actions.

Catch Characteristics

The above discussion of fish length focused on at-large individuals (*i.e.*, the free-swimming population). However, fishing gear, time, and location can result in catches that differ significantly from the characteristics of a free-swimming population. A detailed description of fish catch can help village residents understand how their fishing practices may impact their marine resources. For instance, Froese (2004) proposed three easily understood indicators to help evaluate the status of fish populations. The two simplest measurements are percent of reproductively mature individuals in the catch and percent of individuals within 10% of optimum length (L_{opt}: the length where, for an unexploited population, the number of fish of a given age multiplied by mean weight at that age is maximized and thus maximum yield can be obtained). Applying Froese's indicators to fish catch at Kamiali will allow residents to evaluate whether fishing practices at KWMA are sustainable.

The value of reproductive information is further demonstrated by our ability to model the outcome of fishery management/conservation proposals relative to current fishing practices. These models allow us to explore ways that subsistence fishers can maintain their current harvest levels while simultaneously promoting larger fish populations. Longenecker *et al*. (2011, 2012) presented this information in terms of weight (important to villagers that depend on fish for their primary source of protein) and number of eggs released in a single spawning event (likely to influence the size of future fish populations). Most importantly, this information can be easily understood by non-specialists (*e.g.*, village residents who control marine resources at KWMA and will ultimately be responsible for any conservation/management decisions). For instance, harvest of *ikula sa* (*Cephalopholis cyanostigma*) at KWMA appears non-selective (average size of the catch was the same as that of the free-swimming population), and a catch of 44 fish averaging 19.7 cm yielded 5.62 kg. However, residents can obtain the same 5.62 kg by harvesting only 25 fish equally distributed among 23 – 25 cm size classes. Under this scenario, a hypothetical population would produce an additional 30,105 eggs per spawning event. On the other hand, harvest of *iwaŋgale* (*Parupeneus barberinus*) at KWMA appears to select larger individuals; all fish had reached adult size (but no fish was within 10% of L_{opt}). A catch of 123 fish averaging 16.5 cm yielded 11.08 kg. Residents can obtain the same 11.08 kg by harvesting only 26 fish equally distributed among 26 – 32 mm size classes. Under this scenario, a hypothetical population would produce an additional 543,442 eggs per spawning event. These numbers can be a powerful motivator for subsistence fishers attempting to balance immediate dietary needs with longer term goals of marine conservation.

Purpose

The purpose of this study is to generate more-robust descriptions of the population size-structure of Kamiali's exploited reef fishes by augmenting, with a series of *in situ* surveys, demographic information gathered from 2009 – 2012. Length-frequency information will be examined in light of estimated length at optimum yield and life-history parameters such as maximum length, reproductive size, and sex ratios. For five of the most-abundant species at KWMA (as indicated by our fishery surveys), we will present a time-series of average fish length. These size-structure analyses will provide important baseline information that will allow Kamiali residents to detect changes in fish populations and, when necessary, take action to improve their fish stocks. To address the scarcity of reproductive information on exploited fishes at KWMA, we will describe the reproductive biology of four species. We will also examine the catch characteristics of the most frequently caught of these species to help evaluate whether current fishing practices are sustainable. Providing this information in the context of life-history parameters will allow Kamiali residents to more-precisely define their conservation goals (*e.g.*, from "we want more fish" to "we will fish in a manner consistent with increasing the number of reproductive females"). Combined, the size-structure and life-history information will also serve as the basis for evaluating the effectiveness of conservation efforts enacted by the Kamiali community.

METHODS

Study Area

Kamiali is one of six Kala-speaking villages in Papua New Guinea and is located on the Huon Coast, approximately 64 km SSE of the port city, Lae. Approximately 600 residents hold title to and control the use of land, adjacent marine water, and the resources contained therein. The northern boundary of the Kamiali Wildlife Management Area (KWMA) is the mouth of the Bitoi River, whereas the Sela River is the southern limit. Nassau and Saschen Bays are wholly contained within the management area, as are Lababia and Jawani Islands and Capes Dinga and Roon. The northern part of Hessen Bay is also contained within the management area.

The terrestrial portion of the KWMA is remarkably undeveloped and characterized by lush vegetation. Kamiali Village is concentrated along the northern portion, where the shoreline is exclusively sandy beach. South of the village, the shoreline is dominated by fringing reefs on Capes Dinga and Roon. Fringing reefs also surround the islands of Lababia and Jawani. These reef flats transition abruptly to a fore reef which is steep, typically descending 20 to 30 meters. At their bases, the reefs give way to sandy sediment that is believed to occupy the majority of the marine area. Some coral outcroppings, patch reefs and pinnacles are interspersed throughout this presumably sedimentary area. The combined horizontal and vertical area (on reef flats and fore reefs, respectively) occupied by coral is approximately 248 ha.

Rapid Reproductive Analysis

We chose four species for rapid reproductive analysis, based on the following criteria: 1) all are an important part of village fish catch; 2) village residents expressed an interest in learning more about each species; 3) published reproductive information was lacking or incomplete; and 4) each species is distinctive enough that the chance of misidentification was low. We analyzed *luduŋ mai* (the caesionid, or fusilier, *Caesio cuning*), *kada maba* (the lethrinid, or emperor, *Lethrinus erythropterus*), *imbilĩ tombo gabo* (the holocentrid, or soldierfish, *Myripristis adusta*), and *ikula su tatalõ* (the serranid, or coral trout, *Plectropomus oligacanthus*). Images of each species are presented in Figure 2.

Luduŋ mai (*Caesio cuning*) ranges from Sri Lanka to Vanuatu and from southern Japan to northern Australia (Carpenter 1988). *Kada maba* (*Lethrinus erythropterus*) ranges from the east coast of Africa to the Caroline Islands and from the Philippines to northwestern Australia (Carpenter 2001). *Imbilĩ tombo gabo* (*Myripristis adusta*) is found throughout the Indo-Pacific with the following exceptions: Red Sea, Arabian Sea, Persian Gulf, Hawai‘i, and the Pitcairn Group (Randall & Greenfield 1999). *Ikula su tatalõ* (*Plectropomus oligacanthus*) is known only from the western Pacific Ocean, including the Philippines, Indonesia, New Guinea, northeastern Australia from Cape York to the northern Great Barrier Reef, Palau, Chuuk, the Caroline Islands, Marshall Islands, and Solomon Islands (Heemstra & Randall 1999).

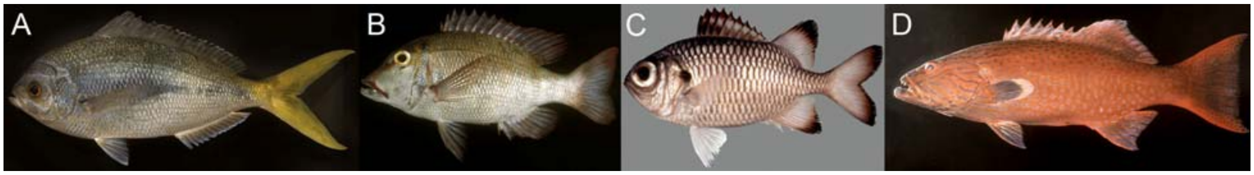


Figure 2. Species chosen for reproductive analysis. A) *luduŋ mai* (*Caesio cuning*), B) *kada maba* (*Lethrinus erythropterus*), C) *imbilĩ tombo gabo* (*Myripristis adusta*), D) *ikula su tatalõ* (*Plectropomus oligacanthus*). Images courtesy of J. Randall.

With the exception of 16 *imbilĩ tombo gabo* (*Myripristis adusta*) and 8 *ikula su tatalõ* (*Plectropomus oligacanthus*) caught and analyzed previously, all specimens used for reproductive analysis were caught by village residents between February and June 2013. They delivered their fish to our processing station and allowed us to obtain the length and weight, and remove the gonads of each fish. Fishers received a modest bounty (3.00 kina) for each specimen and the fish were returned to them for consumption.

We used the methods of Longenecker *et al*. (2013a) for size-at-maturity, reproductive mode, and sex-ratio analyses. We used the methods of Longenecker *et al*. (2013b) to describe length-batch fecundity relationships. However, we analyzed ovarian samples that had reached at least maturation (≥ stage 4a) rather than late vitellogenesis (≥ 3b), and we liberated oocytes from the stroma by vigorous shaking rather than with an ultrasonic cleaner.

Catch Characteristics

We used the specimens obtained for reproductive analysis to describe length-weight relationships for all species chosen for reproductive analysis. *Luduŋ mai* (*Caesio cuning*) was the only species caught in sufficient quantities for a relatively robust catch characterization. For it, we constructed a fishery-dependent length-frequency histogram. We then evaluated fishery selectivity with a two-sample *t*-test comparing mean fish lengths in the harvested and free-swimming populations. We used one-sample *t*-tests to compare mean catch size with empirically derived estimates of L_{opt} (Froese & Binohlan 2000) and our estimate of L_{50} (Longenecker *et al*. in review). We also calculated the percent mature individuals and the percent of individuals within 10% of L_{opt} in the catch.

Fishery Surveys

From 27 May – 11 June 2013, we conducted 14 laser-videogrammetry surveys to describe the size distribution of exploited reef fishes in Kamiali Wildlife Management Area. These surveys were performed at preferred fishing sites, most of which are beyond the depth limits of conventional open-circuit SCUBA. As such, we used closed-circuit rebreathers with 10/50 trimix diluent as life support to reach depths to 91 m. Due to the lengthy decompression obligations incurred while working at these depths (*e.g.*, 3 hours for a 20-minute dive to 91 m), the work was performed in areas with bathymetric profiles that permitted work to continue while ascending. Thus, surveys are concentrated at offshore pinnacles and near fringing reefs (Table 1, Figure 3). 2013 surveys sites were concentrated in areas sparsely covered during 2009 – 2012 field seasons (*e.g.*, patch reefs at the northern end, and bays in the southern portion of KWMA).

A high-definition video camera fitted with parallel laser pointers was used to capture images of individual fish when they were oriented perpendicular to the laser beam axes. We used editing software to review the video and capture still frames where both lasers appeared on the fish. Because the beams are parallel, the lasers superimpose a reference scale on the side of the fish, allowing length estimates by solving for equivalent ratios. Our length estimates were calculated using ImageJ software (Rasband 2009). Longenecker & Langston (2008) have demonstrated a nearly 1:1 relationship between estimated and actual fish lengths. Further, a prediction interval suggested 95% of estimates will be within 0.5 cm of the actual fish length (Longenecker & Langston 2008).

The species included in the fishery survey met the following four criteria: 1) they are reef fishes; 2) exploited by local fishers; 3) common enough to have been captured at least several times on video; and 4) can be reliably identified from still images. A total 84 species representing 19 families (Acanthuridae, Balistidae, Caesionidae, Carangidae, Carcharhinidae, Ephippidae, Haemulidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Nemipteridae, Priacanthidae, Scaridae, Scombridae, Serranidae, and Siganidae) met these criteria.

A systematic literature review was conducted using the methods of Longenecker *et al.* (2008a) to obtain estimates of maximum length (L_{max}), size-at-maturity, size-specific sex ratios, spawning season, and reproductive mode. Briefly, we: 1) searched electronic resources (*e.g.*, Google Scholar, FishBase) using key-word combinations of species names plus "reproduction" or "maturity"; 2) upon obtaining these publications, we identified and obtained additional relevant literature listed in their reference section; 3) we then searched these publications and obtained any additional references.

In summarizing life-history information, preference was given to studies specific to Papua New Guinea (*e.g.*, maximum-length information of Allen & Swainston 1993). Preference was also given to length at 50% maturity (L_{50}) over other estimates of size-at-maturity (*e.g.*, minimum size-at-maturity or L_m). Results from studies outside the southern hemisphere were included only when data for southern populations were not available (*e.g.*, reproductive size for *imaŋalẽ talã* or *Caranx melampygus*). Conversely, information on spawning seasonality was included only for southern hemisphere populations.

We applied the empirically derived equations of Froese & Binohlan (2000) to estimate fishery and, when necessary, reproductive parameters. Published maximum lengths (L_{max}, see Results) were used to generate estimates of L_∞. The latter were then used to generate estimates of L_{opt}. If published values of L_{50} were not available, we also used L_∞ estimates to generate ♀L_m estimates.

Table 1. List of marine sites surveyed at Kamiali Wildlife Management Area during 2013. Latitude and longitude were estimated by GPS using the WGS84 datum. FR = Fringing Reef, OP = Offshore Pinnacle, PR = Patch Reef.

Survey	Date	Latitude (ºS)	Longitude (ºE)	Habitat	Max Depth (m)
1	27-May-13	7.30794777	147.1662683	OP	48
2	28-May-13	7.33912937	147.1567516	FR	45
3	29-May-13	7.34360103	147.1691658	OP	64
4	30-May-13	7.32867178	147.2063146	OP	78
5	31-May-13	7.24444865	147.1584759	FR	39
6	01-Jun-13	7.30437515	147.1542494	FR	91
7	03-Jun-13	7.31348553	147.1471924	FR	63
8	04-Jun-13	7.32404622	147.1396611	FR	43
9	05-Jun-13	7.30417550	147.1542598	FR	57
10	06-Jun-13	7.29858669	147.1318522	FR	27
11	07-Jun-13	7.30463851	147.1474051	FR	21
12	08-Jun-13	7.24775632	147.1482424	PR	10
13	10-Jun-13	7.33996480	147.1431699	FR	41
14	11-Jun-13	7.35337065	147.1509645	FR	19

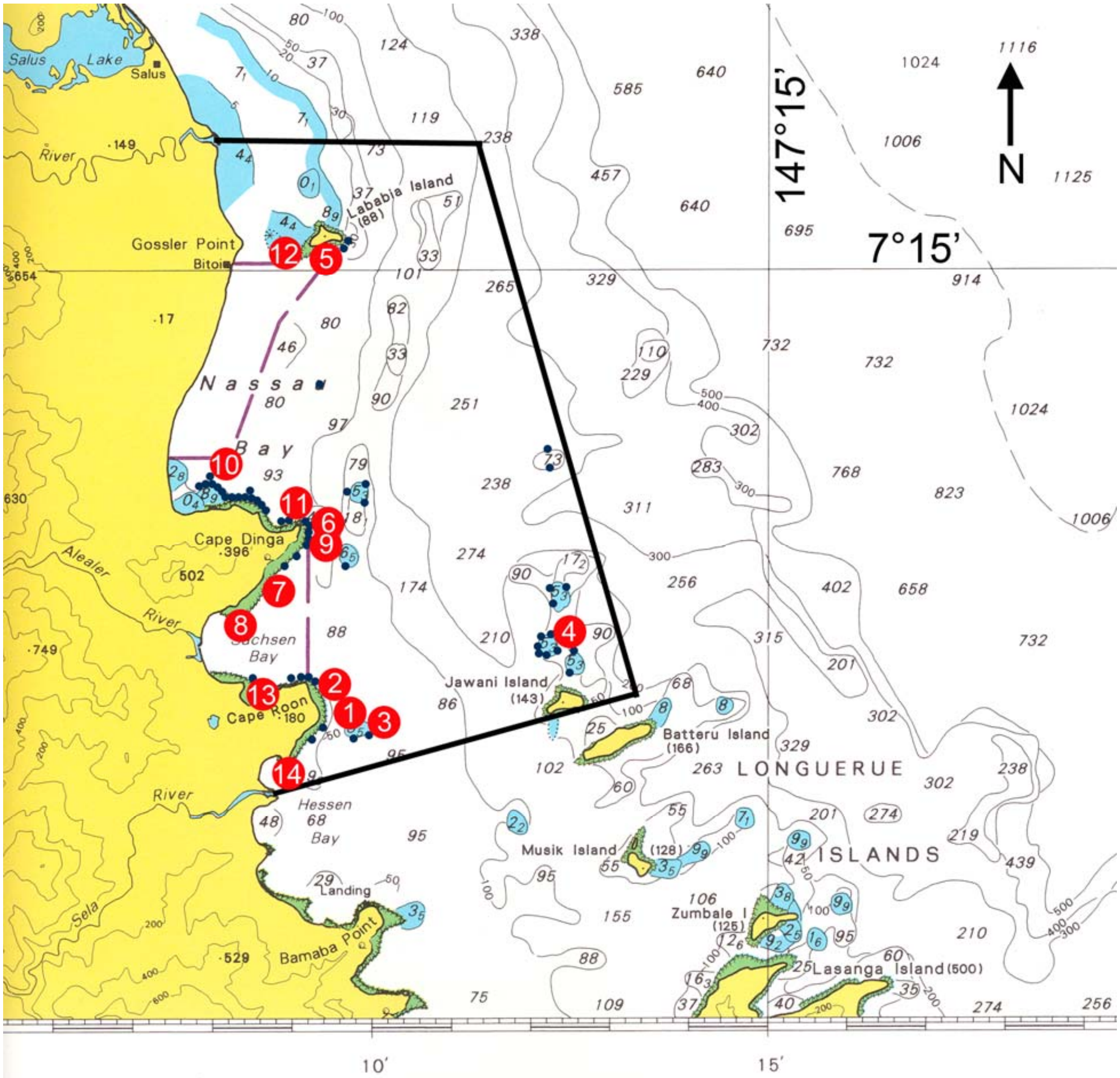


Figure 3. The marine portion of Kamiali Wildlife Management Area (outlined in black). Red circles indicate locations of 2013 survey sites (coordinates are given in Table 1). Smaller blue circles indicate 2009 - 2012 survey sites (coordinates in Longenecker *et al*. 2009, 2010, 2011, 2012). Adapted from chart Aus 523, published by the Australian Hydrographic Service. Depths are in meters.

We constructed length-frequency histograms for each species for which at least 15 individuals were captured on video from 2009 – 2013. To be included in the count of total number of individuals, a still image captured from video must have been of suitable quality for length estimation. Mean length was compared to L_{max}, L_{opt}, and female L_m or L_{50}. When sex ratios were available, we estimated the percentage of reproductive females in each population. The length information presented below is the distance between the front of the head and the end of the middle caudal ray.

Time Series

We plotted a time-series of average length by year for species that were most-frequently and consistently captured on video. To smooth interannual fluctuation and highlight longer-term trends, we also plotted 3-year moving averages. Species we analyzed were represented by at least ~10 specimens each of the last five years. Five species met this criterion: *luduŋ mai* (the caesionid, or fusilier, *Caesio cuning*), *ikula sa* (the serranid, or grouper, *Cephalopholis cyanostigma*), *itale* (the lutjanid, or snapper, *Lutjanus biguttatus*), *iwaŋgale* (the mullid, or goatfish, *Parupeneus barberinus*), and another goatfish, *iwaŋgale bote* (*P. multifasciatus*). Images of each are presented in figure 4.

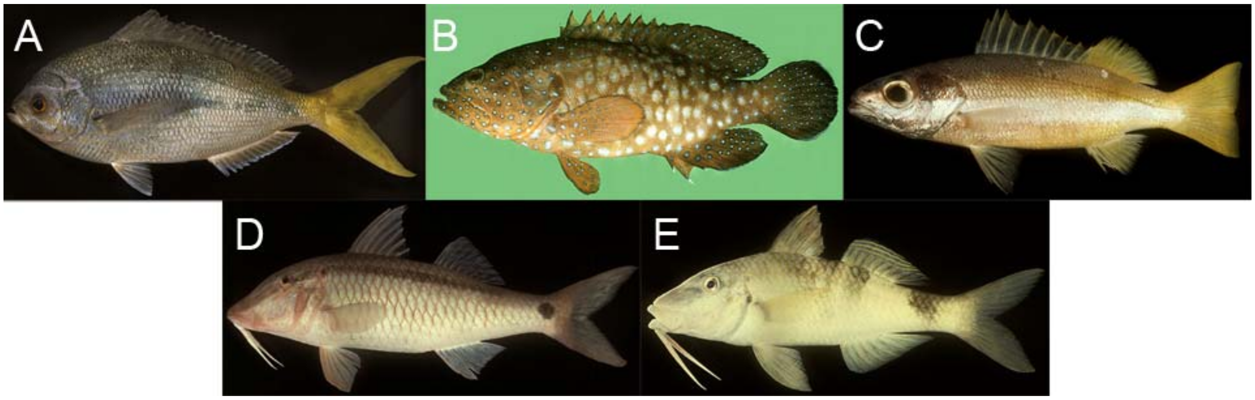


Figure 4. Species used for time-series plots. A) *luduŋ mai* (*Caesio cuning*), B) *ikula sa* (*Cephalopholis cyanostigma*), C) *itale* (*Lutjanus biguttatus*), D) *iwaŋgale* (*Parupeneus barberinus*), E) *iwaŋgale bote* (*P. multifasciatus*). Images courtesy of J. Randall.

RESULTS

Reproductive Analysis

Luduŋ mai (*Caesio cuning*)

Detailed results are presented in Longenecker *et al*. (in review). To summarize, we histologically examined 132 gonads and found male and female L_{50} is 12.6 and 15.3 cm FL, respectively. Females are batch spawners, and we found no evidence of sex change (*i.e.*, the species is gonochoristic). Batch fecundity (BF) is an exponential function of length [BF = $0.1163(\text{FL})^{4.2796}$]. For mature individuals, overall sex ratios are not significantly different from 1:1, but do vary predictably with size. The percentage of females (%*F*) from male L_{50} through maximum observed length can be predicted ($r^2 = 0.82$) by the equation:

$$\%F = 85.81e^{\left(-0.5\left(\frac{\text{FL}-18.62}{1.65}\right)^2\right)}$$

indicating that the population is female biased between 16.9 and 20.3 cm FL, male biased at smaller and larger sizes, and nearly exclusively male at male L_{50} and maximum observed length. The influence of size-specific sex ratios result in 19.2 cm FL individuals making the largest contribution to population-level egg production. Larger size classes make progressively smaller contributions to population-level egg production and egg production effectively stops at 27 cm.

Kada maba (*Lethrinus erythropterus*)

Detailed results for *kada maba* (*Lethrinus erythropterus*) are also presented in Longenecker *et al*. (in review). To summarize, we histologically examined 101 gonads and found male L_m is 19.2 cm FL and female L_{50} is 20.4 cm FL. Females are batch spawners, and the species is a protogynous hermaphrodite (*i.e.*, changes sex from female to male). Because no females had stage 4 oocytes, we could not explore the relationship between FL and BF. Overall sex ratio of mature individuals is not significantly different from 1:1; however sex-ratio does vary predictably with length. %*F*, from female L_{50} through maximum observed length, can be predicted ($r^2 = 0.97$) by the equation: %F = 456.71 – 19.13(FL). At 18.6 cm FL, all mature individuals are female. The transition from a female- to a male-biased state occurs at 21.2 cm FL and the population is exclusively male ≥ 23.9 cm FL.

Imbilĩ tombo gabo (*Myripristis adusta*)

We histologically examined 22 gonads in 2013. The following results include specimens collected and analyzed during our 2010 and 2012 field trips. We examined gonads of 1 undifferentiated individual, 19 males, and 24 females. Because ovaries of mature females contained several discrete stages of oocytes, we classify the species as a batch spawner (*i.e.*, it demonstrates group-synchronous oocyte development) following the terminology of Wallace and Selman (1981). The smallest male with spermiated testes was 13.1 cm FL. We estimate male L_{50} at 15.7 cm FL (Fig. 5). Ovaries contained vitellogenic oocytes in females as small as 16.4 cm FL. We estimate female L_{50} at 16.5 cm FL (Fig. 5). There was no evidence for sex change; a *t*-test for a sex-based bimodal size distribution was not significant, nor did ovaries contain spermatogenic tissue. We classify *imbilĩ tombo gabo* (*Myripristis adusta*) as a gonochore. The sex ratio of mature individuals was is 1:1. However, the sex ratio of mature individuals varied predictably with length; size classes are initially female biased then become male biased (Fig. 5). The percent of mature females (%*F*), from female L_m through maximum observed length, can be predicted ($r^2 = 0.84$) by the equation: %*F* = 369.91 – 15.84(FL). Up to lengths of 17.0 cm FL, all mature individuals are female. The transition from a female- to a male-biased state occurs at 20.2 cm FL and the population is exclusively male ≥ 23.4 cm FL. Only two of the ovarian sections we retained for batch fecundity analysis had oocytes in stages ≥ 4a, therefore we could not construct a length-batch fecundity relationship. However, batch fecundity of a 16.4 and a 18.9 cm female was estimated at 16,729 and 27,195 eggs, resepectively.

Ikula su tatalõ (*Plectropomus oligacanthus*)

We histologically examined 37 gonads in 2013. The following results include specimens collected and analyzed during our 2012 field trip. We examined gonads of 38 females, 5 transitional individuals, and 1 male. Thirty-two immature females ranged from 24.0 – 42.0 cm (average = 32.9 cm). Six mature females ranged from 27.3 – 34.3 cm (average = 30.5 cm). Five transitional individuals ranged from 36.5 – 47.5 cm (average = 43.6 cm). The single mature male was 50.5 cm. Figure 6 shows the relative frequency of reproductive states in each 5-cm size class. The gonads of the 5 transitional individuals contained a mixture of ovarian and spermatogenic tissue, and the single male was larger than all transitional individuals, which were larger than all mature females. Thus we classify the species as a protogynous hermaphrodite. Because ovaries of mature females contained several discrete stages of oocytes, we classify the

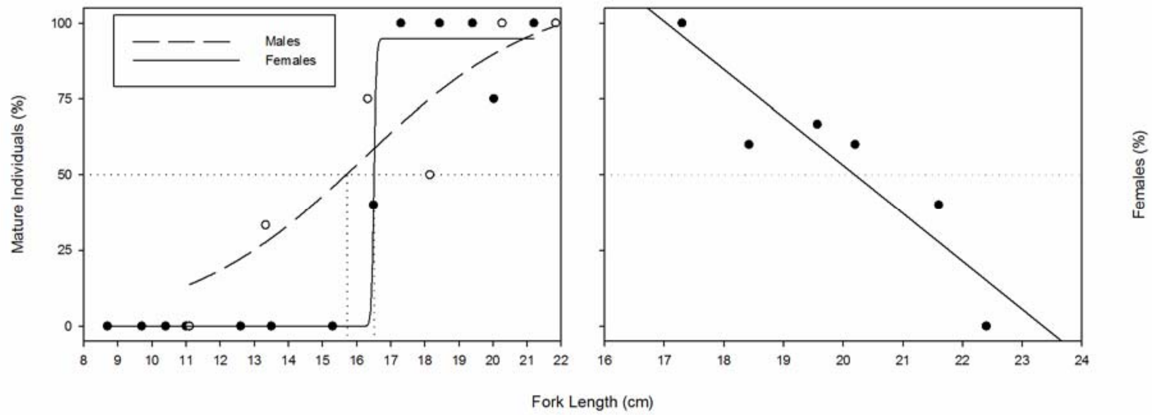


Figure 5. L_{50} (left) and size-specific sex ratios (right) for *Myripristis adusta* (*imbilĩ tombo gabo*). Solid circles = females, open circles = males.

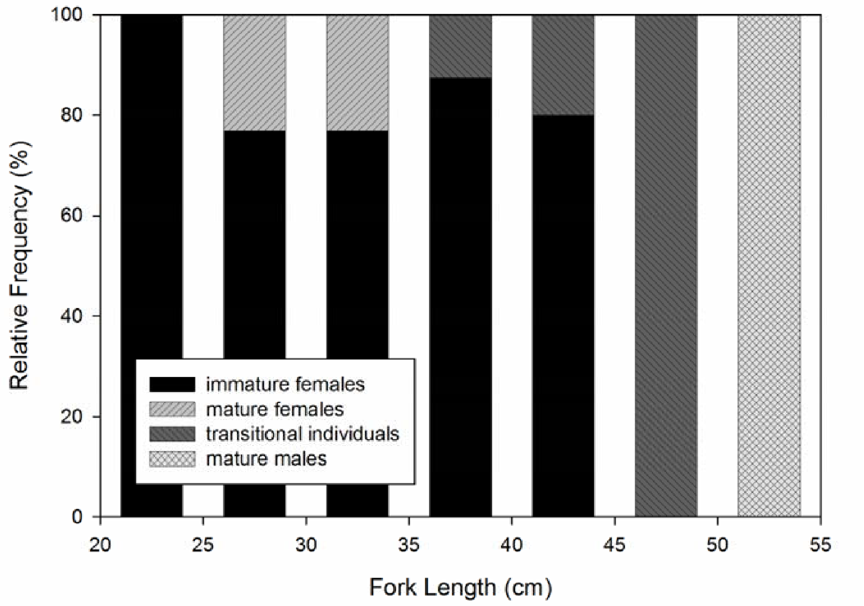


Figure 6. Relative frequency of *Plectropomus oligacanthus* (*ikula su tatalõ*) reproductive states in each 5-cm size class.

species as a batch spawner (*i.e.*, it demonstrates group-synchronous oocyte development) following the terminology of Wallace and Selman (1981). Only one of the ovarian sections we retained for batch fecundity analysis had oocytes in stages ≥ 4a, therefore we could not construct a length-batch fecundity relationship. However, batch fecundity of the 30.1 cm female was estimated at 25,338 eggs. Mature females were only collected from April through June, suggesting a limited reproductive season; however, we lack data for October – December.

Length-Weight Relationships

Length is highly predictive of total body weight for the four species selected for reproductive analyses. For all species, weight is an approximately cubic function of length (Table 2). There is a sex-based difference for *kada maba*, or *Lethrinus erythropterus* (Longenecker *et al.* in review): $W = 0.0077(\mathrm{FL})^{3.2264}$ for females and $W = 0.1673(\mathrm{FL})^{2.3023}$ for males.

Table 2. Length-weight relationships for four exploited fishes. W = total body weight (g), FL = fork length (cm). Information for *C. cuning and L. erythropterus* from Longenecker *et al.* (in review). Information for *M. adusta* and *P. oligacanthus* updated from Longenecker *et al.* (2012).

Species	Equation	N	Range (cm)	r^2
Caesio cuning (*luduŋ mai*)	$W = 0.0208(\mathrm{FL})^{3.0322}$	137	8.0 – 22.7	0.954
Lethrinus erythropterus (*kada maba*)	$W = 0.0145(\mathrm{FL})^{3.0976}$	139	6.4 – 26.0	0.990
Myripristis adusta (*imbilĩ tombo gabo*)	$W = 0.0123(\mathrm{FL})^{3.2627}$	46	8.7 – 22.4	0.980
Plectropomus oligacanthus (*ikula su tatalõ*)	$W = 0.0042(\mathrm{FL})^{3.3133}$	45	24.0 – 50.5	0.973

Fishery Surveys

In 2013, we captured an additional 666 specimens on video suitable for length estimation, yielding a combined total 3,944 individuals from 2009 to 2013. These specimens include 10 species not analyzed in the 2009 - 2012 surveys (Longenecker *et al*. 2012). Mean length, along with known information on maximum length, size-at-maturity, size-specific sex ratios, spawning season, and reproductive mode is presented for each of 84 species in Table 3. Species and family names follow the taxonomy of FishBase (Froese and Pauly 2012). A tilde (~) preceding values in Table 3 indicates uncertainty. These typically occur before maximum length and size-at-maturity values. For maximum length, a lack of published total length to fork length equations prevented accurate determination of fork length. For size-at-maturity values, only minimum size-at-maturity (L_m) values were available. These would be expected to be smaller than the preferred size at 50% maturity (L_{50}).

Weighted percent maximum length of all individuals captured on video was 57%. That is, an exploited reef fish swimming in Kamiali Wildlife Management Area is likely to be about 3/5 its potential maximum length.

Weighted percent estimated optimum length of all individuals captured on video was 89%. In other words, an exploited fish is likely to be about 10% shorter than the length at which the empirical equation of Froese & Binohlan (2000) suggests maximum yield per recruit can be obtained.

Information about reproduction in these species is remarkably scant. Size-at-maturity is known for about half (49%) of the species studied. Of this subset, an individual of the following species was more likely than not to be reproductively mature: *luduŋ mai* (*Caesio cuning*), *imaŋalẽ babaura* (*Carangoides bajad*), *Carcharhinus melanopterus*, *iyabua kurĩ naba* (*Plectorhinchus vittatus*), *imbilĩ tombo gabo* (*Myripristis adusta*), *imbilĩ sa* (*Neoniphon sammara*), *italawe* (*Kyphosus cinerascens*), *ii bui bui* (*Cheilinus fasciatus*), *kada maba* (*Lethrinus erythropterus*), *babaura* (*Lutjanus carponotatu*s), *ina suwi* (*Lutjanus gibbus*), *babaura yumi yayã* (*Lutjanus kasmira*), *isale* (*Lutjanus vitta*), *itale yumi yayã* (*Mulloidichthys vanicolensis*), *iwaŋgale* (*Parupeneus barberinus*), *walia* (*Parupeneus trifasciatus*), *indu iko* (*Priacanthus hamrur*), *Scarus niger*, *indala* (*Rastrelliger kanagurta*), *itaŋgi* (*Scomberomorus commerson*), *ikula bobo* (*Cephalopholis boenak*), *ikula tumi* (*Cephalopholis sexmaculata*), *Epinephelus fasciatus*, *Epinephelus merra*, *yula* (*Plectropomus leopardus*), *ikula su tatalõ* (*Plectropomus oligacanthus*), and *yulawe* (*Siganus lineatus*). These represent 61% of the species for which reproductive information is available. On the other hand, an individual of the following species was most likely to be immature: *iwiliya* (*Acanthurs lineatus*), *biaŋgawe suwi* (*Naso hexacanthus*), *imaŋalẽ talã* (*Caranx melampygus*), *kapa ii* (*Carcharhinus amblyrhynchos*), *kapa bage bula* (*Triaenodon obesus*), *ilĩ* (*Lutjanus argentimaculatus*), *itale* (*Lutjanus biguttatus*), *yame tuaŋ yasai/yame tuaŋ/ilĩ* (*Lutjanus bohar*), *iyayaŋ kurĩ naba* (*Lutjanus fulvus*), *baniŋga* (*Lutjanus monostigma*), *kawasi ŋasiŋa* (*Lutjanus russellii*), *imawe* (*Lutjanus semicinctus*), *iwaŋgale bote* (*Parupeneus multifasciatus*), *itaŋgi talaloŋa* (*Gymnosarda unicolor*), and *ikula sa* (*Cephalopholis cyanostigma*). Further, no individual *godobo manibarã /tarõ* (*Diagramma pictum*), or *ikula su mani balã* (*Plectropomus areolatus*) captured on video had reached maturity.

Given the scarcity of reproductive information, we compared average length relative to minimum size at female maturity (♀L_m), and observed size at which 50% of females are mature (♀L_{50}). For all ♀L_m values combined (observed and estimated), the weighted mean length of 55 species suggests an exploited fish was 101% of minimum size-at-maturity. Published ♀L_{50} values were available for 29 species. For these, average length was 100% of female L_{50}.

For 13 of the 26 species for which information on sex ratios has been published, larger size classes are increasingly male dominated [*luduŋ mai* (*Caesio cuning*), *imbilĩ tombo gabo* (*Myripristis adusta*), *kada maba* (*Lethrinus erythropterus*), *babaura* (*Lutjanus carponotatus*), *ina suwi* (*Lutjanus gibbus*), *isale* (*Lutjanus vitta*), *iwaŋgale* (*Parupeneus barberinus*), *iwaŋgale bote* (*Parupeneus multifasciatus*), *Scarus niger*, *ikula sa* (*Cephalopholis cyanostigma*), *Epinephelus fasciatus*, *ikula su mani balã* (*Plectropomus areolatus*), *yula* (*Plectropomus leopardus*)]. Size-specific sex ratios were not examined in two serranid species with overall female biases [*ikula bobo* (*Cephalopholis boenak*), and *ikula karu guŋ-guŋ* (*Cephalopholis urodeta*)]. However, all serranids are classified as protogynous hermaphrodites (Heemstra & Randall 1993). Because individuals typically mature as females, then change sex with further growth, these species should also be expected to have male-biased sex ratios with increasing size [this assertion is true for *ikula sa* (*Cephalopholis cyanostigma*), *Epinephelus fasciatus*, *ikula su mani balã* (*Plectropomus areolatus*) and *yula* (*Plectropomus leopardus*)]. Nine species occur in an approximately 1:1 sex ratio [*iwiliya* (*Acanthurus lineatus*), *imaŋalẽ babaura* (*Carangoides bajad*), *Carcharhinus melanopterus*, *godobo manibarã* and *godobo tarõ* (*Diagramma pictum*), *ilĩ* (*Lutjanus argentimaculatus*), *itale* (*Lutjanus biguttatus*), *iyayaŋ kurĩ naba* (*Lutjanus fulvus*), *imawe* (*Lutjanus semicinctus*), and *yulawe* (*Siganus lineatus*)]. Overall sex ratios are female-biased for six species [*imaŋalẽ talã* (*Caranx melampygus*), *iyabua kurĩ naba* (*Plectorhinchus vittatus*), *imbilĩ sa* (*Neoniphon sammara*), *babaura yumi yayã* (*Lutjanus kasmira*), *walia* (*Parupeneus trifasciatus*), and *indu iko* (*Priacanthus hamrur*)]; however, the possibility of predictable size-specific sex ratios has not been evaluated for any of the female-biased species. *Itaŋgi* (*Scomberomerus commerson*) is female-biased at larger sizes. When published sex-ratio information is considered, the size-structure data generated from laser-videogrammetry surveys study suggest, on average, 31% of the exploited reef-fish population is composed of mature females.

Demographic information for each of 84 species is presented below. When at least 15 individuals were captured on video suitable for length estimates, we generated size-frequency histograms, with arrows indicating maximum length (L_{max}), optimum length (L_{opt}) and female reproductive length. The reader is cautioned that, depending on the information available, reproductive length may be minimum size-at-maturity (L_m) or size at 50% maturity (L_{50}). Also, note that arrows are solid for published values, or dashed for estimated values.

In an effort to reduce the size of this report and to make information more-easily accessible, species accounts are presented in a telegraphic style (rather than the narrative style used in previous reports). For each species account, the first line indicates the number of specimens captured on video in 2013 and the total number of specimens analyzed from 2009 – 2013. If a species is covered for the first time, the first line begins “First report”, and indicates the total number of specimens analyzed from 2009 – 2013. The second line indicates average length. If a length comparison was possible between 2012 and 2013 (*i.e.*, the species was covered previously *and* specimens were captured on video duing 2013) the relative change is indicated in parentheses: ↑ = increase, ↓ = decrease, or no change. The following three lines compare average length to maximum length (L_{max}), optimum length (L_{opt}) and female size-at-maturity (L_m or L_{50}), respectively. We also indicate whether the length parameters were estimated, reported (published values converted to fork length), or published. When sex ratio information was available, a sixth line indicates the estimated percentage of mature females in the population. Finally, a note may describe any caveats to the information listed in lines 1 – 6.

Table 3. Size and reproductive information for common, exploited fishes in Kamiali Wildlife Management Area (updated from Longenecker *et al*. 2012. Values bridging female and male L_{50} columns (*Naso hexacanthus, Neoniphon sammara*, *Lutjanus monostigma*, *Gymnosarda unicolor*, and *Scomberomorus commerson*) indicate no sex-specific size-at-maturity values were provided.

Taxon (Kala name, if recorded)	N	Mean length (cm)	L_{max} (cm)	Female L_{50} (cm)	Male L_{50} (cm)	Sex ratio	Spawning season	Sex change?
ACANTHURIDAE								
Acanthurus lineatus (iwiliya)	11	17	31[a,b,c]	18[c]	~17[c]	1♂:1.1♀[c]	Sep-Feb[d]	
Ctenochaetus tominiensis (*aloweya yayã*)	10	14	19[a,b]					No[e]
Naso hexacanthus (*biaŋgawe suwi*)	88	43	71[a,b]	~50[b,f]				No[e]
Naso lopezi (*biaŋgawe talõ*)	3	59	48[a,b]					No[e]
Naso vlamingii (*biaŋgawe tumi*)	10	36	51[a,b]					No[e]
BALISTIDAE								
Canthidermis maculata (*labaikã suwi*)	13	33	35[a]					No[e]
CAESIONIDAE								
Caesio cuning (*luduŋ mai*)	1262	16	30[g]	15[g]	13[g]	♀ biased 17-20 cm, otherwise ♂ biased[g]		No[g]
CARANGIDAE								
Carangoides bajad (*imaŋalẽ babaura*)	42	26	51[a,b]	~25[h]		~1:1[h]	Jun-Sep[h]	

Carangoides plagiotaenia (*imaŋalẽ tombo gabo*)	35	27	38[a,b]					
Caranx melampygus (*imaŋalẽ talã*)	38	26	72[a,g]	36[i]		1♂:1.48♀[i]		No[i]
Caranx papuensis (*imaŋalẽ labrã kulĩ*)	16	57	66[b,j]					
CARCHARHINIDAE								
Carcharhinus amblyrhynchos (*kapa ii*)	9	78	217[a,b]	118[b,k]	114[b,k]		May-Oct (biennial)[k]	
Carcharhinus melanopterus	4	80	150[a,l]	80[l]	78[l]	1:1[l]	Jan-Feb[l]	
Triaenodon obesus (*kapa bage bula*)	8	73	177[a,b]	97[b,k]	94[b,k]		May-Oct (biennial)[k]	
EPHIPPIDAE								
Platax orbicularis	5	35	50[a]					
Platax pinnatus (*ibuŋgi tarõ*)	13	25	30[a]					
Platax teira (*ibuŋgi*)	5	33	60[a]					
HAEMULIDAE								
Diagramma pictum (*godobo manibarã* & *godobo tarõ*)	8	25	90[a]	36[m]	27[m]	~1:1[m]	Apr-May & Nov[m]	No[m]
Plectorhinchus chaetodonoides	5	43	~60[a,n] (TL)					

Taxon (Kala name, if recorded)	N	Mean length (cm)	L_{max} (cm)	Female L_{50} (cm)	Male L_{50} (cm)	Sex ratio	Spawning season	Sex change?
Plectorhinchus lineatus (*iyabua sa*)	46	36	50[a]					
Plectorhinchus vittatus (*iyabua kurĩ naba*)	4	28	50[a]	~23[b,o]	~29[b,o]	1♂:1.75♀[o]	Dec-May[o]	
HOLOCENTRIDAE								
Myripristis adusta (*imbilĩ tombo gabo*)	17	19	28[a,p]	17[q]	15[q]	Increasingly male-biased with length[q,r]		No[q]
Myripristis berndti (*imbilĩ yakẽ yayã*)	5	13	26[a,s]					No[e]
Myripristis kuntee (*imbilĩ godõ nambĩ*)	76	12	16[a,t]					No[e]
Myripristis pralinia (*imbilĩ yakẽ suwi*)	3	12	17[a,s]					No[e]
Myripristis violacea (*imbilĩ yakẽ bumbu*)	89	13	17[a,s]					No[e]
Myripristis vittata (*imbilĩ yakẽ suwi*)	20	11	17[a,p]					No[e]
Neoniphon sammara (*imbilĩ sa*)	18	14	~27[a,p]	~8[n,o] (SL)		1♂:2.56♀[o]	Nov-May[o]	No[e]
Sargocentron caudimaculatum (*imbilĩ yasai*)	8	15	19[a,b]					No[e]

Sargocentron melanospilos	3	15	23[a,b]					
KYPHOSIDAE								
Kyphosus cinerascens (*italawe*)	75	30	41[b,j]	~25[u]	~18[u]			
Kyphosus vaigiensis (*italawe talabopia*)	7	35	56[b,j]					
LABRIDAE								
Choerodon anchorago (*ii bui bui*)	5	24	38[a]					
Cheilinus fasciatus (*talulumuã tatalõ*)	35	16	~36[a,n] (TL)	~12[n,v]	~20[n,v]			♀→♂[v]
Oxycheilinus celebicus (*talulumuã bobo*)	24	13	20[a]					
Oxycheilinus digramma (*ikula talulumuã*)	5	17	30[a]					
LETHRINIDAE								
Lethrinus erythropterus (*kada maba*)	5	22	48[a,b]	20[g]	~19[g]	Increasingly male-biased with length[g]	Mar-May[w]	♀→♂[g]
Monotaxis grandoculis (*labaikã taloŋ* & *labaikã*)	70	24	~56[a,p]					
LUTJANIDAE								
Lutjanus argentimaculatus (*ilĩ*)	4	48	118[a,b]	53[x]	47[x]	1♂:1.18♀[x]	Oct-Nov[y], Dec[x]	No[z]

Taxon (Kala name, if recorded)	N	Mean length (cm)	L_{max} (cm)	Female L_{50} (cm)	Male L_{50} (cm)	Sex ratio	Spawning season	Sex change?
Lutjanus biguttatus (*itale*)	480	15	19[a,aa]	17[aa]	13[aa]	1:1[aa]		No[aa]
Lutjanus bohar (*yame tuaŋ yasai, yame tuaŋ,* & *ilĩ*)	4	17	71[a,b]	43[bb]	<30[bb]		Aug-Apr[bb]	No[bb]
Lutjanus boutton (*iyayaŋ*)	215	14	28[a,b]					No[z]
Lutjanus carponotatus (*babaura*)	36	21	38[a,b]	19[cc]		Increasingly male-biased with length[dd]	Oct-Dec[cc]	No[ee]
Lutjanus fulvus (*iyayaŋ kurĩ naba*)	45	18	39[a,b]	19[ff]	14[ff]	1:1[ff]	Year round[z,gg]	No[ff]
Lutjanus gibbus (*ina suwi*)	22	20	42[a,b]	~18[b,o]-23[hh]	~14[b,o]	Increasingly male-biased with length[ii]	Jan-Apr[o]	No[z]
Lutjanus kasmira (*babaura yumi yayã*)	4	16	33[a,jj]	~12[o,jj]	~14[o,jj]	1♂:1.33♀[o]	Year round[z]	No[z]
Lutjanus monostigma (*baniŋga*)	4	21	48[a,b]	~32[kk]			Feb & Nov[z]	No[z]
Lutjanus rivulatus (*isina*)	4	31	63[a,b]					No[z]
Lutjanus russellii (*kawasi ŋasiŋa*)	82	21	43[a,b]	22[ll]			Aug-Feb[mm]	No[z]

Lutjanus semicinctus (*imawe*)	52	20	34[a,b]	21[nn]	18[nn]	Varies unpredictably with length (~1:1)[nn]		No[nn]
Lutjanus vitta (*isale*)	24	16	37[a,b]	15[oo]		Increasingly male-biased > 29 cm[pp]	Sep-Apr[pp,qq]	No[z]
Macolor macularis (*labaikã tewe yayã*)	17	31	55[a,b]					
Macolor niger (*labaikã yasai*)	5	28	~60[a,n] (TL)					
MULLIDAE								
Mulloidichthys vanicolensis (*itale yumi yayã*)	7	21	34[a,b]	17[rr]			Oct-Nov[ss]	
Parupeneus barberinus (*iwaŋgale*)	154	15	44[a,p]	~12[nn]	~14[nn]	Increasingly male-biased with length[nn]	Oct-May[o]	No[nn]
Parupeneus cyclostomus (*iwaŋgale bokole*)	27	18	44[a,tt]					
Parupeneus multifasciatus (*iwaŋgale bote*)	108	14	26[a,uu]	15[uu]	15[uu]	Increasingly male-biased with length[uu]		No[uu]
Parupeneus trifasciatus (*walia*)	52	18	30[a,vv]	~11[o,vv]	~16[o,vv]	1♂:1.67♀[o]	Sep-Apr[o]	
NEMIPTERIDAE								
Scolopsis bilineata (*buamea*)	10	13	~23[a,n] (TL)					♀→♂[ww]
Scolopsis ciliata	6	12	~22[a,n] (TL)					

Taxon (Kala name, if recorded)	N	Mean length (cm)	L_{max} (cm)	Female L_{50} (cm)	Male L_{50} (cm)	Sex ratio	Spawning season	Sex change?
PRIACANTHIDAE								
Priacanthus hamrur (*indu iko*)	4	23	~40[a,n] (TL)	20[xx]	18[xx]	1♂:1.77♀[xx]	Apr-Jul[xx]	
SCARIDAE								
Chlorurus bleekeri (*iŋga bobo* & *iŋga talã*)	23	18	30[a]					
Chlorurus bowersi (*guniau*)	4	22	31[yy]					
Scarus flavipectoralis (*iŋga talaŋ* & *iŋga tali lau*)	58	18	29[a,b]					
Scarus niger	4	18	~35[a,n]	17[zz]	28[zz]	Increasingly male-biased with length[aaa]		♀→♂[aaa]
SCOMBRIDAE								
Gymnosarda unicolor (*itaŋgi talaloŋa*)	18	59	137[a,b]	~70[bbb]			Dec-Feb[ccc]	No[ccc]
Rastrelliger kanagurta (*indala*)	10	23	33[a,b]	19[ddd]	18[ddd]		Oct-Jul[ddd]	No[ccc]
Scomberomorus commerson (*itaŋgi*)	10	70	218[a,eee]	~65[fff]		Female biased >90 cm[fff]	Jul-Dec[ccc]	No[ccc]
SERRANIDAE								
Anyperodon leucogrammicus (*ikula damasã*)	17	25	52[a]					♀→♂[ggg]

Cephalopholis boenak (*ikula bobo*)	10	16	24[a]	15[hhh]	16[hhh]	1♂:5.30♀[iii]	Apr-Oct[hhh]	♀→♂[hhh]
Cephalopholis cyanostigma (*ikula sa*)	86	19	35[a]	23[nn]	20[nn]	Increasingly male-biased with length[nn]		♀→♂[nn]
Cephalopholis microprion (*ikula yuyeŋ*)	25	13	23[a]					♀→♂[ggg]
Cephalopholis sexmaculata (*ikula tumi*)	4	24	47[a]	~24[jjj]			Mar-May[jjj]	♀→♂[ggg]
Cephalopholis urodeta (*ikula karu guŋ-guŋ*)	6	18	27[a]			1♂:28.50♀[iii]		♀→♂[ggg]
Epinephelus fasciatus	3	16	40[a]	~14[kkk]	~18[kkk]	Increasingly male-biased with length[kkk]		♀→♂[kkk]
Epinephelus merra	3	22	28[a]	11[lll]				♀→♂[ggg]
Plectropomus areolatus (*ikula su mani balã*)	15	18	70[a]	40[b,mmm]	48[b,mmm]	Increasingly male-biased with length[nnn]	Jan-May[mmm]	♀→♂[ggg]
Plectropomus leopardus (*yula*)	10	32	68[a,b]	32[ooo]	37[hhh]	Increasingly male-biased > 44 cm[ooo]	Sep-Dec[ppp]	♀→♂[ppp]
Plectropomus oligacanthus (*ikula su tatalõ*)	61	32	65[a]	~27[q]	~41[q]		Apr-Jun[q]	♀→♂[q]
SIGANIDAE								
Siganus doliatus	3	16	~30[a,n]	~18[qqq]	~18[qqq]			No[qqq]

Taxon (Kala name, if recorded)	N	Mean length (cm)	L_{max} (cm)	Female L_{50} (cm)	Male L_{50} (cm)	Sex ratio	Spawning season	Sex change?
Siganus javus (*yulawe kokoranawa*)	33	25	~53[j,n] (TL)					
Siganus lineatus (*yulawe*)	66	26	41[a,b]	24[nn]	~19[nn]	~1:1[nn]	Year round[w]	No[nn]
Siganus puellus (*indaŋa*)	3	22	~38[a,n] (TL)					
Siganus vulpinus (*indaŋa*)	8	15	30[a]					

(a) Allen & Swainston 1993; (b) estimated using length-length relationship from Froese & Pauly 2012; (c) Craig *et al*. 1997 (d) however, spawning occurs year round; Craig 1998 (e) Thresher 1984; (f) Choat & Robertson 2002 (authors do not describe how estimate was obtained); (g) Longenecker *et al*. in review (h) Grandcourt *et al*. 2003; (i) Sudekum *et al*. 1991; (j) Randall *et al*. 1990; (k) Robbins 2006; (l) Lyle 1987 (m) Grandcourt *et al*. 2011; (n) no relationship available to estimate fork length; (o) Anand & Pillai 2002 (authors report minimum size-at-maturity based on a combination of gross and histological examination of individuals in variable size classes, above lengths are the mean of minimum and maximum class limits); (p) Longenecker *et al*. 2010; (q) present study; (r) %F = 369.91 – 15.84(FL); (s) FL estimated from a general *Myripristis* length relationship (C.J. Bradley, unpublished data) based on Hawaiian specimens of at least three species: *M. berndti*, *M. chryseres*, *M. kuntee*: FL = -0.4139 + 0.8919(TL); r^2 = 0.993; n = 50; (t) FL estimated from Hawaiian specimens (Longenecker 2008 and C.J. Bradley, unpublished data) FL = 0.4314 + 0.8288(TL), r^2 = 0.993, n = 13; (u) Longenecker *et al.* 2012; (v) Hubble 2003; (w) Hamilton *et al*. 2004; (x) Russell & McDougall 2008; (y) Pakoa 1998; (z) Allen 1985; (aa) Longenecker *et al*. 2013a; (bb) Marriott *et al* 2007; (cc) Kritzer 2004; (dd) authors' interpretation of data in Heupel *et al*. 2010: %♀ = 146.986 – 3.735(FL); (ee) Evans *et al*. 2008; (ff) Longenecker *et al*. 2013b; (gg) Caillart *et al*. 1994; (hh) Heupel *et al*. 2009 (all females > 23 cm FL were mature); (ii) results from Heupel *et al*. 2009 suggest the proportion of females is inversely related to size; (jj) Friedlander *et al*. 2002; (kk) Munro & Williams 1985 (length at first maturity); (ll) Kritzer in Williams *et al*. 2002; (mm) authors' interpretation of GSI and developmental stages in Sheaves 1995; (nn) Longenecker *et al*. 2011; (oo) Davis & West 1993; (pp) authors' interpretation of data in Davis & West 1992: sex ratio is 1:1 to 29 cm, then %♀ = 1.986 – 0.00534(FL); (qq) Loubens 1980; (rr) Cole 2008; (ss) Jehangeer 2003; (tt) FL estimated from Hawaiian specimens (Longenecker 2008): FL = 0.3132 + 0.8657(TL), r^2 = 0.998, n = 14; (uu) Longenecker & Langston 2008, %♀ = 141.3 – 0.6167(FL in mm) with all individuals male above 225 mm; (vv) FL estimated from relationships for Hawaiian specimens: FL = 0.827 + 0.840(TL), r^2 = 0.99, n = 3; FL = 1.029 + 1.044(SL), r^2 = 0.97, n = 3; (ww) Russell 1990; (xx) Sivakami *et al*. 2001; (yy) Bellwood 2001; (zz) Barba 2010; (aaa) Choat & Robertson 1975; (bbb) Sivadas & Anasukoya 2005 report that all individuals < 70 cm were immature; (ccc) Collette & Nauen 1983; (ddd) Abdussamad *et al*. 2010; (eee) Mackie *et al.* 2003; (fff) Lewis *et al*. 1974 (length at first maturity, sex ratio was ~1:1 in specimens <90 cm, but larger size classes were female biased, 4♂:38♀); (ggg) Heemstra & Randall 1993; (hhh) Chan & Sadovy 2002; (iii) Were 2009; (jjj) Shakeel & Ahmed 1996 report the smallest mature female was 24 cm; (kkk) Mishina *et al*. 2006; (lll) Murty 2002; (mmm) Rhodes & Tupper 2007; (nnn) authors' interpretation of data in Williams *et al*. 2008: %♀ = 285.0 – 4.346(FL); (ooo) authors' interpretation of data in Ferreira 1995: sex ratio is ~1♂:4♀ to 44 cm, then %♀ = 333 – 5.6(FL), maximum female size is 56 cm; (ppp) Ferreira 1995; (qqq) Brandl & Bellwood 2013.

Species Accounts

Acanthuridae

Acanthurus lineatus **(Linnaeus, 1758);** or ***iwiliya***. Figure 7.

First report; 11 specimens
Mean FL = 17 cm
57% of reported L_{max} (31 cm)
85% of estimated L_{opt} (20 cm)
94% of published ♀L_{50} (18 cm)

← Figure 7. *Iwiliya* (*Acanthurs lineatus*). Inter-laser distance 32 mm.

Ctenochaetus tominiensis **Randall, 1955** or ***aloweya yayã***. Figure 8.

4 new specimens; 10 total
Mean FL = 14 cm (↓)
74% of reported L_{max} (19 cm)
117% of estimated L_{opt} (12 cm)
108% of estimated ♀L_m (13 cm)

← Figure 8. *Aloweya yayã* (*Ctenochaetus tominiensis*). Inter-laser distance 31.5 mm.

Naso hexacanthus **(Bleeker, 1855)** or ***biaŋgawe suwi***. Figure 9.

Figure 9. *Biaŋgawe suwi* (*Naso hexacanthus*). Inter-laser distance 36 mm.

0 new specimens; 88 total (Figure 10)
Mean "FL" = 43 cm
61% of estimated L_{max} (71 cm)
91% of estimated L_{opt} (47 cm)
86% of estimated ♀L_{50} (50 cm)

Note: We were not able to evaluate the reliability of the size-at-maturity estimate from Choat & Robertson (2002).

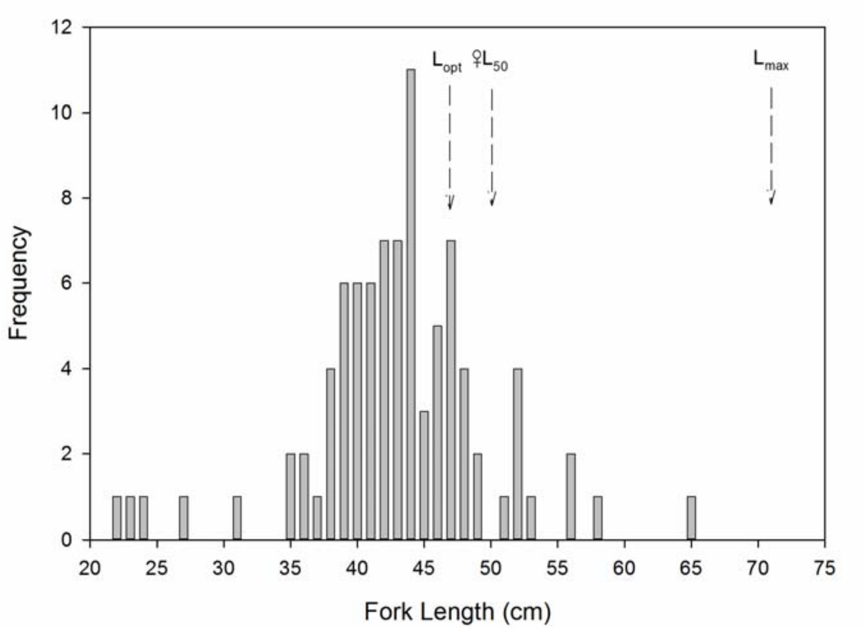


Figure 10. Size structure of *Naso hexacanthus*.

Naso lopezi **Herre, 1927** or ***biaŋgawe talõ***. Figure 11.

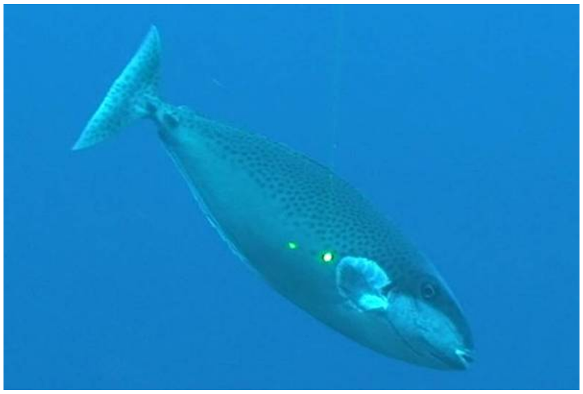


Figure 11. *Biaŋgawe talõ* (*Naso lopezi*). Inter-laser distance 36 mm.

0 new specimens; 3 total
Mean FL = 59 cm
123% of estimated L_{max} (48 cm)
190% of estimated of L_{opt} (31 cm)
190% of estimated ♀L_m (31 cm)

Note: L_{max} reported by Allen & Swainston (1993) may be an underestimate. Estimated length of the largest specimen captured on video was 85 cm, or 177% of published L_{max}.

Naso vlamingii **(Valenciennes, 1835)** or ***biaŋgawe tumi***. Figure 12.

0 new specimens; 10 total
Mean FL = 36 cm
71% of estimated L_{max} (51 cm)
109% of estimated of L_{opt} (33 cm)
109% of estimated ♀L_m (33 cm)

← Figure 12. *Biaŋgawe tumi* (*Naso vlamingii*).

Balistidae

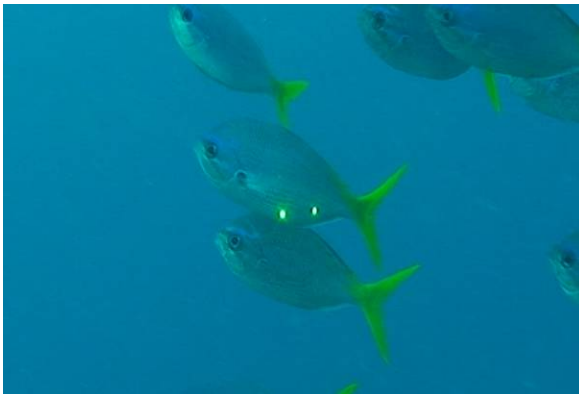
Canthidermis maculata (Bloch, 1786) or *labaikã suwi*. Figure 13.

0 new specimens; 13 total
Mean TL = 33 cm
94% of reported L_{max} (35 cm)
143% of estimated L_{opt} (23 cm)
143% of estimated ♀L_m (23 cm)

← Figure 13. *Labaikã suwi* (*Canthidermis maculata*). Inter-laser distance 36 mm.

Caesionidae

Caesio cuning (Bloch, 1791) or *luduŋ mai*. Figure 14.



197 new specimens; 1262 total (Figure 15)
Mean FL = 16 cm (no change)
53% of published L_{max} (30 cm)
84% of estimated L_{opt} (19 cm)
107% of published ♀L_{50} (15 cm)
36% mature ♀

← Figure 14. *Luduŋ mai* (*Caesio cuning*). Inter-laser distance 31.5 mm.

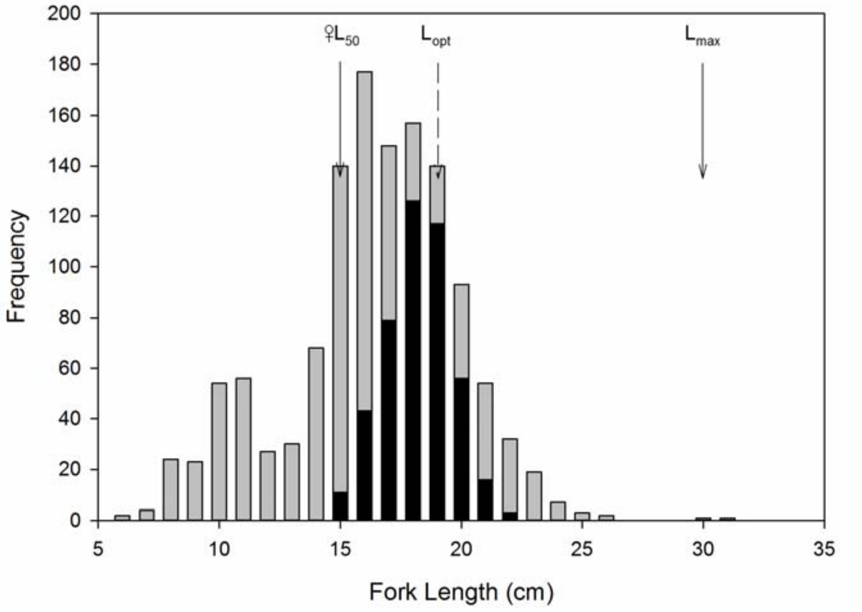


Figure 15. Size structure of *Caesio cuning*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Carangidae

Carangoides bajad* (Forsskål, 1775)** or ***imaŋalẽ babaura. Figure 16.

1 new specimen; 42 total (Figure 17)
Mean FL = 26 cm (no change)
51% of estimated L_{max} (51 cm)
79% of estimated L_{opt} (33 cm)
104% of published ♀L_m (25 cm)
33% mature ♀

← Figure 16. *Imaŋalẽ babaura* (*Carangoides bajad*). Inter-laser distance 39 mm.

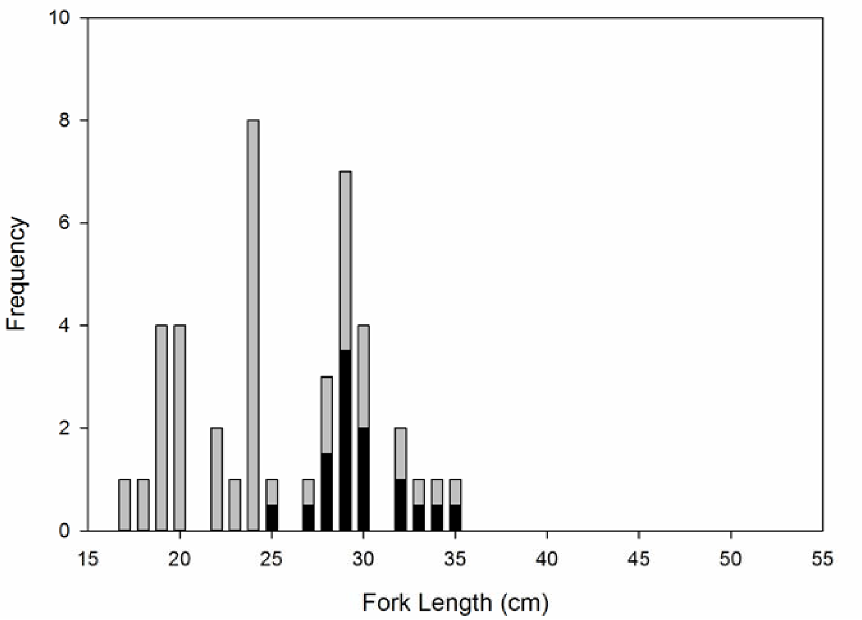


Figure 17. Size structure of *Carangoides bajad*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Carangoides plagiotaenia* Bleeker, 1857** or ***imaŋalẽ tombo gabo. Figure 18.

5 new specimens; 35 total (Figure 19)
Mean FL = 27 cm (↑)
71% of estimated L_{max} (38 cm)
108% of estimated L_{opt} (25 cm)
108% of estimated ♀L_m (25 cm)

← Figure 18. *Imaŋalẽ tombo gabo* (*Carangoides plagiotaenia*). Inter-laser distance 36 mm.

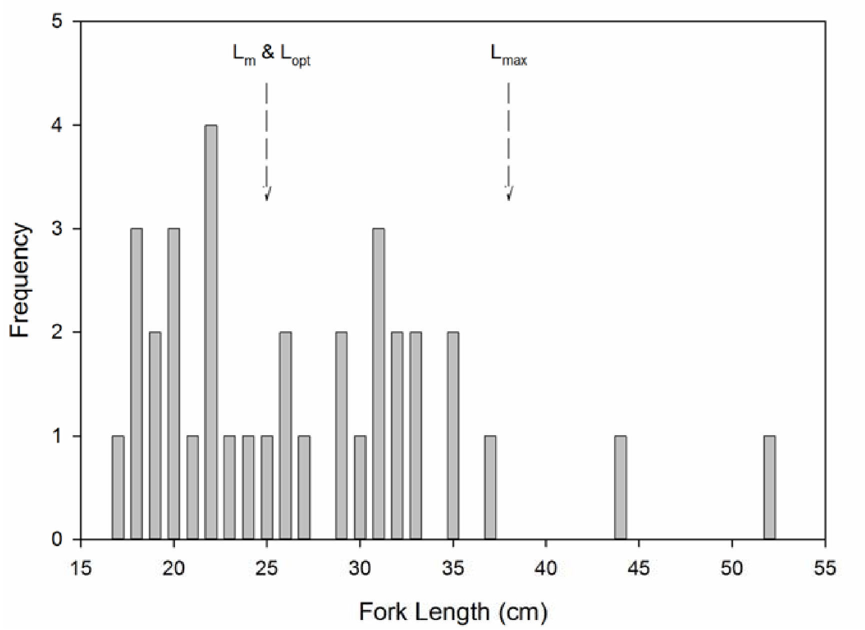


Figure 19. Size structure of *Carangoides plagiotaenia*.

Caranx melampygus **Cuvier, 1833** or ***imaŋalẽ talã***. Figure 20.

3 new specimens; 38 total (Figure 21)
Mean FL = 26 cm (no change)
36% of reported L_{max} (72 cm)
55% of estimated L_{opt} (47 cm)
84% of published ♀L_m (36 cm)
8% mature ♀

← Figure 20. *Imaŋalẽ talã* (*Caranx melampygus*).

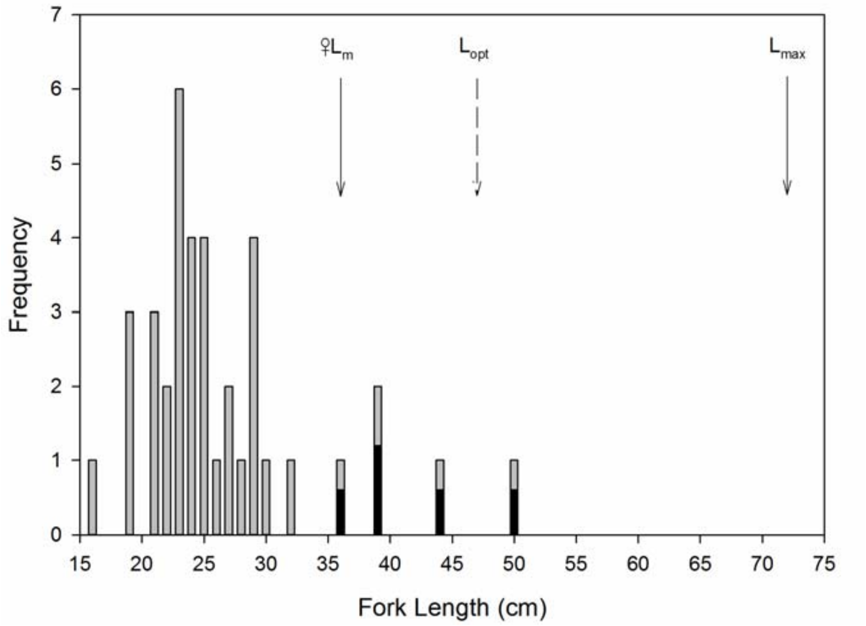
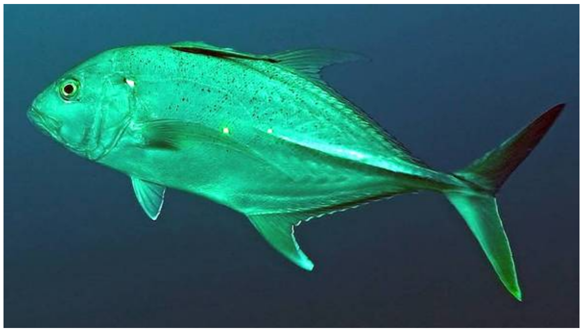


Figure 21. Size structure of *Caranx melampygus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Caranx papuensis **Alleyne & MacLeay, 1877** or ***imaŋalẽ labrã kulĩ***. Figure 22.



3 new specimens; 16 total (Figure 23)
Mean FL = 57 cm (↓)
86% of estimated L_{max} (66 cm)
133% of estimated L_{opt} (43 cm)
136 % of estimated ♀L_m (42 cm)

← Figure 22. *Imaŋalẽ labrã kulĩ* or *Caranx papuensis* (with a remora attached near the origin of the first dorsal fin). Inter-laser distance 39 mm.

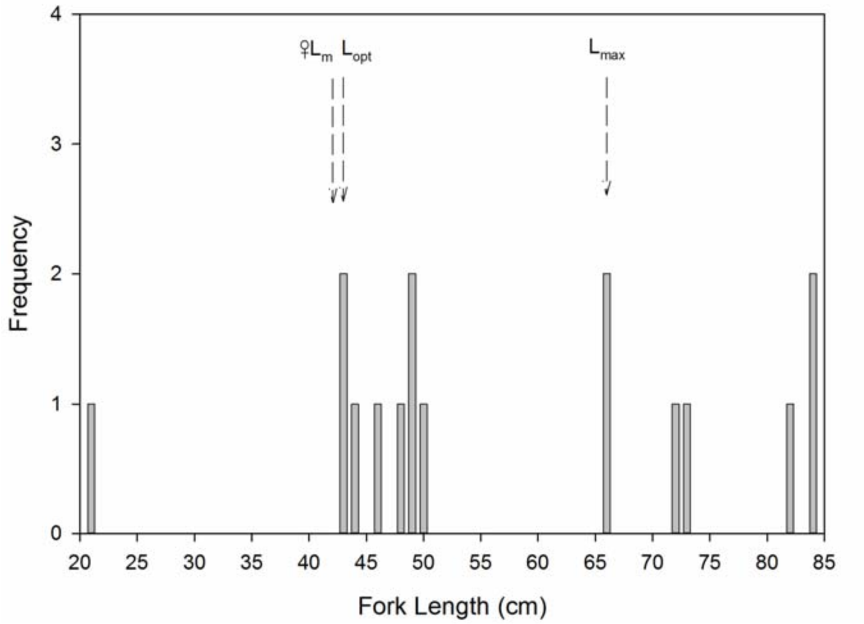


Figure 23. Size structure of *Caranx papuensis*.

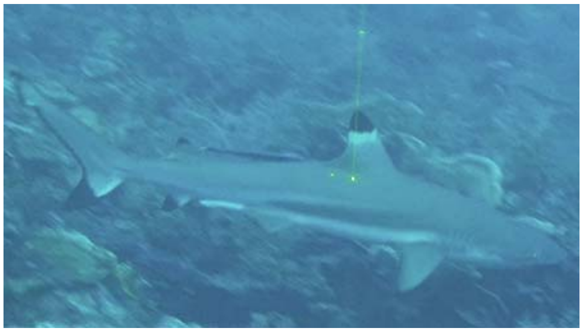
<u>Carcharhinidae</u>

Carcharhinus amblyrhynchos* (Bleeker, 1856)** or ***kapa ii. Figure 24.

1 new specimen; 9 total
Mean FL = 78 cm (no change)
36% of estimated L_{max} (217 cm)
53% of estimated L_{opt} (147 cm)
66% of published ♀L_{50} (118 cm)

← Figure 24. *Kapa ii* (*Carcharhinus amblyrhynchos*).

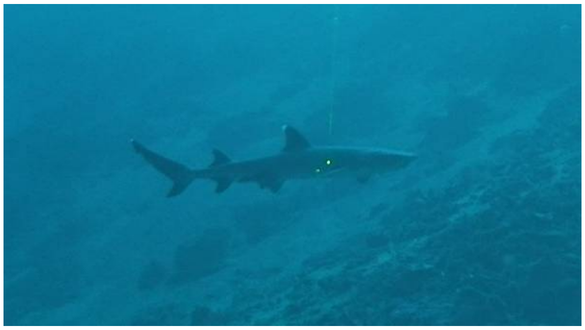
***Carcharhinus melanopterus* (Quoy & Gaimard, 1824)**; Kala name not yet recorded. Figure 25.



First report; 4
Mean FL = 80 cm
53% of reported L_{max} (150 cm)
79% of estimated L_{opt} (101 cm)
100% of published 100% L_m (80 cm)

← Figure 25. *Carcharhinus melanopterus*. Inter-laser distance 36 mm.

Triaenodon obesus*) (Rüppell, 1837)** or ***kapa bage bula. Figure 26.



1 new specimen; 8 total
Mean FL = 73 cm (↑)
41% of reported L_{max} (177 cm)
61% of estimated L_{opt} (119 cm)
75% of published ♀L_{50} (97 cm)

← Figure 26. *Kapa bage bula* (*Triaenodon obesus*). Inter-laser distance 35.5 mm.

Ephippidae

***Platax orbicularis* (Forsskål, 1775)**; Kala name not yet recorded. Figure 27.

First report; 5 specimens
Mean FL = 35 cm
70% of reported L_{max} (50 cm)
106% of estimated L_{opt} (33 cm)
109% of estimated ♀L_m (32 cm)

← Figure 27. *Platax orbicularis*. Inter-laser distance 32 mm.

Platax pinnatus* (Linneaus, 1758)** or ***ibuŋgi tarõ. Figure 28.

2 new specimens; 13 total
Mean TL = 25 cm (no change)
83% of reported L_{max} (30 cm)
132% of estimated L_{opt} (19 cm)
125% of estimated ♀L_m (20 cm)

← Figure 28. *Ibuŋgi tarõ* (*Platax pinnatus*). Inter-laser distance 36 mm.

Platax teira* (Forsskål, 1775)** or ***ibuŋgi. Figure 29.

1 new specimen; 5 total
Mean TL = 33 cm (↓)
55% of reported L_{max} (60 cm)
85% of estimated L_{opt} (39 cm)
89% of estimated ♀L_m (38 cm)

← Figure 29. *Ibuŋgi* (*Platax teira*). Inter-laser distance 39 mm.

Haemulidae

Diagramma pictum* (Thunberg, 1792)** or ***godobo manibarã (juvenile) and ***godobo tarõ*** (adult). Figure 30.

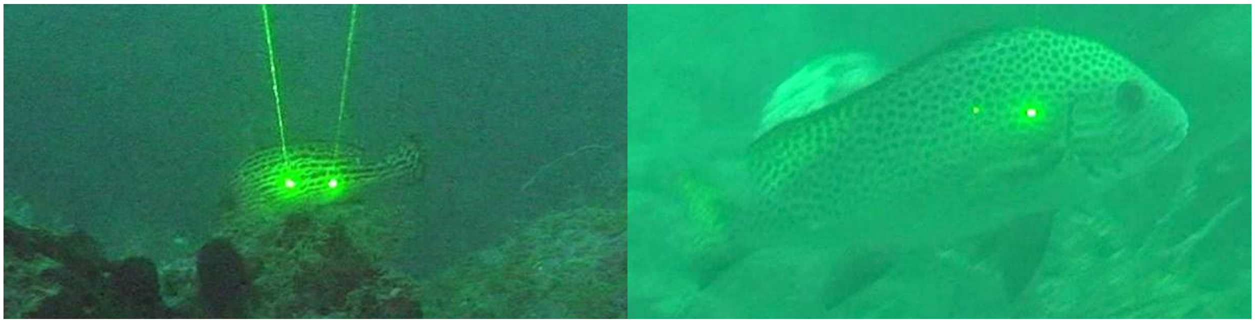


Figure 30. *Godobo manibarã* (left) and *godobo tarõ* (right) or *Diagramma pictum* juvenile (left) and adult (right). Inter-laser distance 31 and 36 mm, respectively.

0 new specimens; 8 total
Mean TL = 25 cm
28% of reported L_{max} (90 cm)
57% of the published L_{opt} (44 cm)
69% of the published ♀L_{50} (36 cm)

Note: None of the individuals captured on video had reached female L_{50}.

***Plectorhinchus chaetodonoides* Lacepède, 1801;** Kala name not yet recorded. Figure 31

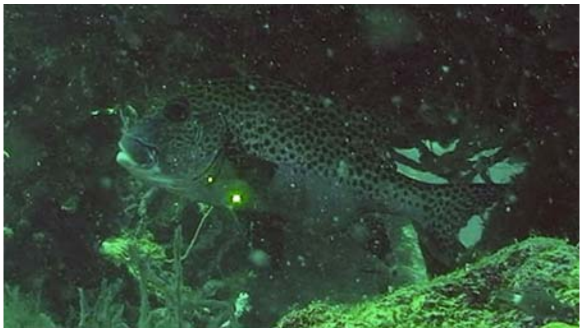


Figure 31. *Plectorhinchus chaetodonoides*. Inter-laser distance 36 mm.

First report; 5 specimens
Mean FL = 43 cm
72% of reported L_{max} (60 cm TL)
110% of estimated L_{opt} (39 cm TL)
113% of estimated ♀L_m (38 cm TL)

Note: L_{max}, L_{opt}, & ♀L_{50} values are presented as total length because the relationship between total and fork lengths is unknown. The above percentages are likely underestimates.

Plectorhinchus lineatus (Linnaeus, 1758) or ***iyabua sa***. Figure 32.

24 new specimens; 46 total (Figure 33)
Mean TL = 36 cm (no change)
72% of reported L_{max} (50 cm)
109% of estimated L_{opt} (33 cm)
113% of estimated ♀L_m (32 cm)

← Figure 32. *Iyabua sa* (*Plectorhinchus lineatus*). Inter-laser distance 39 mm.

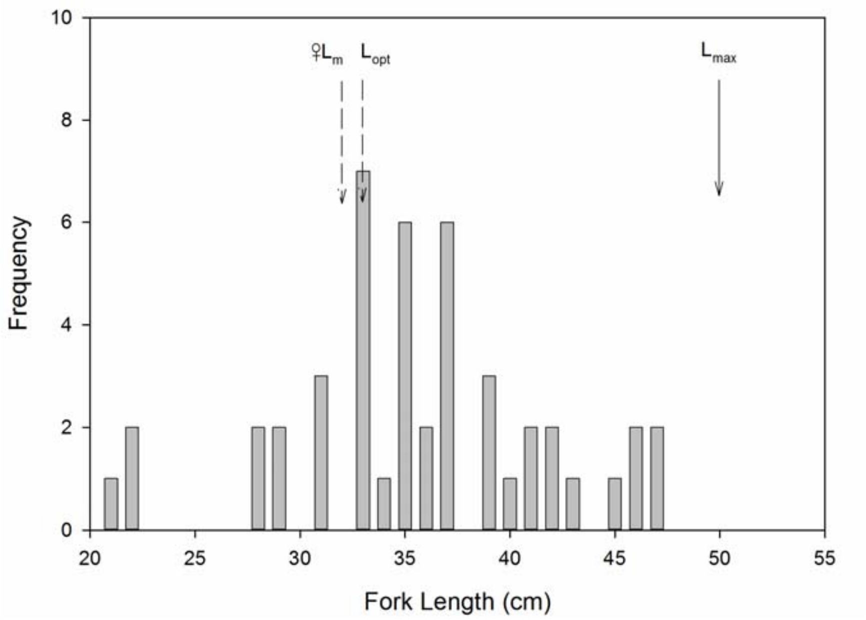


Figure 33. Size structure of *Plectorhinchus lineatus*.

Plectorhinchus vittatus*) (Linnaeus, 1758)** or ***iyabua kurĩ naba. Figure 34.

1 new specimen; 4 total
Mean TL = 28 cm (↓)
56% of reported L_{max} (50 cm)
85% of estimated L_{opt} (33 cm)
122% of published ♀L_m of (23 cm)
64% mature ♀

← Figure 34. *Iyabua kurĩ naba* (*Plectorhinchus vittatus*). Inter-laser distance 31.5 mm.

Holocentridae

Myripristis adusta* Bleeker, 1853** or ***imbilĩ tombo gabo. Figure 35.

1 new specimen; 17 total (Figure 36)
Mean FL = 19 cm (↑)
68% of reported L_{max} (28 cm)
106% of estimated L_{opt} (18 cm)
112% of observed ♀L_{50} (17 cm)
60% mature ♀

← Figure 35. *Imbilĩ tombo gabo* (*Myripristis adusta*).

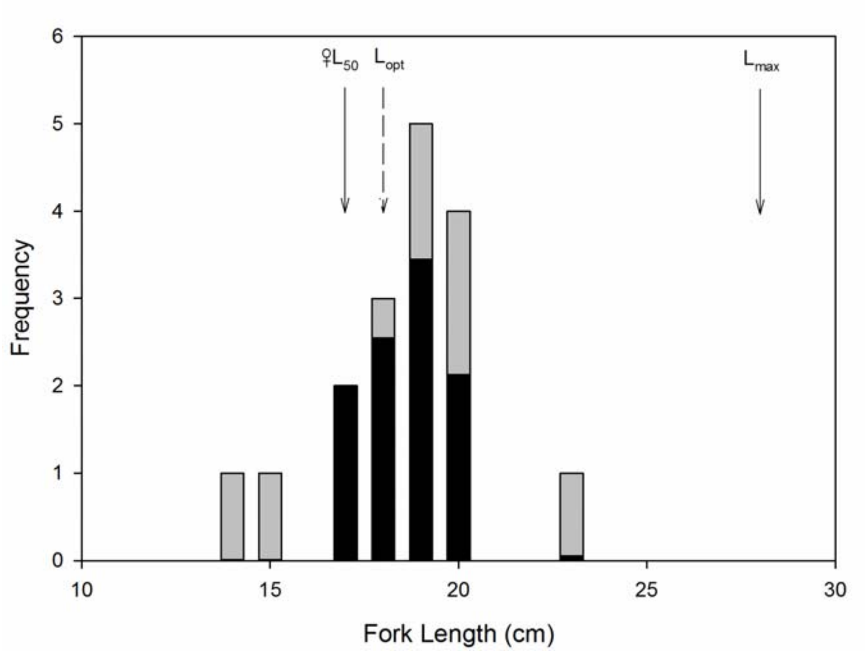


Figure 36. Size structure of *Myripristis adusta*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Myripristis berndti) (Jordan & Evermann, 1903) or *imbilĩ yakẽ yayã*. Figure 37.

1 new specimen; 5 total
Mean FL = 13 cm (↑)
50% of reported L_{max} (26 cm)
76% of estimated L_{opt} (17 cm)
72% of estimated ♀L_m (18 cm)

← Figure 37. *Imbilĩ yakẽ yayã* (*Myripristis berndti*).

Myripristis kuntee Valenciennes, 1831 or *imbilĩ godõ nambĩ*. Figure 38.

Figure 38. *Imbilĩ godõ nambĩ* (*Myripristis kuntee*). Inter-laser distance 39 mm.

11 new specimens; 76 total (Figure 39)
Mean FL = 12 cm (no change)
75% of reported L_{max} (16 cm)
109% of estimated L_{opt} (11 cm)
100% of estimated ♀L_m (12 cm)

Note: Length estimates for 2 individuals (17 & 18 cm FL) were larger than L_{max} derived from Allen & Swainston (1993).

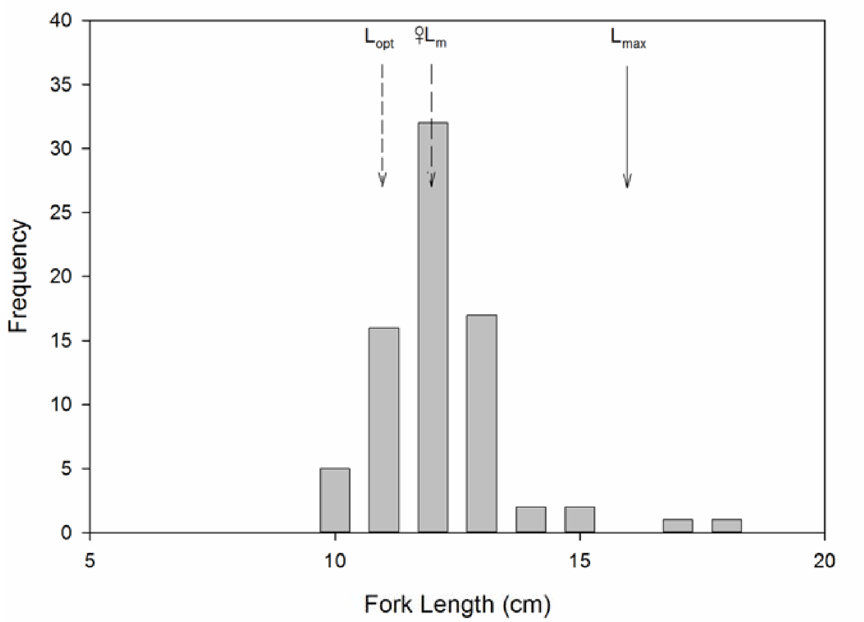


Figure 39. Size structure of *Myripristis kuntee*.

Myripristis pralinia* Cuvier, 1829** or ***imbilĩ yakẽ suwi. Figure 40.

0 new specimens; 12 total
Mean FL = 12 cm
86% of reported L_{max} (17 cm)
109% of estimated L_{opt} (11 cm)
100% of estimated ♀L_m (12 cm)

← Figure 40. *Imbilĩ yakẽ suwi* (*Myripristis pralinia*).

Myripristis violacea* Bleeker, 1851** or ***imbilĩ yakẽ bumbu. Figure 41.

20 new specimens; 89 total (Figure 42)
Mean FL = 13 cm (no change)
76% of estimated L_{max} (17 cm)
118% of estimated L_{opt} (11 cm)
108% of estimated ♀L_m (12 cm)

← Figure 41. *Imbilĩ yakẽ bumbu* (*Myripristis violacea*).

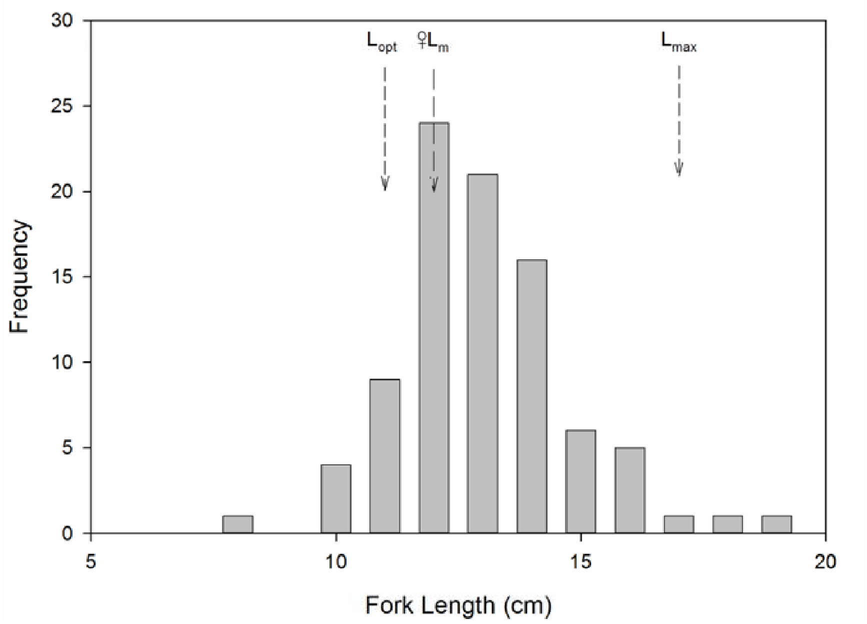
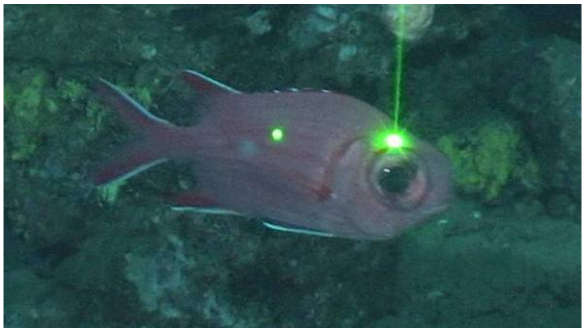


Figure 42. Size structure of *Myripristis violacea*.

Myripristis vittata **Valenciennes, 1831** or ***imbilĩ yakẽ suwi***. Figure 43.



0 new specimens; 20 total (Figure 44)
Mean FL = 11 cm
65% of reported L_{max} (17 cm)
100% of estimated L_{opt} (11 cm)
92% of the estimated ♀L_m (12 cm)

← Figure 43. *Imbilĩ yakẽ suwi* (*Myripristis vittata*). Inter-laser distance 36 mm.

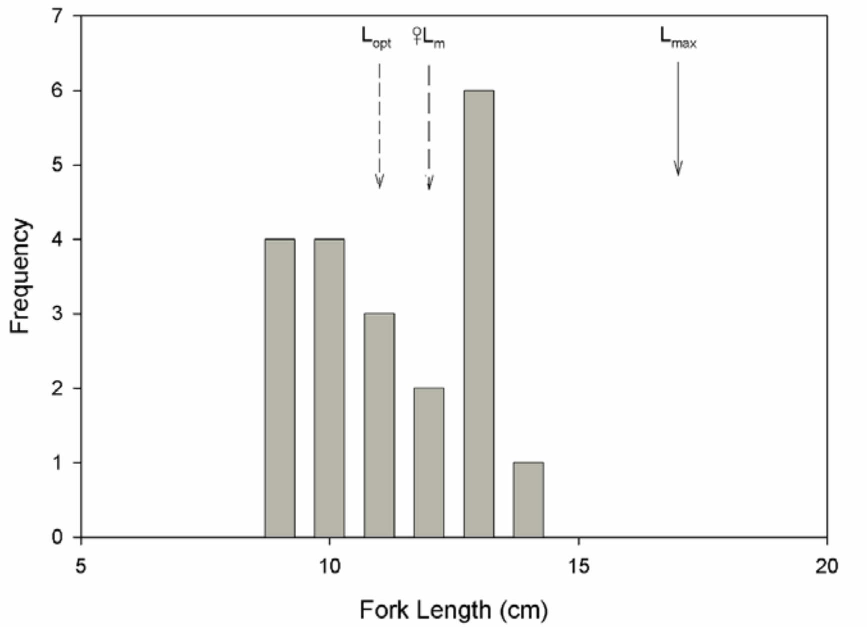


Figure 44. Size structure of *Myripristis vittata*.

Neoniphon sammara* (Forsskål, 1775)** or ***imbilĩ sa. Figure 45.

2 new specimens; 18 total (Figure 46)
Mean FL = 14 cm (no change)
52% of estimated L_{max} (27 cm)
82% of estimated L_{opt} (17 cm)
175% of published ♀L_m (8 cm)
72% mature ♀

← Figure 45. *Imbilĩ sa* (*Neoniphon sammara*). Inter-laser distance 39 mm.

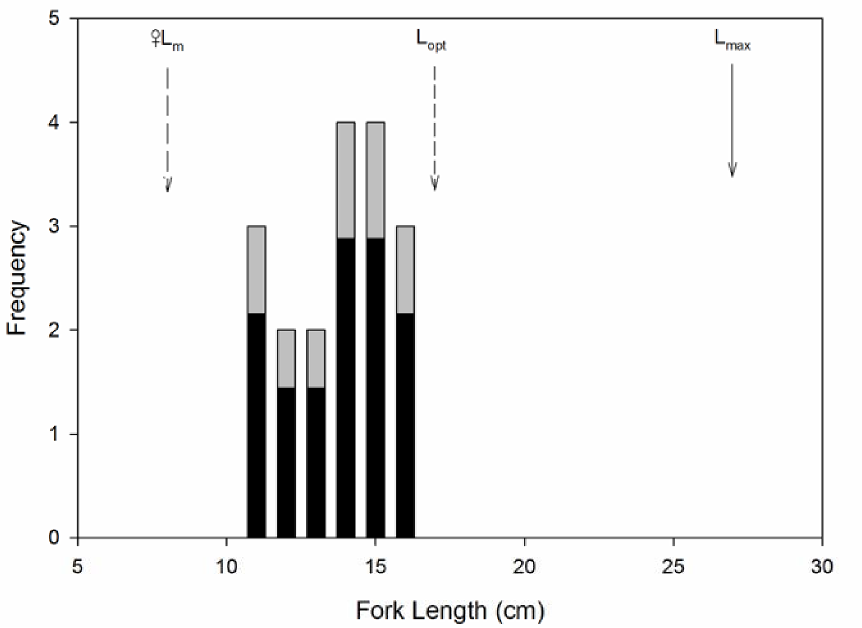


Figure 46. Size structure of *Neoniphon sammara*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Sargocentron caudimaculatum* (Rüppell, 1838)** or ***imbilĩ yasai. Figure 47.

1 new specimen; 8 total
Mean FL = 15 cm (no change)
79% of reported L_{max} (19 cm)
125% of estimated L_{opt} (12 cm)
115% of estimated ♀L_m (13 cm)

← Figure 47. *Imbilĩ yasai* (*Sargocentron caudimaculatum*). Inter-laser distance 31 mm.

***Sargocentron melanospilos* (Bleeker, 1858);** Kala name not yet recorded. Figure 48

First report; 3 specimens
Mean FL = 15 cm
65% of reported L_{max} (23 cm)
100% of estimated L_{opt} (15 cm)
94% of estimated ♀L_m (16 cm)

← Figure 48. *Sargocentron melanospilos*. Inter-laser distance 32 mm.

Kyphosidae

Kyphosus cinerascens* (Forsskål, 1775)** or ***italawe. Figure 49.

8 new specimens; 75 total (Figure 50)
Mean FL = 30 cm (no change)
73% of estimated L_{max} (41 cm)
111% of estimated L_{opt} (27 cm)
120% of published ♀L_m (25 cm)

← Figure 49. *Italawe* (*Kyphosus cinerascens*). Inter-laser distance 39 mm.

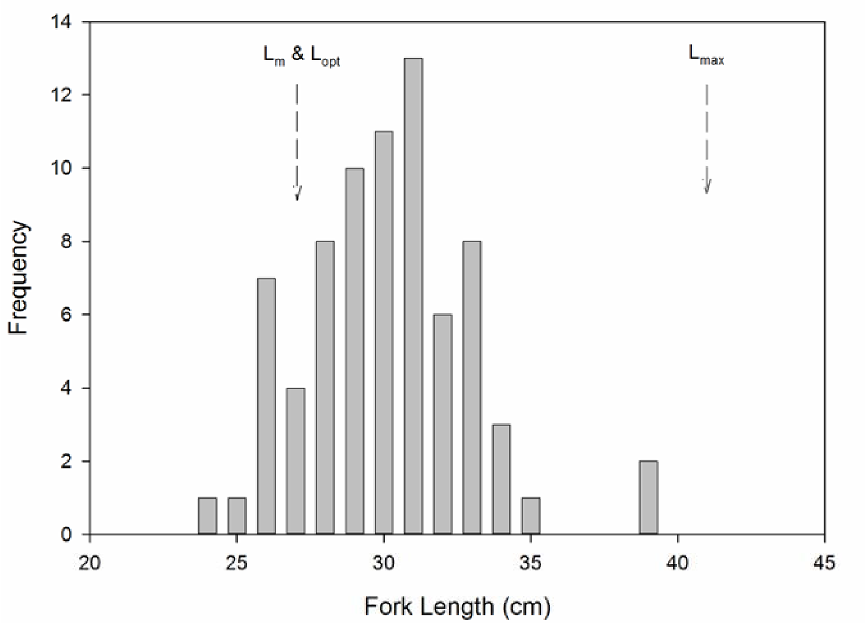


Figure 50. Size structure of *Kyphosus cinerascens*.

Kyphosus vaigiensis* (Quoy & Gaimard, 1825)** or ***italawe talabopia. Figure 51.

2 new specimens; 7 total
Mean FL = 35 cm (↓)
63% of estimated L_{max} (56 cm)
95% of estimated L_{opt} (37 cm)
97% of estimated ♀L_m (36 cm)

← Figure 51. *Italawe talabopia* (*Kyphosus vaigiensis*). Inter-laser distance 39 mm.

<u>Labridae</u>

***Choerodon anchorago* (Bloch, 1791)**; Kala name not yet recorded. Figure 52.

1 new specimen; 5 total
Mean FL = 24 cm (↑)
63% of published L_{max} (38 cm)
96% of estimated L_{opt} (25 cm)
96% of estimated ♀L_m (25 cm)

← Figure 52. *Choerodon anchorago*. Inter-laser distance 36 mm.

Cheilinus fasciatus* (Bloch, 1791)** or ***ii bui bui. Figure 53.

Figure 53. *Ii bui bui* (*Cheilinus fasciatus*). Inter-laser distance 39 mm.

23 new specimens; 35 total (Figure 54)
Mean FL = 16 cm (↓)
44% of estimated L_{max} (36 cm TL)
70% of estimated L_{opt} (23 cm TL)
133% of published ♀L_{50} (12 cm TL)

Note: L_{max}, L_{opt}, & ♀L_{50} values are presented as total length because the relationship between total and fork lengths is unknown. The above percentages are likely underestimates.

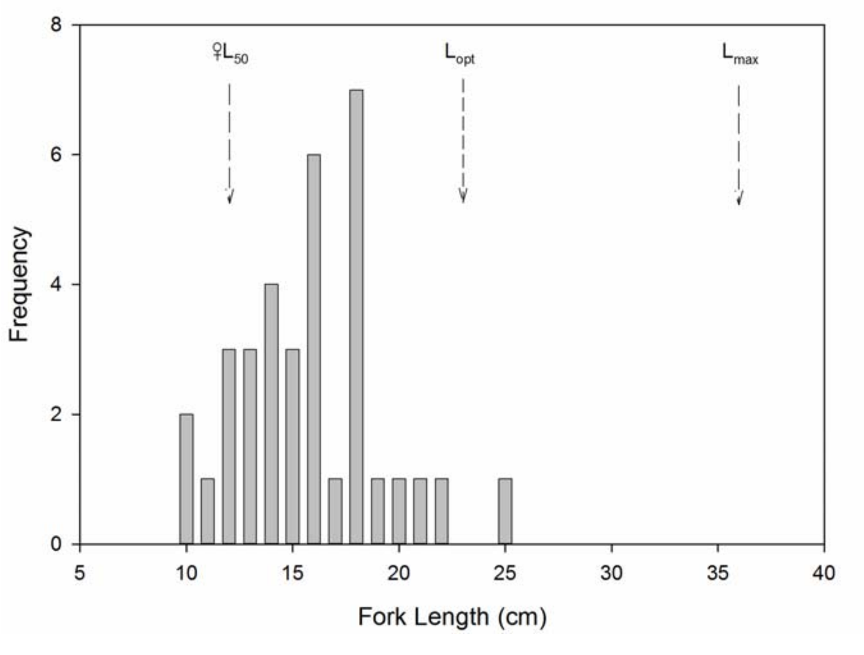
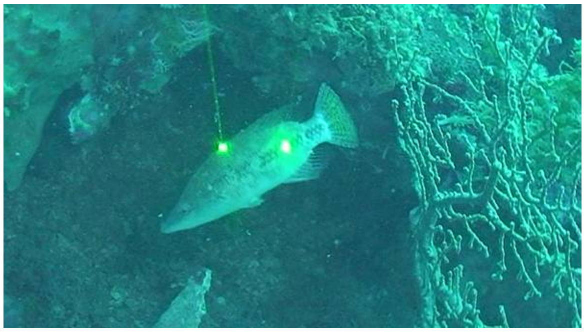


Figure 54. Size structure of *Cheilinus fasciatus*. Estimates of female L_{50}, L_{opt}, and L_{max} are total lengths.

Oxycheilinus celebicus **(Bleeker, 1853)** or ***talulumuã bobo***. Figure 55.



18 new specimens; 24 total (Figure 56)
Mean TL = 13 cm (↓)
65% of published L_{max} (20 cm)
93% of estimated L_{opt} (14 cm)
100% of estimated ♀L_m (13 cm)

← Figure 55. *Talulumuã bobo* (*Oxycheilinus celebicus*). Inter-laser distance 31 mm.

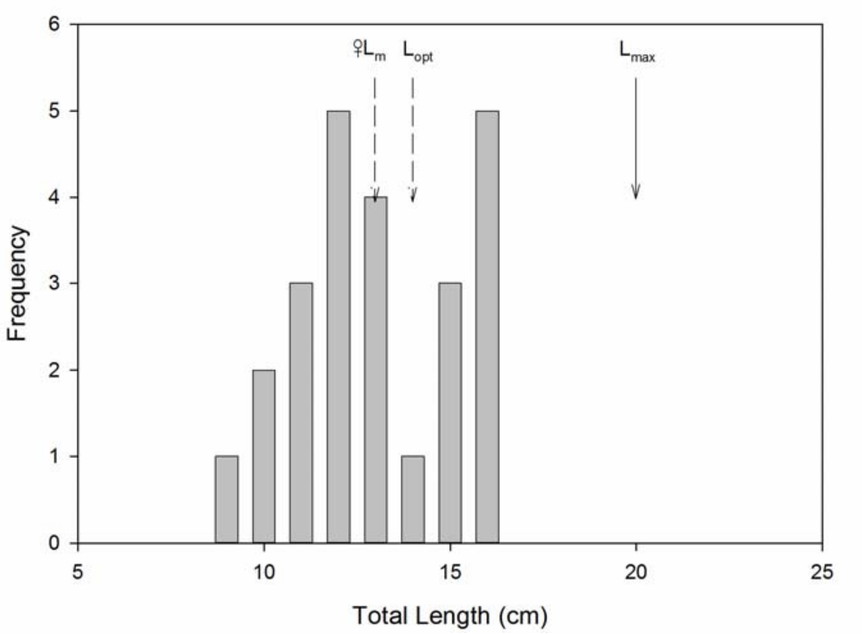


Figure 56. Size structure of *Oxycheilinus celebicus*.

Oxycheilinus digramma **(Lacepède, 1801)** or ***ikula talulumuã***. Figure 57.

1 new specimen; 5 total
Mean TL = 17 cm (↓)
57% of estimated L_{max} (30 cm)
89% of estimated L_{opt} (19 cm)
85% of estimated ♀L_m (20 cm)

← Figure 57. *Ikula talulumuã* (*Oxycheilinus digramma*). Inter-laser distance 36.5 mm.

Lethrinidae

Lethrinus erythropterus **Valenciennes, 1830** or ***kada maba***. Figure 58.

0 new specimens; 5 total
Mean FL = 22 cm
46% of estimated L_{max} (48 cm)
71% of estimated L_{opt} (31 cm)
110% of observed ♀L_{50} (20 cm)
22% mature ♀

← Figure 58. *Kada maba* (*Lethrinus erythropterus*). Inter-laser distance 31 mm.

Monotaxis grandoculis **(Forsskål, 1775)** or ***labaikã taloŋ*** (juvenile) and ***labaikã*** (adult). Figure 59.

Figure 59. *Labaikã taloŋ* (left) and *labaikã* (right) or *Monotaxis grandoculis* juvenile (left) and adult (right).

6 new specimens; 70 total (Figure 60)
Mean FL = 24 cm (↓)
43% of estimated L_{max} (56 cm)
65% of estimated L_{opt} (37 cm)
67% of estimated ♀L_m (36 cm)

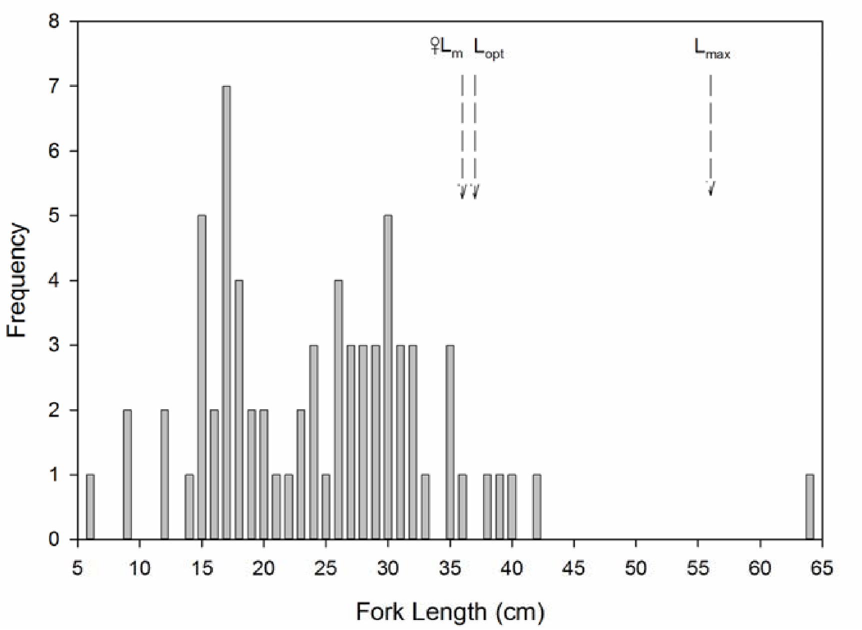
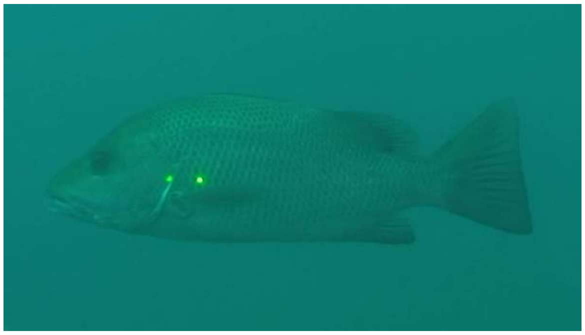


Figure 60. Size structure of *Monotaxis grandoculis*.

Lutjanidae

Lutjanus argentimaculatus* (Forsskål, 1775)** or ***ilĩ. Figure 61.



0 new specimens; 4 total
Mean FL = 48 cm
41% of reported L_{max} (118 cm)
61% of estimated L_{opt} (79 cm)
91% of published ♀L_{50} (53 cm)
27% mature ♀

← Figure 61. *Ilĩ* (*Lutjanus argentimaculatus*). Inter-laser distance 36 mm.

Lutjanus biguttatus* (Valenciennes, 1830)** or ***itale. Figure 62.

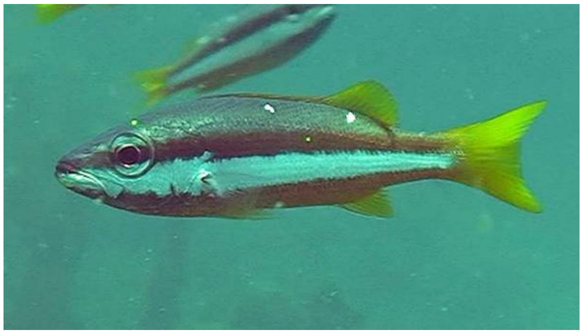


Figure 62. *Itale* (*Lutjanus biguttatus*). Inter-laser distance 39 mm.

53 new specimens; 480 total (Figure 63)
Mean FL = 15 cm (↑)
79% of published L_{max} (19 cm)
125% of estimated L_{opt} (12 cm)
88% of published ♀L_{50} (17 cm)
16% mature ♀

Note: L_{max} of Allen & Swainston (1993) may be an underestimate for the region; 9% of the individuals captured on video are larger. The largest individual observed at KWMA was 23 cm FL.

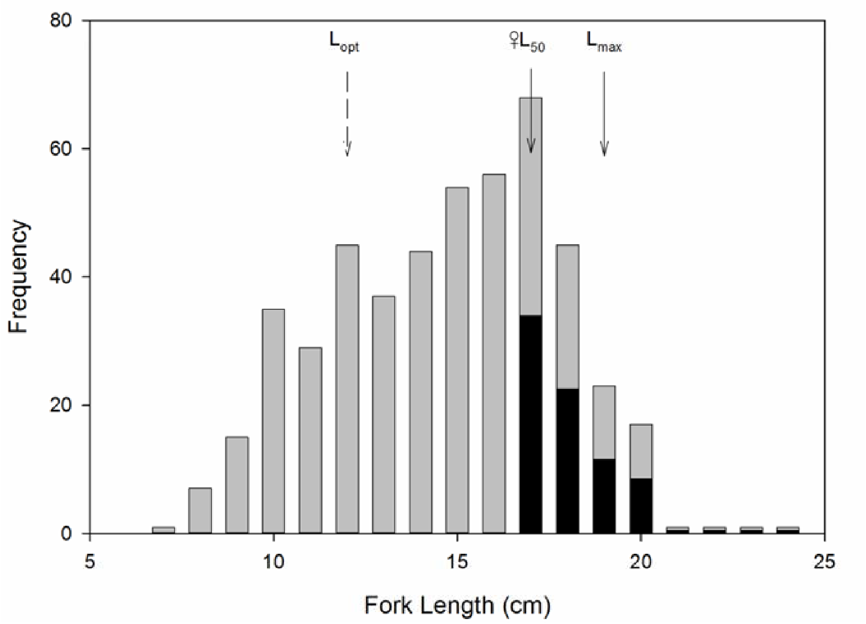


Figure 63. Size structure of *Lutjanus biguttatus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Lutjanus bohar* (Forsskål, 1775)** or ***yame tuaŋ yasai, ***yame tuaŋ***, and ***ilĩ*** (juvenile through adult stages). Figure 64.

Figure 64. *Yame tuaŋ yasai*, *yame tuaŋ*, & *ilĩ* (*Lutjanus bohar*). Inter-laser distance 31 mm.

0 new specimens; 4 total
Mean FL = 17 cm
24% of reported L_{max} (71 cm)
36% of estimated L_{opt} (47 cm)
40% of published $♀L_{50}$ (43 cm)

Note: The low percentages above may be an artifact of our methods. Color patterns allow accurate identification of juveniles; however, adults are difficult to distinguish from *L. argentimaculatus* (note the same Kala name for both species) and may have been classified as unidentified individuals.

Lutjanus boutton* (Lacepède, 1802)** or ***iyayaŋ. Figure 65.

55 new specimens; 215 total (Figure 66)
Mean FL = 14 cm (no change)
50% of estimated L_{max} (28 cm)
78% of estimated L_{opt} (18 cm)
74% of estimated ♀L_m of (19 cm)

← Figure 65. *Iyayaŋ* (*Lutjanus boutton*). Inter-laser distance 39 mm.

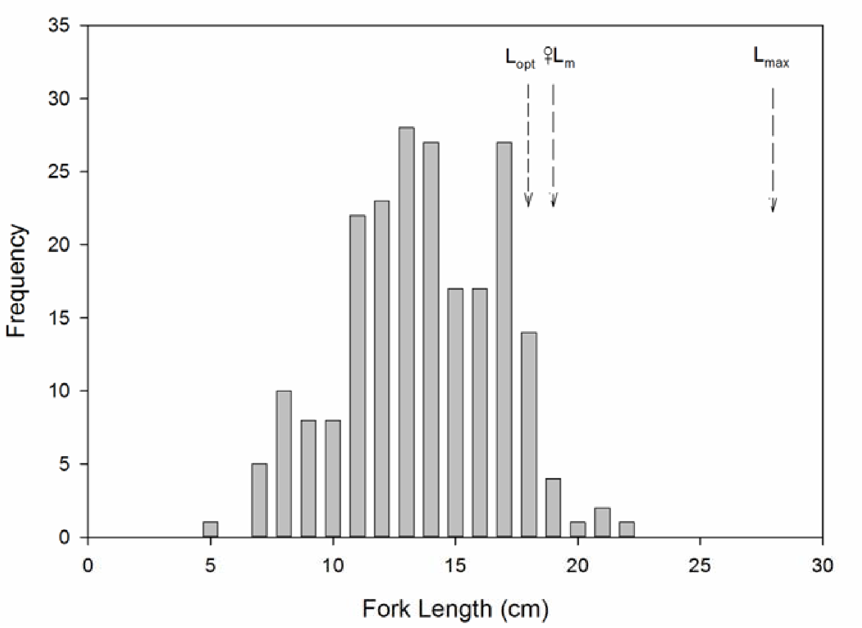


Figure 66. Size structure of *Lutjanus boutton*.

Lutjanus carponotatus* (Richardson, 1842)** or ***babaura. Figure 67.

6 new specimens; 36 total (Figure 68)
Mean FL = 21 cm (↑)
55% of reported L_{max} (38 cm)
84% of estimated L_{opt} (25 cm)
111% of published ♀L_{50} (19 cm)
28% mature ♀

← Figure 67. *Babaura* (*Lutjanus carponotatus*).

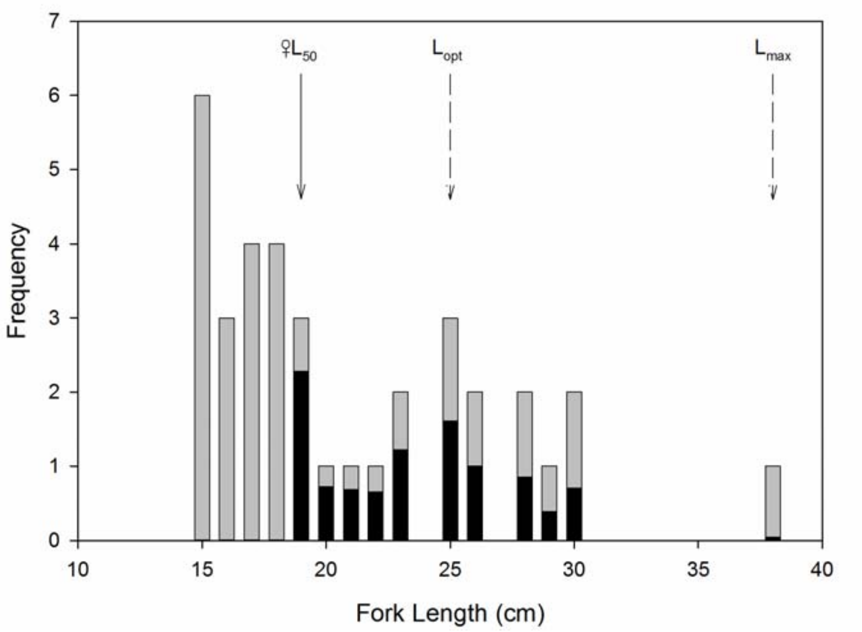


Figure 68. Size structure of *Lutjanus carponotatus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Lutjanus fulvus **(Forster, 1801)** or ***iyayaŋ kurĩ naba***. Figure 69.

4 new specimens; 45 total (Figure 70)
Mean FL = 18 cm (no change)
46% of reported L_{max} (39 cm)
72% of estimated L_{opt} (25 cm)
95% of published ♀L_{50} (19 cm)
21% mature ♀

← Figure 69. *Iyayaŋ kurĩ naba* (*Lutjanus fulvus*).

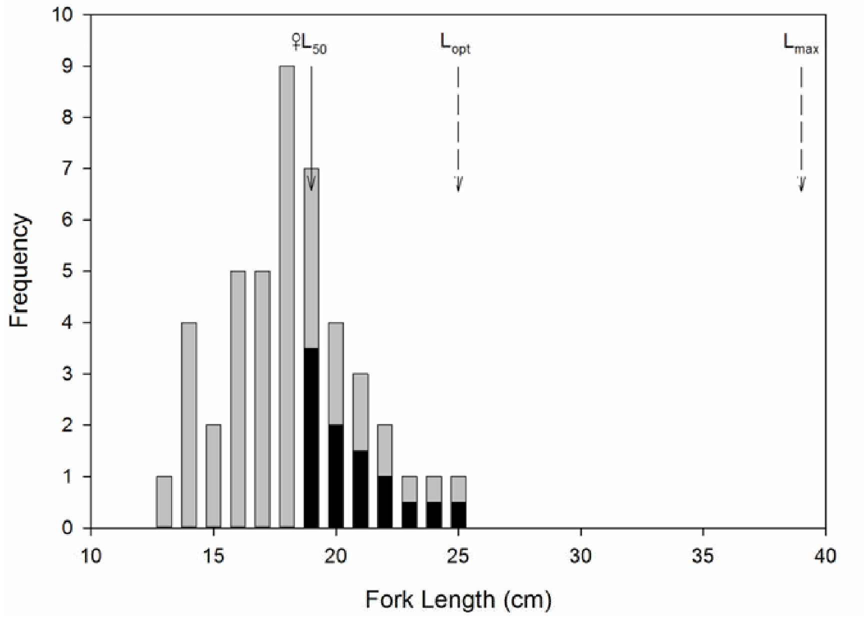


Figure 70. Size structure of *Lutjanus fulvus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Lutjanus gibbus **(Forsskål, 1775)** or ***ina suwi***. Figure 71.

0 new specimens; 22 total (Figure 72)
Mean FL = 20 cm
48% of estimated L_{max} (42 cm)
74% of estimated L_{opt} (27 cm)
111% of published ♀L_m (18 cm)

← Figure 71. *Ina suwi* (*Lutjanus gibbus*). Inter-laser distance 39 mm.

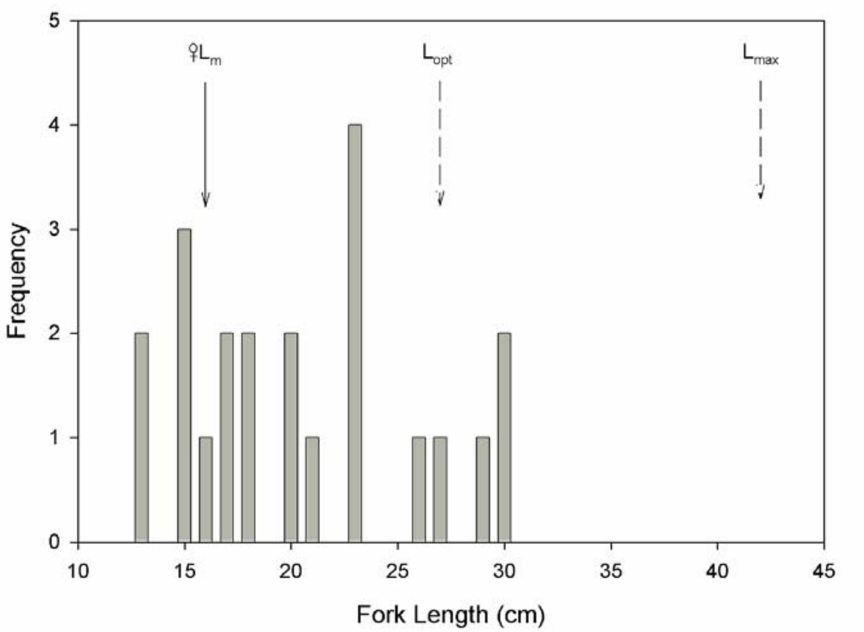


Figure 72. Size structure of *Lutjanus gibbus*.

Lutjanus kasmira* (Forsskål, 1775)** or ***babaura yumi yayã. Figure 73.

0 new specimens; 4 total
Mean FL = 16 cm
48% of published L_{max} (33 cm)
76% of estimated L_{opt} (21 cm)
133% of published ♀L_m (12 cm)
43% mature ♀

← Figure 73. *Babaura yumi yayã* (*Lutjanus kasmira*). Inter-laser distance 36 mm.

Lutjanus monostigma* (Cuvier, 1828)** or ***baniŋga. Figure 74.

0 new specimens; 4 total
Mean FL = 21 cm
44% of estimated L_{max} (48 cm)
68% of estimated L_{opt} (31 cm)
66% of published ♀L_m (32 cm)

← Figure 74. *Baniŋga* (*Lutjanus monostigma*). Inter-laser distance 31 mm.

Lutjanus rivulatus **(Cuvier, 1828)** or ***isina***. Figure 75.

0 specimens; 4 total
Mean FL = 31 cm
49% of estimated L_{max} (63 cm)
76% of estimated L_{opt} (41 cm)
78% of estimated ♀L_m (40 cm)

← Figure 75. *Isina* (*Lutjanus rivulatus*). Inter-laser distance 39 mm.

Lutjanus russellii **(Bleeker, 1849)** or ***kawasi ŋasiŋa***. Figure 76.

7 new specimens; 82 total (Figure 77)
Mean FL = 21 cm (↓)
49% of estimated L_{max} (43 cm)
75% of estimated L_{opt} (28 cm)
95% of published ♀L_{50} (22 cm)

← Figure 76. *Kawasi ŋasiŋa* (*Lutjanus russellii*). Inter-laser distance 39 mm.

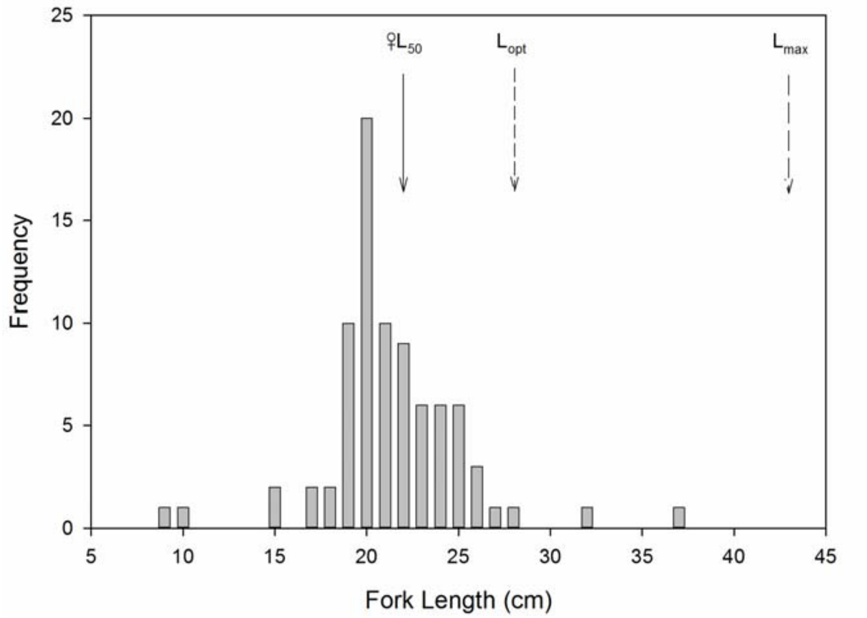


Figure 77. Size structure of *Lutjanus russellii*.

Lutjanus semicinctus **Quoy & Gaimard, 1824** or ***imawe***. Figure 78.

Figure 78. *Imawe* (*Lutjanus semicinctus*). Inter-laser distance 39 mm.

3 new specimens; total 52 (Figure 79)
Mean FL = 20 cm (no change)
59% of estimated L_{max} (34 cm)
91% of estimated L_{opt} (22 cm)
95% of published ♀L_{50} (21 cm)
15% mature ♀

Note: Information on size-specific sex ratios (Longenecker *et al*. 2011) is limited and may underestimate of the number of mature females in large size classes.

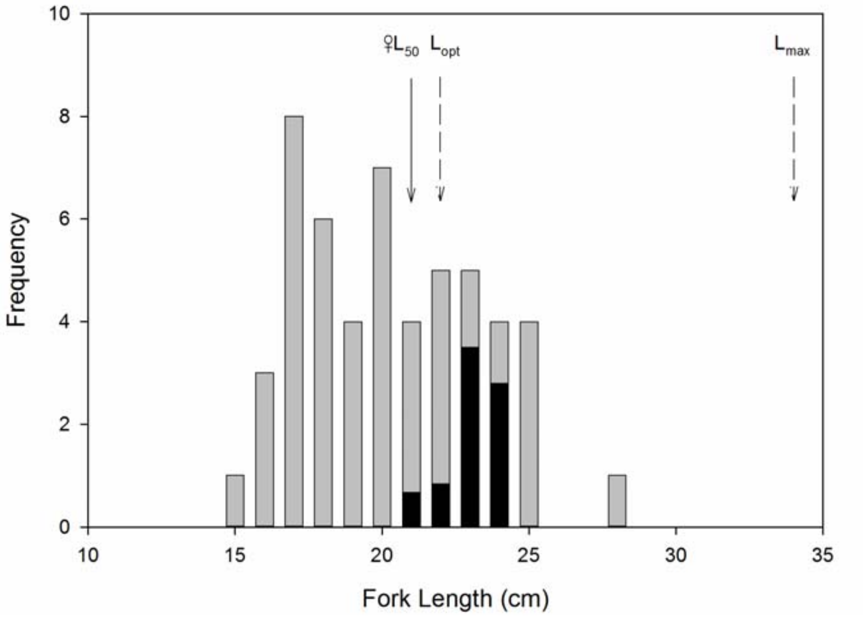


Figure 79. Size structure of *Lutjanus semicinctus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Lutjanus vitta **(Quoy & Gaimard, 1824)** or ***isale***. Figure 80.

5 new specimens; 24 total (Figure 81)
Mean FL = 16 cm (↑)
43% of estimated L_{max} (37 cm)
67% of estimated L_{opt} (24 cm)
107% of published ♀L_{50} (15 cm)
29% mature ♀

← Figure 80. *Isale* (*Lutjanus vitta*). Inter-laser distance 39 mm.

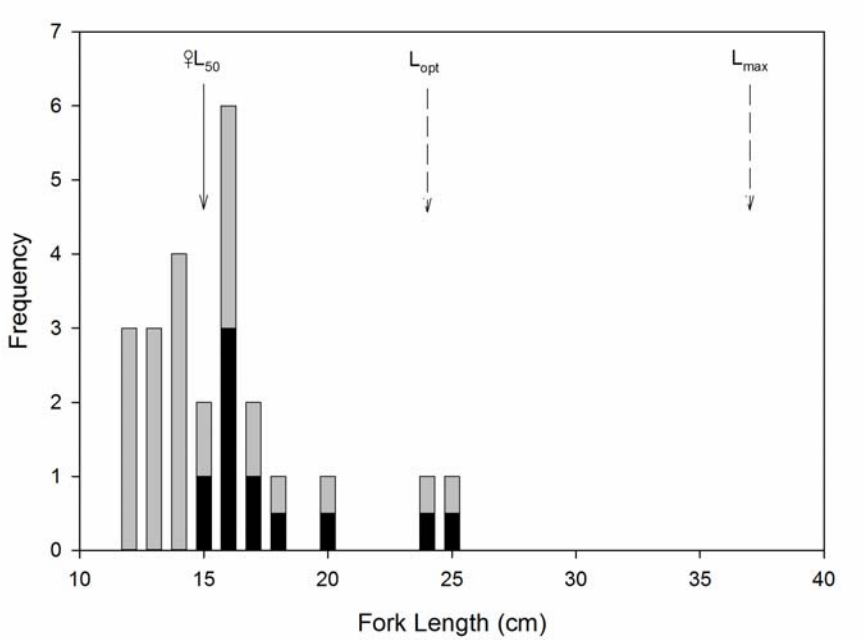
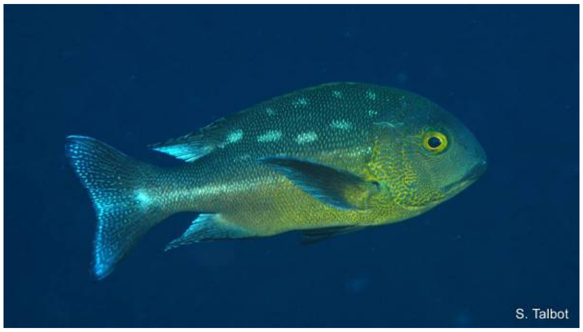


Figure 81. Size structure of *Lutjanus vitta*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Macolor macularis **Fowler, 1931** or ***labaikã tewe yayã***. Figure 82.



0 new specimens; 17 total (Figure 83)
Mean FL = 31 cm
56% of estimated L_{max} (55 cm)
86% of estimated L_{opt} (36 cm)
89% of estimated ♀L_m (35 cm)

← **Figure 82.** ***Labaikã tewe yayã*** **(*Macolor macularis*).**

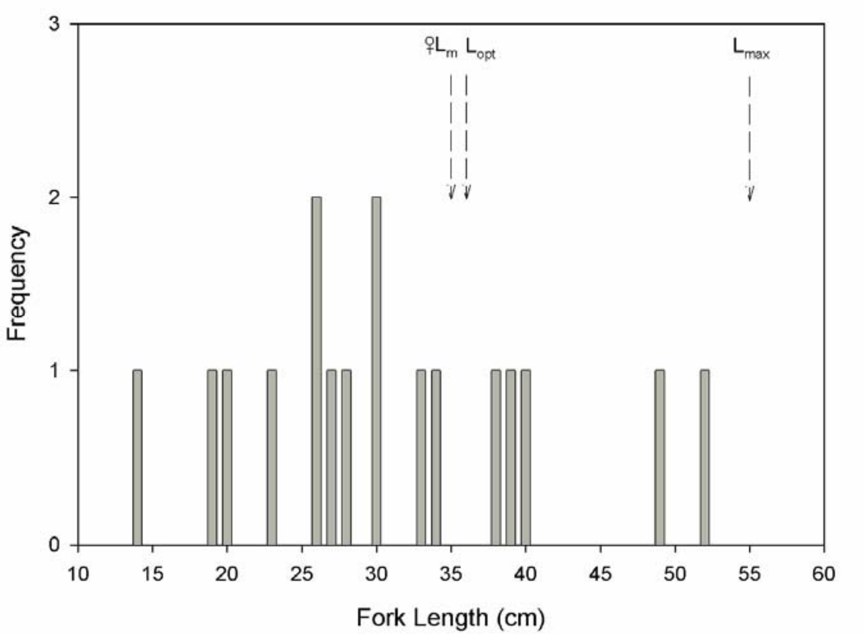


Figure 83. Size structure of *Macolor macularis*.

Macolor niger* (Forsskål, 1775)** or ***labaikã yasai. Figure 84.

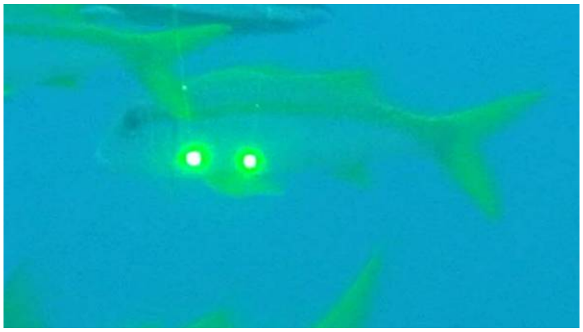
Figure 84. *Labaikã yasai* (*Macolor niger*). Inter-laser distance 31 mm.

0 new specimens; 5 total
Mean FL = 28 cm
47% of estimated L_{max} (60 cm TL)
72% of estimated L_{opt} (39 cm TL)
74% of estimated ♀L_m (38 cm TL)

Note: L_{max}, L_{opt}, & ♀L_{50} values are presented as total length because the relationship between total and fork lengths is unknown. The above percentages are likely underestimates.

Mullidae

Mulloidichthys vanicolensis* (Valenciennes, 1831)** or ***itale yumi yayã. Figure 85.



0 new specimens; 7 total
Mean FL = 21 cm
62% of estimated L_{max} (34 cm)
95% of estimated L_{opt} (22 cm)
124% of published ♀L_{50} (17 cm)

← Figure 85. *Itale yumi yayã* (*Mulloidichthys vanicolensis*). Inter-laser distance 31 mm.

Parupeneus barberinus* (Lacepède, 1801)** or ***iwaŋgale. Figure 86.

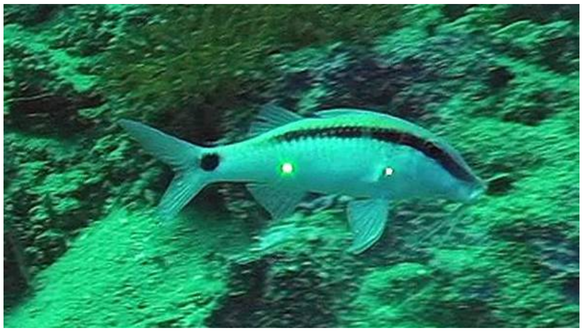


Figure 86. *Iwaŋgale* (*Parupeneus barberinus*). Inter-laser distance 39 mm.

19 new specimens; 154 total (Figure 87)
Mean FL = 15 cm (no change)
34% of estimated L_{max} (44 cm)
52% of estimated L_{opt} (29 cm)
125% of published ♀L_m (12 cm)
44% mature ♀

Note: L_{max} of Allen & Swainston (1993) may be an overestimate for the region; of 265 individuals physically collected or captured on video, the largest individual at KWMA was 25 cm FL.

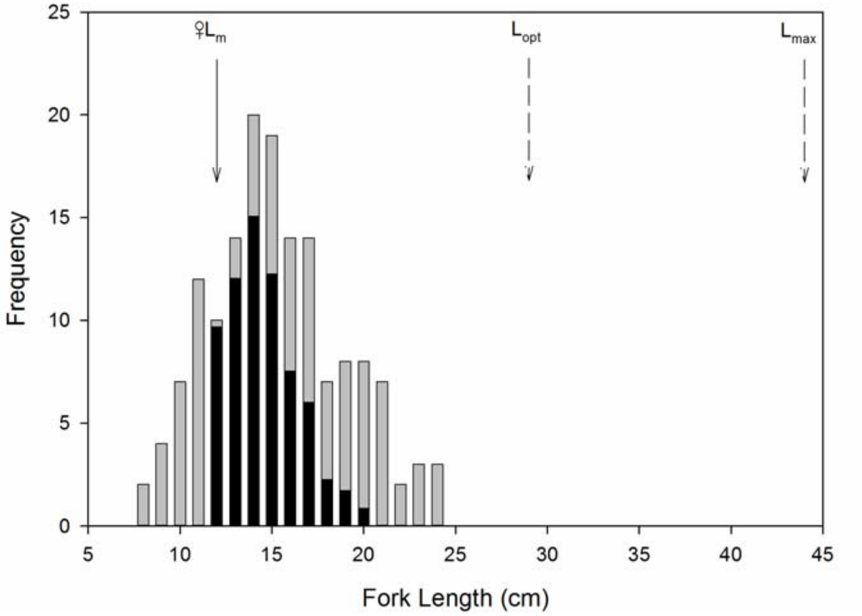


Figure 87. Size structure of *Parupeneus barberinus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Parupeneus cyclostomus* (Lacepède, 1801)** or ***iwaŋgale bokole. Figure 88.

7 new specimens; 27 total (Figure 89)
Mean FL = 18 cm (no change)
41% of reported L_{max} (44 cm)
62% of estimated L_{opt} (29 cm)
62% of estimated ♀L_m (29 cm)

← Figure 88. *Iwaŋgale bokole* (*Parupeneus cyclostomus*).

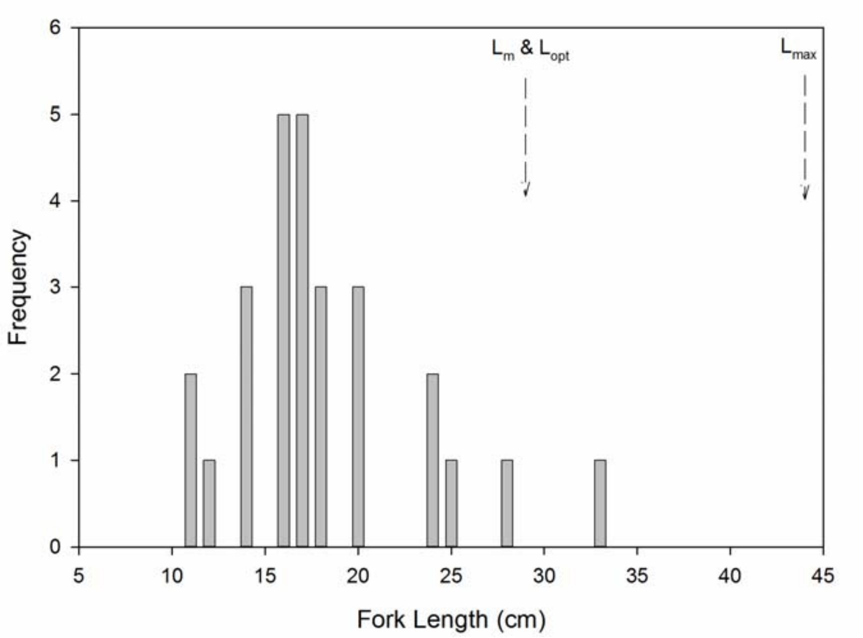


Figure 89. Size structure of *Parupeneus cyclostomus*.

Parupeneus multifasciatus* (Quoy & Gaimard, 1825)** or ***iwaŋgale bote. Figure 90.

9 new specimens; 108 total (Figure 91)
Mean FL = 14 cm (no change)
54% of reported L_{max} (26 cm)
82% of estimated L_{opt} (17 cm)
93% of published ♀L_{50} (15 cm)
15% mature ♀

← Figure 90. *Iwaŋgale bote* (*Parupeneus multifasciatus*).

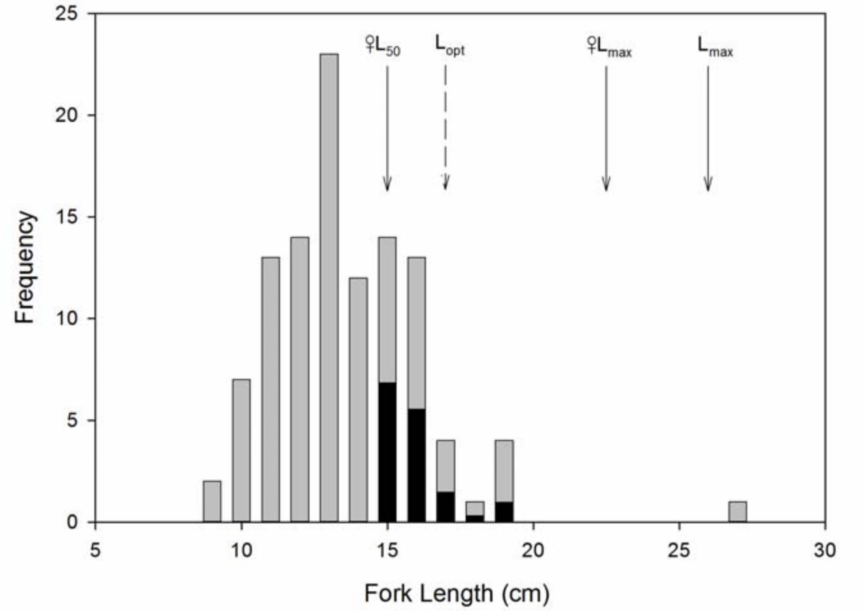


Figure 91. Size structure of *Parupeneus multifasciatus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Parupeneus trifasciatus* (Lacepède, 1801)** or ***walia. Figure 92.

17 new specimens; 52 total (Figure 93)
Mean FL = 18 cm (↓)
58% of estimated L_{max} (31 cm)
90% of estimated L_{opt} (20 cm)
164% of published ♀L_m (11 cm)
63% mature ♀

← Figure 92. *Walia* (*Parupeneus trifasciatus*). Inter-laser distance 39 mm.

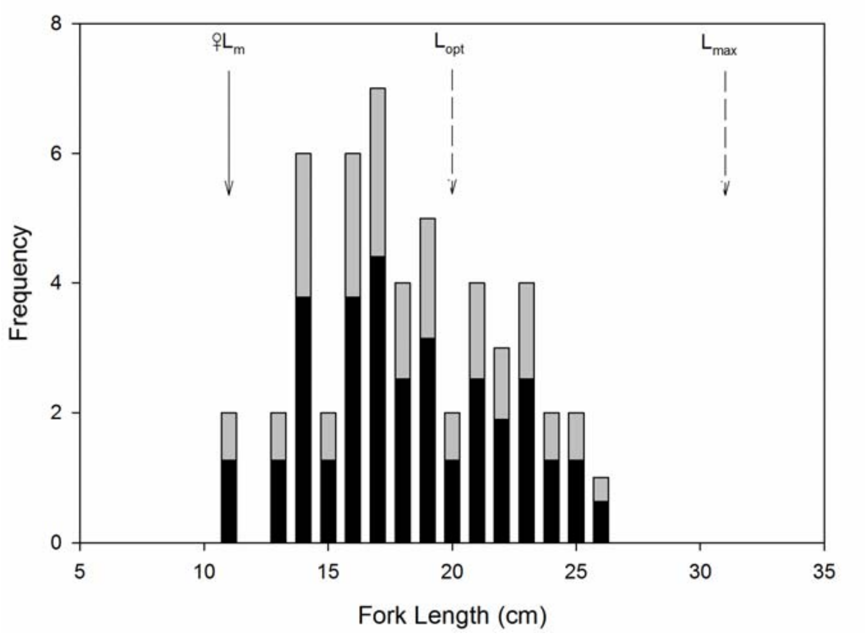


Figure 93. Size structure of *Parupeneus trifasciatus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Nemipteridae

Scolopsis bilineata* (Bloch, 1793)** or ***buamea. Figure 94.

Figure 94. *Buamea* (*Scolopsis bilineata*). Inter-laser distance 39 mm.

2 new specimens; 10 total
Mean FL = 13 cm (no change)
57% of reported L_{max} (23 cm TL)
87% of estimated L_{opt} (15 cm TL)
81% of estimated ♀L_m (16 cm TL)

Note: L_{max}, L_{opt}, & ♀L_m values are presented as total length because the relationship between total and fork lengths is unknown. The above percentages are likely underestimates.

***Scolopsis ciliata* (Lacepède, 1802);** Kala name not yet recorded. Figure 95

Figure 95. *Scolopsis ciliata*. Inter-laser distance 32 mm.

First report; 6 specimens
Mean FL = 12 cm
55% of reported L_{max} (22 cm TL)
86% of estimated L_{opt} (14 cm TL)
80% of estimated ♀L_m (15 cm TL)

Note: L_{max}, L_{opt}, & ♀L_m values are presented as total length because the relationship between total and fork lengths is unknown. The above percentages are likely underestimates.

Priacanthidae

Priacanthus hamrur* (Forsskål, 1775)** or ***indu iko. Figure 96.

Figure 96. *Indu iko* (*Priacanthus hamrur*). Inter-laser distance 39 mm.

1 new specimen; 4 total
Mean FL = 23 cm (no change)
58% of published L_{max} (40 cm TL)
88% of estimated L_{opt} (26 cm TL)
115% of published ♀L_{50} (20 cm, assumed FL)
43% mature ♀

Note: L_{max} & L_{opt} values are presented as total length because the relationship between total and fork lengths is unknown. The corresponding percentages are likely underestimates.

Scaridae

Chlorurus bleekeri*) (de Beaufort, 1940)** or ***iŋga bobo (intial phase) and ***iŋga talã*** (terminal male). Figure 97

Figure 97. *Iŋga bobo* (left) and *iŋga talã* (right) or *Chlorurus bleekeri* initial phase (left) and terminal male (right). Inter-laser distance 31.5 mm.

18 new specimens; 23 total (Figure 98)
Mean FL = 18 cm (no change)
60% of published L_{max} (30 cm)
95% of estimated L_{opt} (19 cm)
90% of estimated ♀L_m (20 cm)

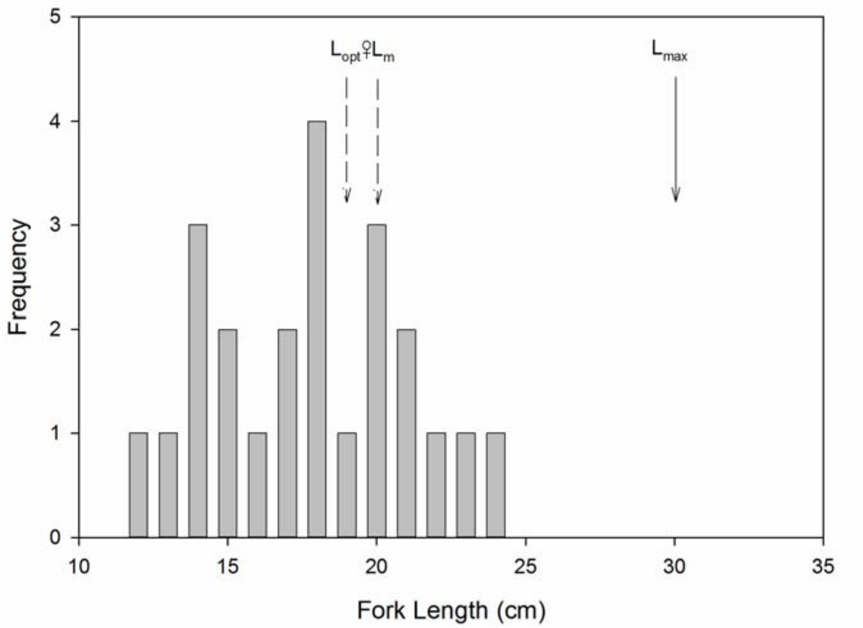


Figure 98. Size structure of *Chlorurus bleekeri*.

Chlorurus bowersi*) (Snyder, 1909)** or ***guniau. Figure 99.

1 new specimen; 4 total
Mean FL = 22 cm (no change)
71% of published L_{max} (31 cm)
110% of estimated L_{opt} (20 cm)
105% of estimated ♀L_m (21 cm)

← Figure 99. *Guniau* (*Chlorurus bowersi*). Inter-laser distance 31 mm.

Scarus flavipectoralis* Schultz, 1958** or ***iŋga talaŋ (initial phase) and ***iŋga tali lau*** (terminal male). Figure 100.

Figure 100. *Iŋga talaŋ* (left) and *iŋga tali lau* (right) or *Scarus flavipectoralis* initial phase (left) and terminal male (right). Inter-laser distance 36 and 39 mm, respectively.

31 new specimens; 58 total (Figure 101)
Mean TL = 18 cm (↓)
62% of reported L_{max} (29 cm)
95% of estimated L_{opt} (19 cm)
95% of estimated ♀L_m (19 cm)

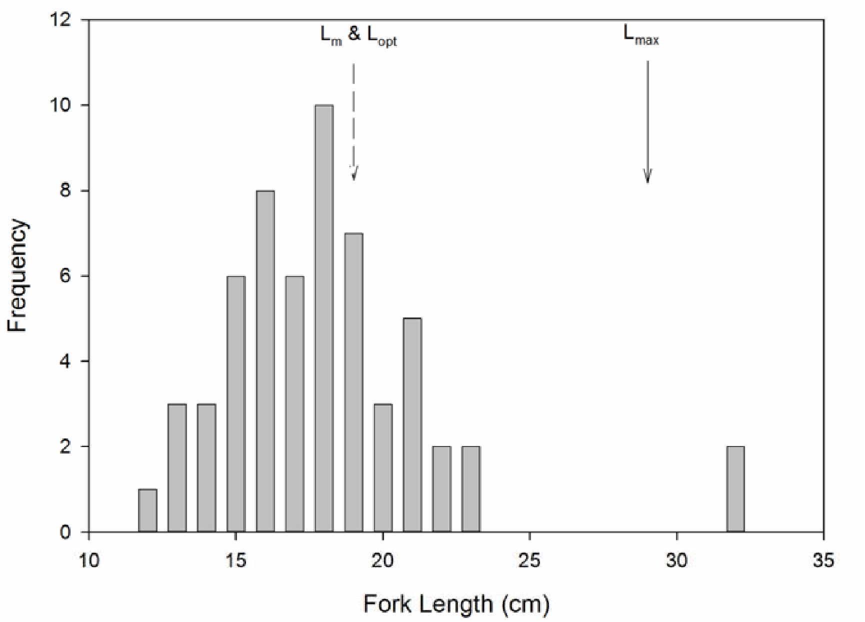


Figure 101. Size structure of *Scarus flavipectoralis*.

***Scarus niger* Forsskål, 1775**; Kala name not yet recorded. Figure 102

First report; 4 specimens
Mean FL = 18 cm
51% of reported L_{max} (35 cm)
78% of estimated L_{opt} (23 cm)
106% of published ♀L_{50} (17 cm)

← Figure 102. *Scarus niger*. Inter-laser distance 31.5 mm.

Scombridae

Gymnosarda unicolor* (Rüppell, 1836)** or ***itaŋgi talaloŋa. Figure 103.

0 new specimens; 18 total (Figure 104)
Mean FL = 59 cm
43% of estimated L_{max} (137 cm)
64% of estimated L_{opt} (92 cm)
85% of published ♀L_m (70 cm)

← Figure 103. *Itaŋgi talaloŋa* (*Gymnosarda unicolor*). Inter-laser distance 31.5 mm.

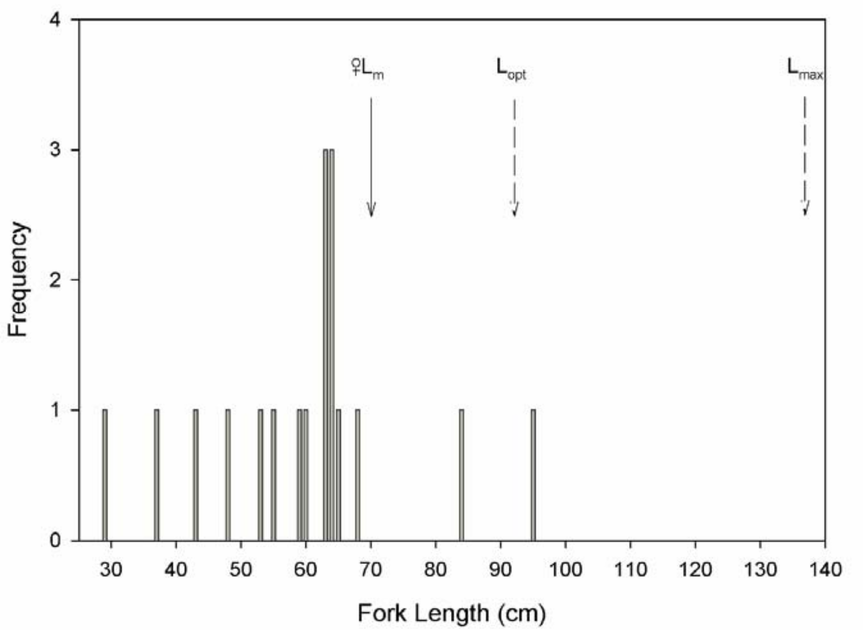


Figure 104. Size structure of *Gymnosarda unicolor*.

Rastrelliger kanagurta **(Cuvier, 1816)** or ***indala***. Figure 105.

6 new specimens; 10 total
Mean FL = 23 cm (no change)
70% of reported L_{max} (33 cm)
110% of estimated L_{opt} (21 cm)
121% of published ♀L_{50} (19 cm)

← Figure 105. *Indala* (*Rastrelliger kanagurta*). Inter-laser distance 31.5 mm.

Scomberomorus commerson **(Lacepède, 1800)** or ***itaŋgi***. Figure 106.

5 new specimens; 10 total
Mean FL = 70 cm (↓)
32% of reported L_{max} (218 cm)
47% of estimated L_{opt} (148 cm)
108% of published ♀L_m (65 cm)
46% mature ♀

← Figure 106. *Itaŋgi* (*Scomberomorus commerson*). Inter-laser distance 31 mm.

Serranidae

Anyperodon leucogrammicus **(Valenciennes, 1828)** or ***ikula damasã***. Figure 107.

2 new specimens; 17 total (Figure 108)
Mean TL = 25 cm (no change)
48% of reported L_{max} (52 cm)
74% of estimated L_{opt} (34 cm)
76% of estimated ♀L_m (33 cm)

← Figure 107. *Ikula damasã* (*Anyperodon leucogrammicus*). Inter-laser distance 39 mm.

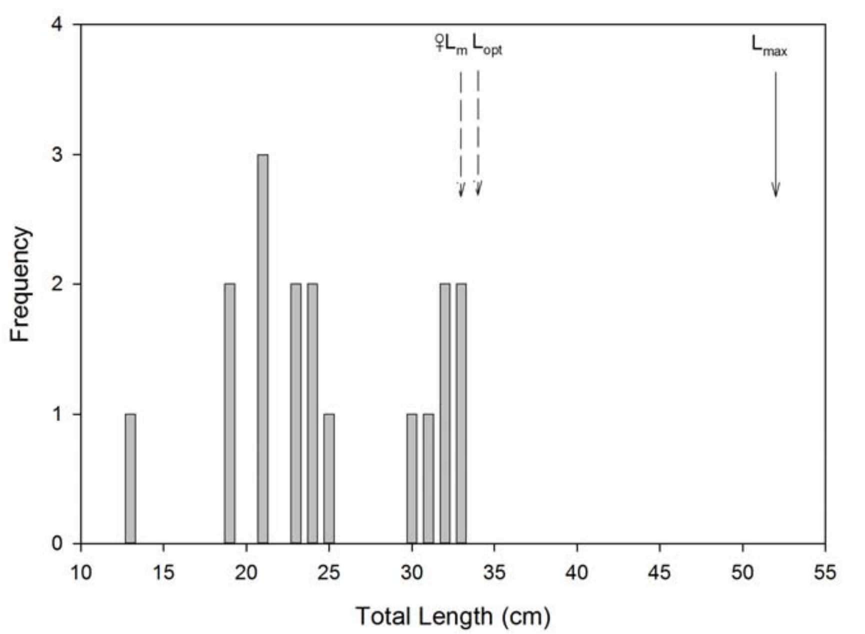


Figure 108. Size structure of *Anyperodon leucogrammicus*.

***Cephalopholis boenak* (Bloch, 1790) or *ikula bobo*.** Figure 109.

0 new specimens; 10 total
Mean TL = 16 cm
67% of reported L_{max} (24 cm)
107% of estimated L_{opt} (15 cm)
107% of published ♀L_{50} (15 cm)
63% mature ♀

← **Figure 109. *Ikula bobo* (*Cephalopholis boenak*).**

***Cephalopholis cyanostigma* (Valenciennes, 1828) or *ikula sa*.** Figure 110.

Figure 110. *Ikula sa* (*Cephalopholis cyanostigma*).

10 new specimens; 86 total (Figure 111)
Mean TL = 19 cm (no change)
54% of reported L_{max} (35 cm)
83% of estimated L_{opt} (23 cm)
83% of published ♀L_{50}, (23 cm)
37% mature ♀

Note: The estimate of % mature ♀ is based on L_m. If a problematic estimate of ♀L_{50} (Longenecker *et al.* 2011) is used, as few as 0.8 % may be mature ♀.

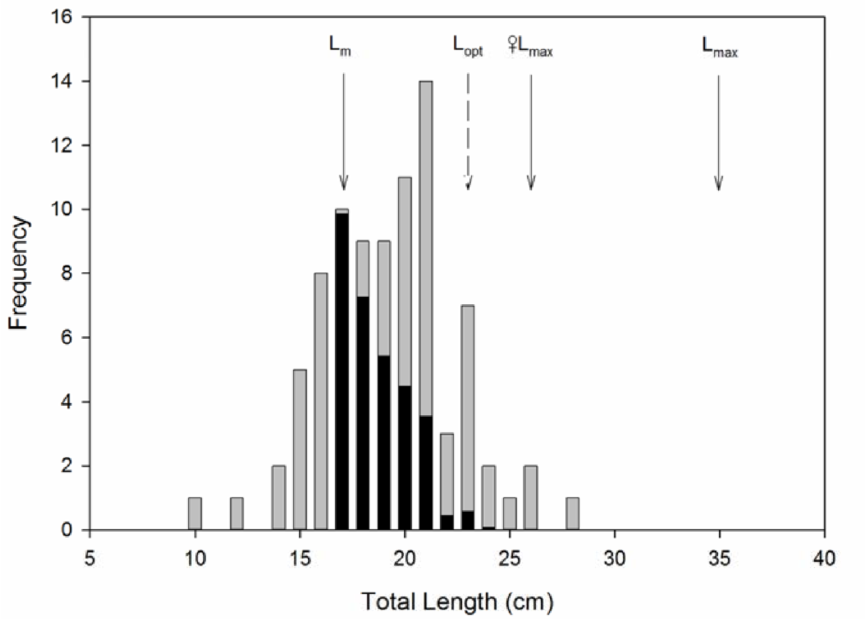


Figure 111. Size structure of *Cephalopholis cyanostigma*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Cephalopholis microprion* (Bleeker, 1852)** or ***ikula yuyeŋ. Figure 112.

3 new specimens; 25 total (Figure 113)
Mean TL = 13 cm (no change)
57% of reported L_{max} (23 cm)
87% of estimated L_{opt} (15 cm)
81% of estimated ♀L_m (16 cm)

← Figure 112. *Ikula yuyeŋ* (*Cephalopholis microprion*). Inter-laser distance 39 mm.

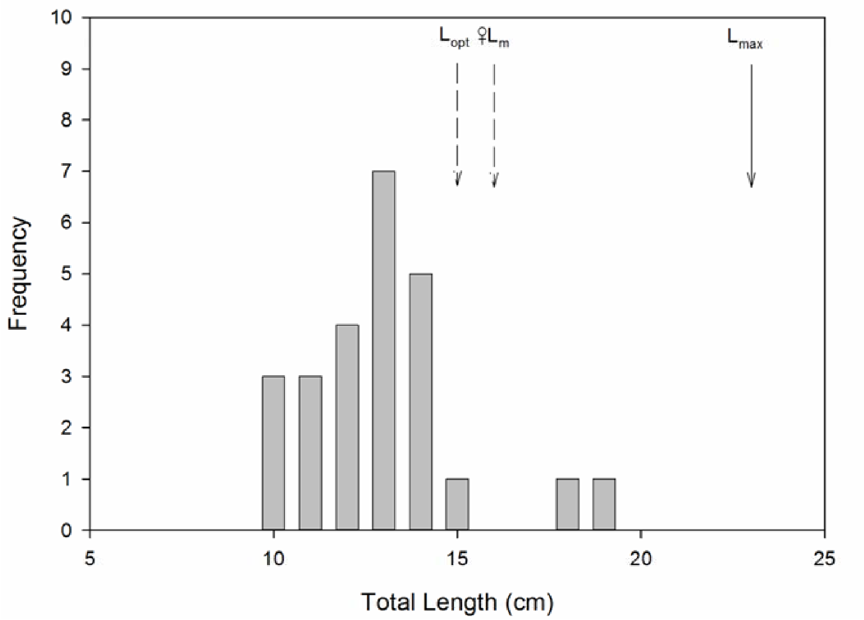


Figure 113. Size structure of *Cephalopholis microprion*.

Cephalopholis sexmaculata **(Rüppell, 1830)** or ***ikula tumi***. Figure 114.

0 new specimens were; 4 total
Mean TL = 24 cm
51% of published L_{max} (47 cm)
77% of estimated L_{opt} (31 cm)
100% of published ♀L_m (24 cm)

← Figure 114. *Ikula tumi* (*Cephalopholis sexmaculata*). Inter-laser distance 36 mm.

Cephalopholis urodeta **(Forster, 1801)** or ***ikula karu guŋ-guŋ***. Figure 115.

0 new specimens; 6 total
Mean TL = 18 cm
67% of reported L_{max} (27 cm)
106% of estimated L_{opt} (17 cm)
100% of estimated ♀L_m (18 cm)
49% mature ♀

← Figure 115. *Ikula karu guŋ-guŋ* (*Cephalopholis urodeta*). Inter-laser distance 39 mm.

***Epinephelus fasciatus* (Forsskål, 1775)**; Kala name not yet recorded. Figure 116.

First report; 3 specimens
Mean FL = 16 cm
40% of reported L_{max} (40 cm)
62% of estimated L_{opt} (26 cm)
114% of published ♀L_m (14 cm)

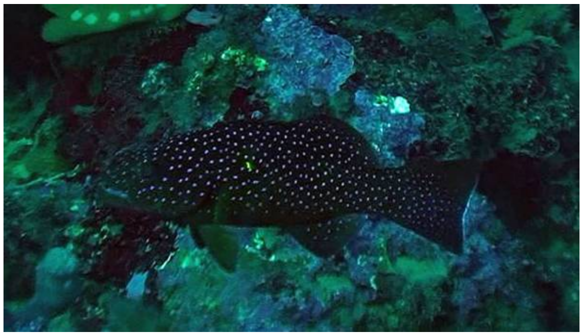
← Figure 116. *Epinephelus fasciatus*. Inter-laser distance 39 mm.

***Epinephelus merra* Bloch, 1793**; Kala name not yet recorded. Figure 117.

First report; 3 specimens
Mean FL = 22 cm
79% of reported L_{max} (28 cm)
122% of estimated L_{opt} (18 cm)
200% of published ♀L_{50} (11 cm)

← Figure 117. *Epinephelus merra*. Inter-laser distance 32 mm.

Plectropomus areolatus* (Rüppell, 1830)** or ***ikula su mani balã. Figure 118.



0 new specimens; 15 total (Figure 119)
Mean TL = 18 cm
26% of reported L_{max} (70 cm)
39% of estimated L_{opt} (46 cm)
45% of published ♀L_{50} (40 cm)
0% mature ♀

← Figure 118. *Ikula su mani balã* (*Plectropomus areolatus*). Inter-laser distance 39 mm.

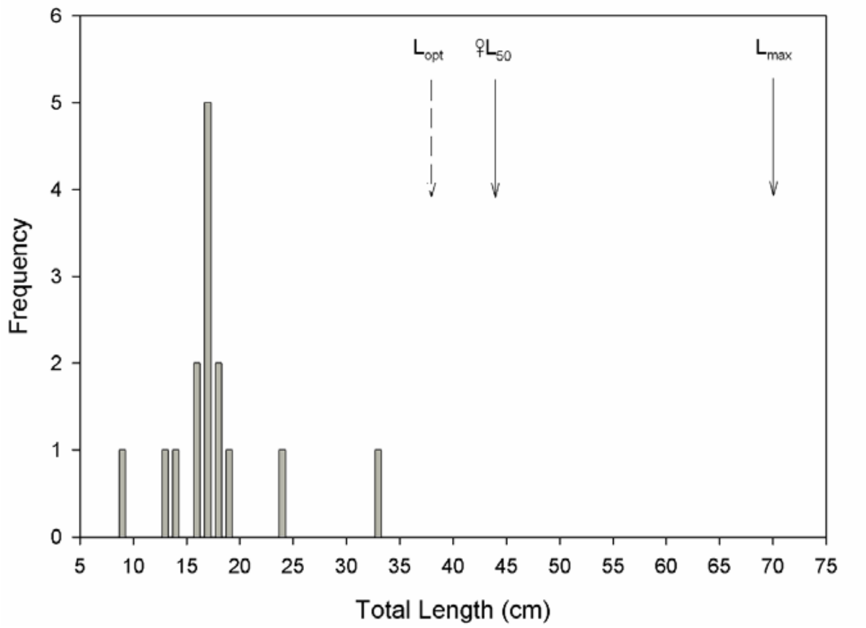
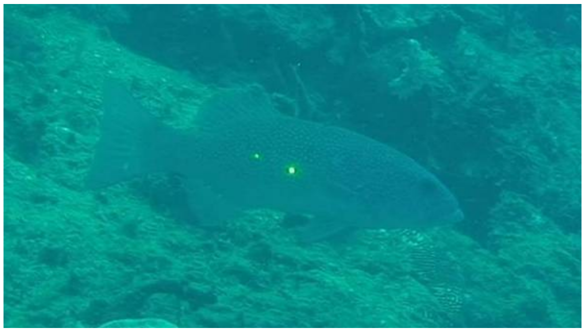


Figure 119. Size structure of *Plectropomus areolatus.*

Plectropomus leopardus* (Lacepède, 1802)** or ***yula. Figure 120.



0 new specimens; 10 total
Mean TL = 32 cm
47% of estimated L_{max} (68 cm)
71% of estimated L_{opt} (45 cm)
100% of published ♀L_{50} (32 cm)
56% mature ♀

← Figure 120. *Yula* (*Plectropomus leopardus*). Inter-laser distance 36 mm.

Plectropomus oligacanthus* (Bleeker, 1855)** or ***ikula su tatalõ. Figure 121.

7 new specimens; 61 total (Figure 122)
Mean FL = 32 cm (↓)
49% of reported L_{max} (65 cm)
74% of estimated L_{opt} (43 cm)
119% of observed ♀L_m of (27 cm)

← Figure 121. *Ikula su tatalõ* (*Plectropomus oligacanthus*).

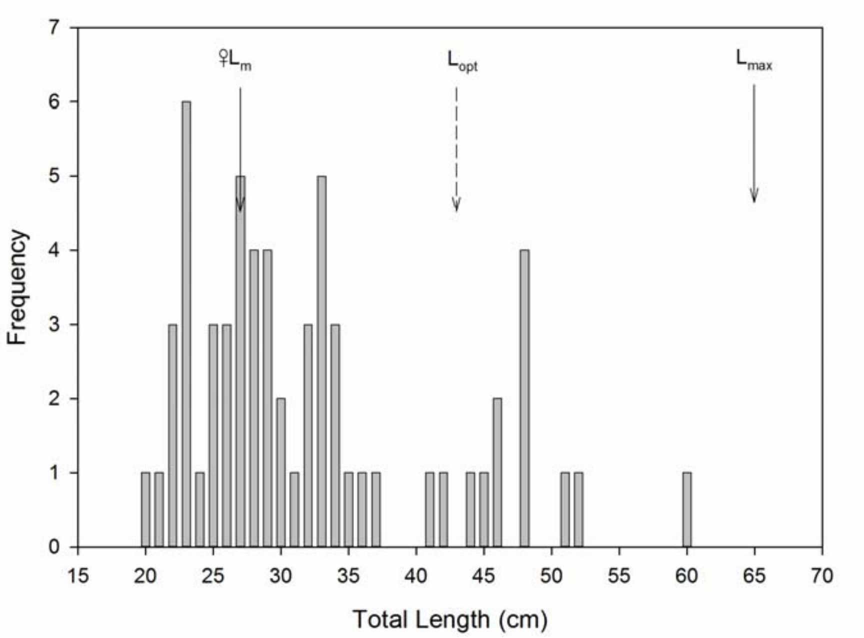


Figure 122. Size structure of *Plectropomus oligacanthus*.

Siganidae

***Siganus doliatus* Guérin-Méneville, 1829-38;** Kala name not yet recorded. Figure 123

Figure 123. *Siganus doliatus*. Inter-laser distance 31.5 mm.

First report; 3 specimens
Mean FL = 16 cm
53% of reported L_{max} (30 cm TL)
84% of estimated L_{opt} (19 cm TL)
89% of estimated ♀L_m (18 cm TL)

Note: L_{max}, L_{opt}, & ♀L_m values are presented as total length because the relationship between total and fork lengths is unknown. The above percentages are likely underestimates.

***Siganus javus* (Linnaeus, 1766) or *yulawe kokoranawa*. Figure 124.**

Figure 124. *Yulawe kokoranawa* (*Siganus javus*). Inter-laser distance 39 mm.

0 new specimens; 33 total (Figure 125)
Mean "FL" = 25 cm
47% of reported L_{max} (53 cm TL)
71% of estimated L_{opt} (35 cm TL)
74% of estimated ♀L_m (34 cm TL)

Note: L_{max}, L_{opt}, & ♀L_m values are presented as total length because the relationship between total length and the length to the middle ray of the slightly emarginate caudal fin (*i.e.*, "fork" length) is unknown. The above percentages are likely underestimates.

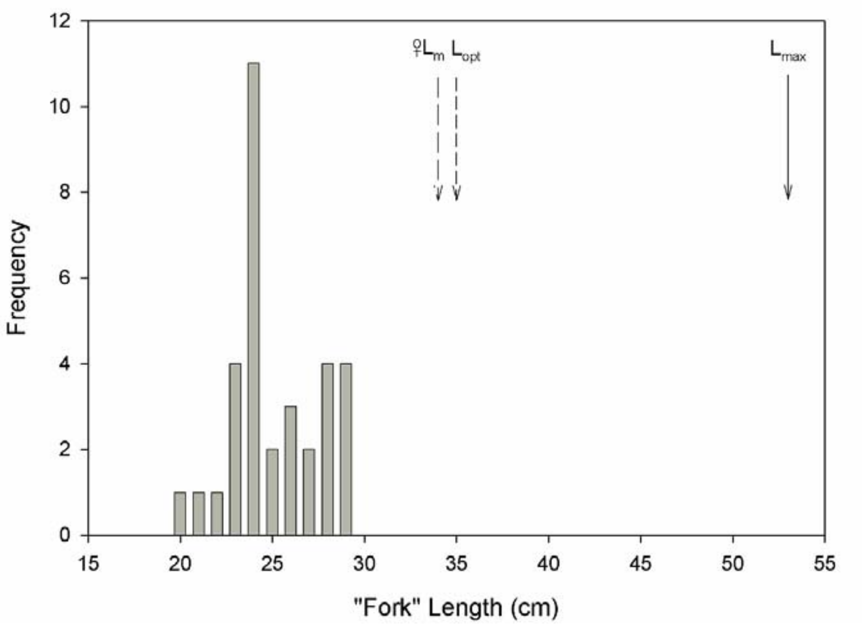
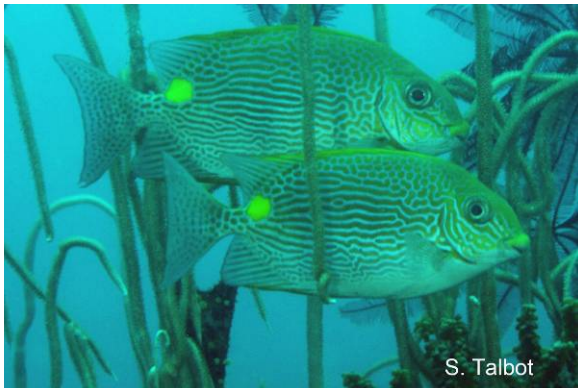


Figure 125. Size structure of *Siganus javus*.

***Siganus lineatus* (Valenciennes, 1835) or *yulawe*. Figure 126.**



0 new specimens; 66 total (Figure 127)
Mean "FL" = 26 cm
63% of estimated L_{max} (41 cm)
96% of estimated L_{opt} (27 cm)
108% of published ♀L_{50} (24 cm)
32% mature ♀

← Figure 126. *Yulawe* (*Siganus lineatus*).

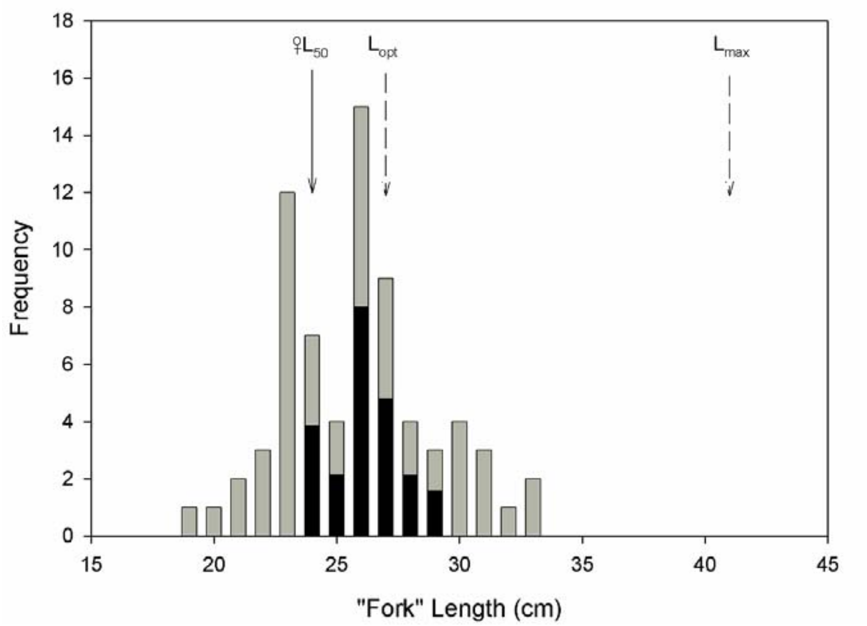
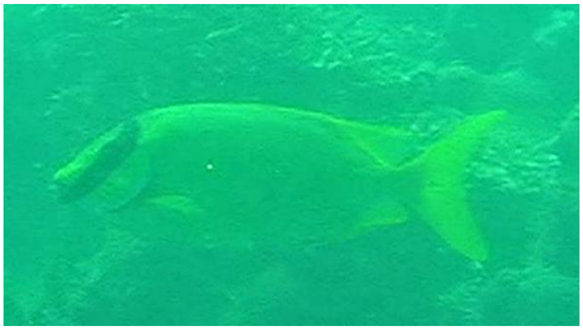


Figure 127. Size structure of *Siganus lineatus*. The dark portion of bars represent estimated number of mature females, light portion represents all other individuals.

Siganus puellus **(Schlegel, 1852)** or ***indaŋa***. Figure 128.



0 new specimens; 3 total
Mean FL = 22 cm
58% of estimated L_{max} (38 cm)
88% of estimated L_{opt} (25 cm)
88% of estimated ♀L_m (25 cm)

← **Figure 128. *Indaŋa* (*Siganus puellus*). Inter-laser distance 39 mm.**

Siganus vulpinus **(Schlegel & Müller, 1845)** or ***indaŋa***. Figure 129.

4 new specimens; 8 total
Mean TL = 15 cm (↓)
50% of reported L_{max} (30 cm)
75% of estimated L_{opt} (20 cm)
75% of estimated ♀L_m (20 cm)

← **Figure 129. *Indaŋa* (*Siganus vulpinus*). Inter-laser distance 31.5 mm.**

Catch Characteristics and Fishery Selectivity

A size-frequency histogram of *luduŋ mai* (*Caesio cuning*) caught by village residents participating in our fishing program from February through June 2013 is presented in Figure 130. We assume the catch is representative of normal village fishing practices. A *t*-test indicated average length (16.7 cm FL) was significantly greater than the at-large population mean of 16.2 cm. Harvest of *Caesio cuning* at KWMA appears to select larger individuals. Average fork length is 12% lower than the estimated optimum length (L_{opt}) of 19 cm, but 11% greater than the observed female L_{50}, of 15 cm. One-sample *t*-tests indicate average size is significantly smaller than L_{opt} but significantly larger than female L_{50}. Fifty-eight percent of individuals in the catch were within 10% of L_{opt}. We estimate that 45% of the catch was composed of mature females.

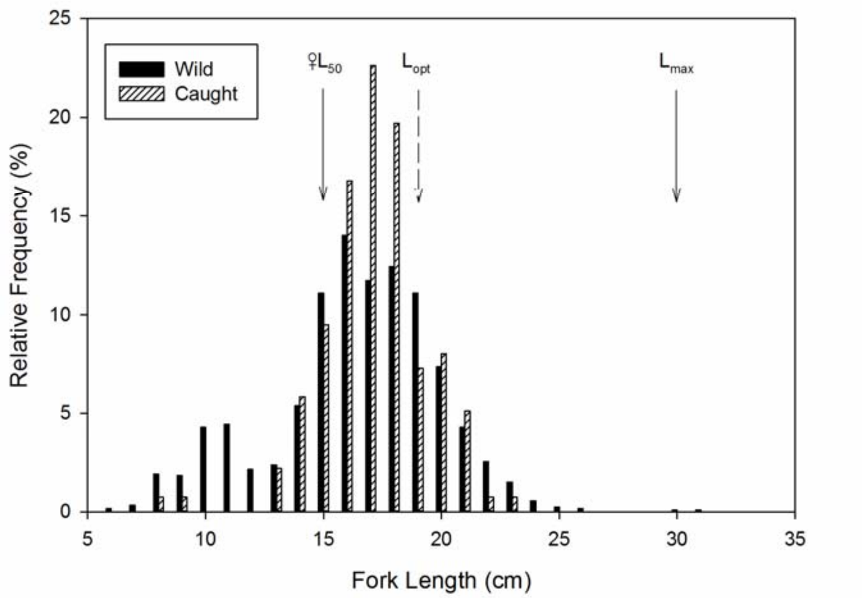


Figure 130. Size structure of at-large population (dark bars) and catch (hashed bars) of *luduŋ mai (Caesio cuning)* at Kamiali Wildlife Management Area.

Time Series

Plots of annual average length estimates are presented in Figure 131 for *luduŋ ŋai* or *mai* (*Caesio cuning*), *ikula sa* (*Cephalopholis cyanostigma*), *itale* (*Lutjanus biguttatus*), *iwaŋgale* (*Parupeneus barberinus*), and *iwaŋgale bote* (*Parupeneus multifasciatus*). Three-year moving averages suggest that the average size of all species is relatively stable. Mean lengths for all species are within a few centimeters of female reproductive size.

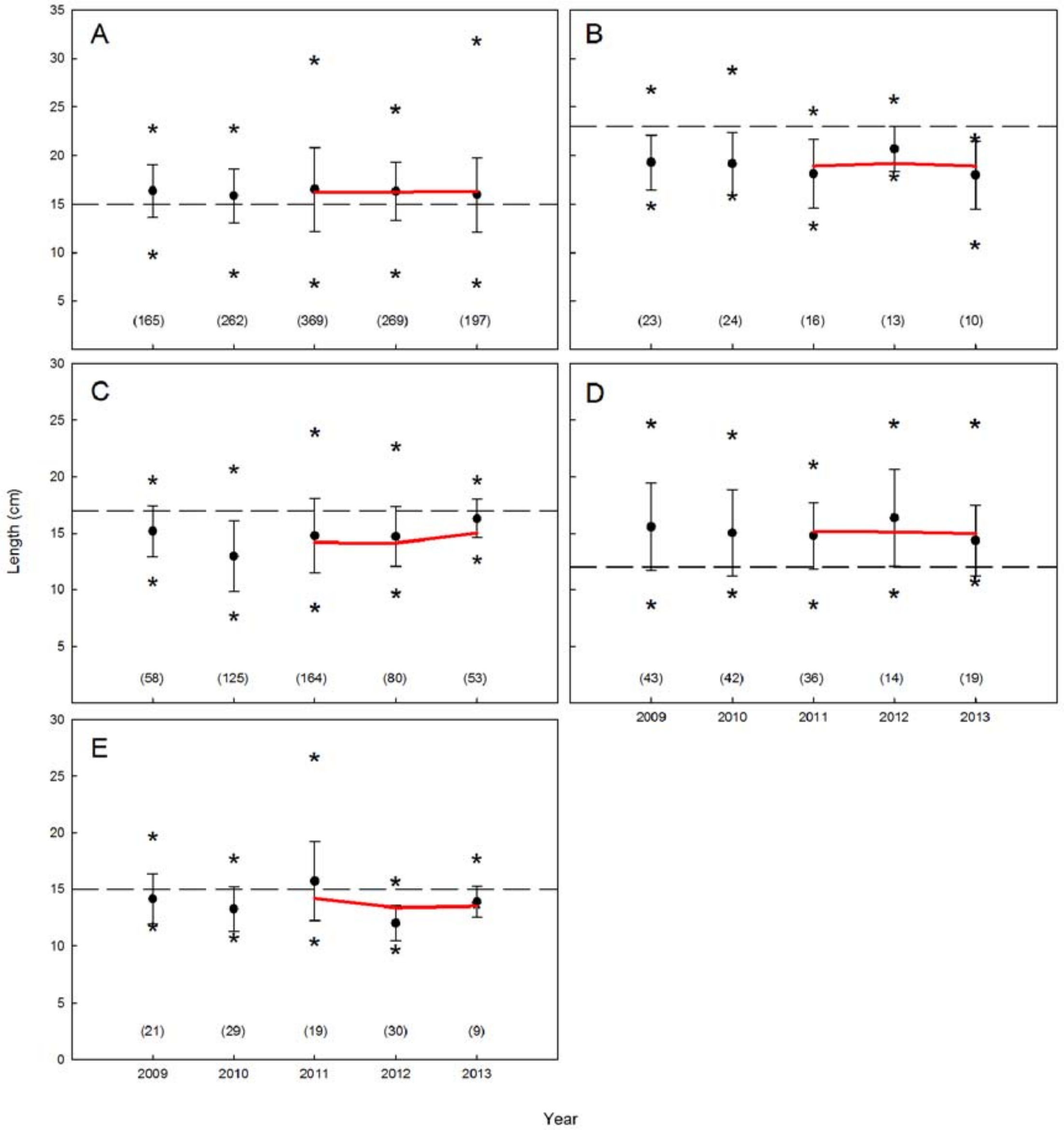


Figure 131. Time-series plots of average length. Red lines = 3-year moving average; dashed lines = female L_{50}, solid circles = annual means; vertical bars = standard deviation; asterisks = minima and maxima. Number of specimens in parentheses. A) *luduŋ mai* (*Caesio cuning*), B) *ikula sa* (*Cephalopholis cyanostigma*), C) *itale* (*Lutjanus biguttatus*), D) *iwaŋgale* (*Parupeneus barberinus*), E) *iwaŋgale bote* (*Parupeneus multifasciatus*).

DISCUSSION

Reproductive Analysis

We generated histology-based reproductive information for four exploited fishes at Kamiali Wildlife Management Area (KWMA). Three of these species have broad geographic ranges [*luduŋ mai* (*Caesio cuning*), *kada maba* (*Lethrinus erythropterus*), *imbilĩ tombo gabo* (*Myripristis adusta*)]. Thus, the results of our reproductive analyses provide crucial information for the conservation and management of reef fishes throughout the Indo-Pacific region. The fourth species, *ikula su tatalõ* (*Plectropomus oligacanthus*), is known only from the Western Pacific (*i.e.*, the Coral Triangle). However, it is considered Near Threatened because it is overexploited for subsistence fishing and exported for the live-reef-fish trade (Cabanban *et al*. 2008). Given that very little has been published on the biology of this rare species (Heemstra & Randall 1993, 1999), any information should be useful for its recovery.

A thorough analysis of reproduction in *luduŋ mai* (*Caesio cuning*) and *kada maba* (*Lethrinus erythropterus*) is presented in Longenecker *et al*. (in review). Unfortunately, village fishing efforts within KWMA in 2013 resulted in too few specimens for complete reproductive analyses for the remaining two species [*imbilĩ tombo gabo* (*Myripristis adusta*), and *ikula su tatalõ* (*Plectropomus oligacanthus*)]. However, the specimens we did obtain provided preliminary estimates of minimum size-at-maturity, and allowed descriptions of reproductive mode.

Results of our reproductive analyses and literature review support our past assertion that size-at-maturity estimates based on the empirical equations of Froese and Binohlan (2000) systematically overestimate female size-at-maturity for exploited fishes at KWMA (see Longenecker *et al*. 2011). On the basis of results to date, the equation overestimates female L_{50} for 20 of 22 species for which L_{50} is known. Further, the degree of overestimation increases as maximum size increases (Figure 132). This comparison highlights the need for and value of continued histology-based reproductive analysis, particularly where conservation efforts must be balanced against subsistence-fishing needs. If reproductive size is the basis of conservation and management decisions (*e.g.*, minimum catch size = reproductive size), using estimates of size-at-maturity may be counterproductive at KWMA. The estimates would unnecessarily raise minimum catch size, perhaps making it more difficult to catch food (in a manner consistent with conservation guidelines) and ultimately leading to lower compliance. On the other hand, decisions based on more-accurate species-specific life-history analysis should be more-readily accepted.

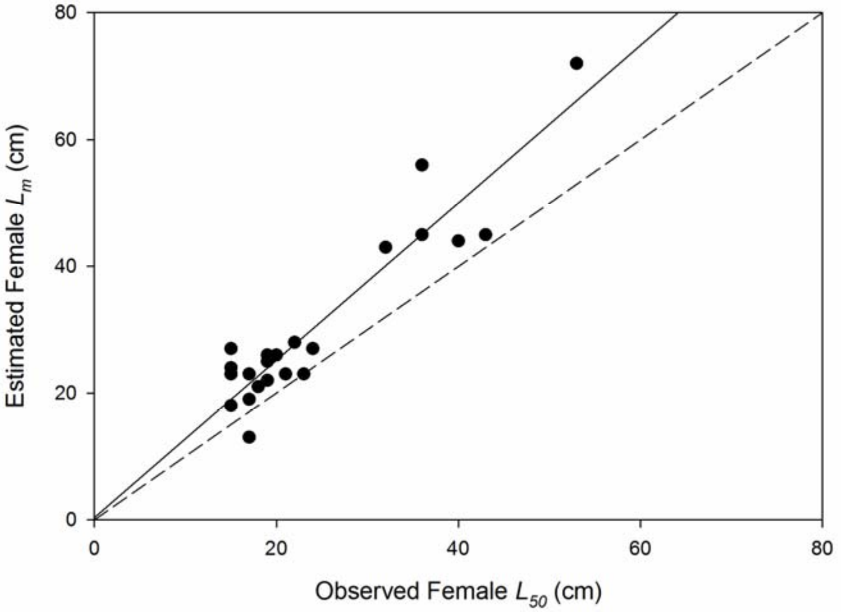


Figure 132. Observed L_{50} versus estimated L_m. Dashed line is a 1:1 reference.

Catch Characteristics

The value of life-history analysis is further demonstrated by our ability to model the outcome of fishery management/conservation proposals relative to current fishing practices. These models allow us to explore ways that subsistence fishers can maintain their current harvest levels while simultaneously promoting larger fish populations.

Here, we compare current fishing practices to a hypothetical harvest under a combination of two of Froese's (2004) suggested fishing practices (all fish in the catch are mature and within 10% of estimated L_{opt}). The observed catch of 137 *luduŋ mai* (*Caesio cuning*) yielded 15.23 kg. However, if only individuals within 10% of L_{opt} are harvested (all of which would be mature), 96 individuals distributed equally among 17 - 21 cm FL size classes will yield the same weight. The latter scenario leaves more individuals to grow into the size classes generating most of the population-level egg production per spawning event (see Longenecker *et al.* in review).

We now make the simplistic assumption that each individual remaining in the at-large population, after either observed or optimum catch, grows one centimeter. By following the optimum catch guidelines, an extra 355,288 eggs would be produced during <u>every</u> spawning event (relative to egg production under the observed harvest scenario). Thus, village residents can obtain the same amount of food <u>and</u> promote population growth of *luduŋ mai* (*Caesio cuning*) at KWMA by shifting fishing efforts to the 17 – 21 cm size classes.

Fishery Surveys

Most of the size-structure information presented above should be viewed as preliminary. For 79% of the species included in our laser-videogrammetry surveys, we captured too few individuals on video to describe population size structure, mean size changed with the addition of new specimens in 2013, or we did not capture additional individuals in 2013 and thus could not detect changes in mean length estimates. For these species, additional data would lead to more robust population characterizations. For 18 species, there was no change in average length estimates between 2012 and 2013. This suggests that our population characterizations are suitably robust for these species. We include in this group: *luduŋ mai* (*Caesio cuning*), *imaŋalẽ babaura* (*Carangoides bajad*), *imaŋalẽ talã* (*Caranx melampygus*), *iyabua sa* (*Plectorhinchus lineatus*), *imbilĩ godõ nambĩ* (*Myripristis kuntee*), *imbilĩ yakẽ bumbu* (*Myripristis violacea*), *imbilĩ sa* (*Neoniphon sammara*), *italawe* (*Kyphosus cinerascens*), *iyayaŋ* (*Lutjanus boutton*), *iyayaŋ kurĩ naba* (*Lutjanus fulvus*), *imawe* (*Lutjanus semicinctus*), *iwaŋgale* (*Parupeneus barberinus*), *iwaŋgale bokole* (*Parupeneus cyclostomus*), *iwaŋgale bote* (*Parupeneus multifasciatus*), *iŋga bobo*/*iŋga talã* (*Chlorurus bleekeri*), *ikula damasã* (*Anyperodon leucogrammicus*), *ikula sa* (*Cephalopholis cyanostigma*), and *ikula yuyeŋ* (*Cephalopholis microprion*).

Results from a literature review indicate that remarkably little is known about reproductive parameters for these coral reef fishes. In 2009, size-at-maturity was known for only 27% of species examined (Longenecker *et al.* 2009). In 2010, the number increased to 41% (Longenecker *et al.* 2010). In 2011, there was a slight increase to 42%. That small increase was a function of adding 16 species to our fishery surveys. In 2012, size-at-maturity was known for 49%. This value remains at 49% for 2013; however, 10 species were added to our fishery surveys. Reproductive parameters continue to be unknown for more than half of the exploited reef-associated fishes examined at Kamiali Wildlife Management Area. This lack of information is a common problem for coral-reef fisheries, even in developed countries. Longenecker *et al.*

(2008a) report that size-at-maturity is unknown for 38% of the 13 most-heavily exploited reef fishes in Hawaii. It is impossible to evaluate the breeding status of a population or create biologically meaningful management strategies when this information is lacking.

Estimating the proportion of mature females in a population is further hindered by the scarcity of information on size-specific sex ratios. Of the 18 species at KWMA for which data on size-specific sex ratios exists, the proportion of males in a population increases with length for 72% (Davis & West 1992; Ferreira 1995; Longenecker & Langston 2008; Williams *et al.* 2008; Heupel *et al.* 2009, 2010; Longenecker *et al.* 2011, Longenecker *et al.* in review). The same trend would be expected for protogynous fishes (*e.g.*, Scaridae, Serranidae, and Labridae) and is seen in many groupers (Loubens 1980). Elsewhere in the Pacific the same pattern was found in each of four of five species examined (Longenecker & Langston 2008, Longenecker *et al.* 2008b, Langston *et al.* 2009). Because females can be absent from larger size classes of these species, the reproductive status of any population would be better understood if size-specific sex ratios are known.

Given the above caveats, a typical individual in the exploited reef-fish community at Kamiali Wildlife Management Area is 57% of its maximum length and 89% of its estimated optimum length. In the subset of 29 species for which female L_{50} is known, a typical individual is 100% of female reproductive size. All of these values are marked increases from 2012 estimates. These increases are primarily due to a revision of maximum size and size-at-maturity for *luduŋ mai* (*Caesio cuning*), the most abundant species in our fishery surveys. Notably, no individual of two of the larger species considered in this subset [*godobo manibarã/tarõ* (*Diagramma pictum*) and *ikula su mani balã* (*Plectropomus areolatus*)], was of mature size. Of the remaining 55 species for which L_m (either published or estimated) is our only indicator of female reproductive size, an average individual is 101% of size-at-maturity. Considering sex ratios, known for 26 species, approximately 31% of a population, on average, is composed of mature females. This is an increase from our estimates of 26% for 23 species considered in 2012 (Longenecker *et al.* 2012), 25% for 12 species considered in 2011 (Longenecker *et al.* 2011) and 20% for 7 species considered in 2010 (Longenecker *et al.* 2010). The inter-annual fluctuations in estimates of percent female reproductive size and percent mature females suggest more reproductive analysis is needed before robust statements about the reproductive status of exploited fish populations at KWMA can be made.

Time Series

The above information (relative to maximum and optimum lengths) provides important baselines that can be used to detect future shifts in reef-fish populations. However, the static nature of the average-length information does little to identify long-term trends. To address this limitation, we plotted a time series of average-length data for the more-common exploited reef fishes. Although of limited duration, we also plotted 3-year moving averages to smooth short-term fluctuations and highlight longer-term trends (Figure 131). Average length appears stable for all species considered [*luduŋ mai* (*Caesio cuning*), *ikula sa* (*Cephalopholis cyanostigma*), *itale* (*Lutjanus biguttatus*), *iwaŋgale* (*Parupeneus barberinus*), and *iwaŋgale bote* (*Parupeneus multifasciatus*]. Additional monitoring is needed to fully evaluate the trends.

Mean lengths of four species are greater than [*luduŋ mai* (*Caesio cuning*), *iwaŋgale* (*Parupeneus barberinus*)] or within a few centimeters of [*ikula sa* (*Cephalopholis cyanostigma*), *itale* (*Lutjanus biguttatus*), and *iwaŋgale bote* (*Parupeneus multifasciatus*)] reproductive length. *Ikula sa* (*Cephalopholis cyanostigma*) appears to have the greatest negative deviation from reproductive size, however the L_{50} estimate (Longenecker *et al.* 2011) may be high.

General Conclusions

To give the above information immediate conservation relevance, it must be viewed in the context of the village's subsistence fishing practices and needs. Historically, there was no strong need to regulate marine resources use to avoid over-exploitation along the Huon Coast (Kinch 2006). Today, two canoes, on average, engage in fishing at KWMA at any one time during the day (Longenecker *et al*. 2008c). Thus, the ~600 residents of KWMA appear to obtain their primary source of dietary protein with relative ease. We present this as evidence that overfishing is not occurring on the coral reefs of Kamiali Wildlife Management Area (with the possible exception of some larger-bodied species for which we rarely observed reproductively sized individuals). If our assertion is correct, average lengths > ½ maximum size can be used as evidence of robust fish populations.

In general, people along the Huon Coast have little pragmatic concern for the environment (Kinch 2006). Despite the apparent lack of overfishing at Kamiali Wildlife Management Area, residents do not consider themselves practitioners of reef-fish conservation. There are no gear restrictions, creel limits, minimum or maximum size limits, or seasonal closures for any species (Longenecker *et al*. 2009). Nor are Kamiali residents prohibited from fishing in any part of KWMA. Finally, because of severe barotrauma to fish caught by handline in deeper water (Longenecker *et al*. 2008c), small individuals are not returned to the water. In other words, life-history-based fishery-management methods are not currently used at KWMA.

We suggest that life-history-based methods would be appropriate for populations with few reproductive-sized individuals. However, the necessary life-history information must be generated and disseminated. KWMA is rapidly approaching the point where sufficient reproductive information is available (and, in fact, has become a major source of reproductive information for Indo-Pacific reef fishes). In 2009, size-at-maturity was known for only 27% of 33 species. Today, size-at-maturity is known for 49% of 84 species. In other words, absolute and relative numbers have increased dramatically over a five-year period. We suggest that we now have enough reproductive information to produce a life-history-based marine management plan for many species at KWMA.

Until the time that a science-based management plan is created, we think preserving aspects of village life consistent with marine conservation will be the most effective way to promote robust fish populations at KWMA. Several characteristics of the village and its fishery appear to reduce the risk of overfishing. Those are reproduced below from Longenecker *et al.* (2011):

1) Customary tenure. Given that Kamiali residents do not view themselves as conservation practitioners in the marine environment, we agree with Polunin (1984) and Ruttan (1998) that the intent of traditional resource management is to increase human gain from the natural environment, not to conserve biological resources. However, customary tenure appears to have a conservation function because outsiders are prohibited from fishing within Kamiali Wildlife Management Area. Territoriality at KWMA resulted in a *de facto* limited-entry fishery.
2) Distance to commercial markets. Kamiali is 64 km from the city of Lae, the nearest place where fish can be sold commercially. Cinner & McClanahan (2006) suggest proximity to markets (<16 km) increases the likelihood of overfishing in Papua New Guinea. Commercial fishing in Kamiali presents an economic challenge. Because there are no roads, individuals selling fish must have a motorized vessel to transport fish to market. The cost of operating these is high; a liter of fuel can cost up to $2 (US). Based on our own travels to the

village on these vessels, approximately 100 liters of fuel is used in a typical round trip, resulting in an overhead cost of about $200 (US) per commercial sale. Because there is no electrical service in Kamiali, ice must be purchased in Lae. Therefore, economic success in commercial fishing requires that a sufficient quantity of fish be caught before ice melts, and that market prices justify a costly trip to Lae. Variability in catch rate and market prices in the face of high fuel costs thus presents a significant barrier to entry in commercial fishing.

3) Subsistence economy. Because cash is limited, technologies that may lead to fishery overexploitation are cost-prohibitive. Fishing is done primarily from small, human-powered, handmade, outrigger canoes (Longenecker *et al*. 2008c). Transportation to bottom-fishing sites and propulsion while trolling requires a significant input of human energy. Hook-and-line fishing with homemade handreels and weights, or handcrafted outriggers, is the dominant fishing technique. Two spearing methods are also used. Most common is aerial hand-launching of bamboo poles fitted with metal tines (Longenecker *et al*. 2008c). Catching fish by this method appears to be infrequent. Less common are homemade spearguns used while freediving. Because dive fins are not used, a depth refuge from spearing exists. Gillnets are rare, and we have not seen traps or weirs at Kamiali. Finally, lack of refrigeration reduces the motivation to catch more than can be used within a few days.
4) Plant-based diet. Although fish is the major source of dietary protein consumed by Kamiali residents, the majority of their calories are derived from fruits and vegetables grown in swidden gardens. Time spent fishing is limited by the need to conduct labor-intensive gardening.
5) Family and community obligations. As above, time spent fishing must be balanced against other time-intensive activities. These include building and repairing houses and canoes (both made from materials harvested from the surrounding forests), and attending community meetings.
6) Tidal cycles. Poison fishing is limited. The use of *Derris*, a native plant containing the non-selective ichthyocide rotenone, is limited to reef flats during lowest-low tides. This timing appears to be driven by the desire to maximize catch; extreme low tides create pools of still water where poison can be concentrated but fish cannot escape. Higher water during the majority of a lunar cycle effectively prohibits use of the method most of the time.

The factors listed above do not act in isolation. Distance to market is negatively related to the likelihood that a community will exclude outsiders from exploiting its marine environment. On the other hand, communities that subsist on marine resources may be more likely to exclude outsiders (Cinner 2005).

Ongoing and anticipated changes at Kamiali may threaten the sustainable use of its coral-reef fishes. The community is undergoing a transformation from a common-property system to a cash-based economy (Wagner 2002), and lower dependence on marine resources may reduce the likelihood that a community employs exclusionary marine tenure regimes (Cinner 2005). Cinner *et al*. (2007) indicate that customary management is at risk during economic modernization such as that underway at Kamiali Wildlife Management Area. They suggest that marine conservation initiatives based on customary tenure are more likely to succeed if organizations help reduce the impact of socioeconomic transformations. The Kamiali Initiative, by establishing a pathway to economic development that is based on effective environmental conservation, is helping to maintain a traditional lifestyle as the village economy changes.

Continued conservation success at KWMA will be sustained by information, such as that presented above, necessary to make science-based environmental-management decisions. We maintain that more life-history research is the most productive pathway to future reef-fish conservation at Kamiali Wildlife Management Area and throughout the Indo-Pacific region.

ACKNOWLEDGMENTS

An anonymous private foundation generously provided financial support for this study. We thank the residents of Kamiali for their hospitality, openness, and willingness to have their environment and fishing practices examined. We wish to extend thanks to the men, women, and children who participated in our specimen sampling program. Gabu Reuben provided Kala fish names.

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