



**Reproduction, growth,
and mortality of kole,
*Ctenochaetus strigosus***

Final Report

July, 2009



Hawaii Division of Aquatic Resources

COVER

Image capture of kole using laser videogrametry analysis. The green dots on the side, projected by parallel lasers affixed to an underwater video camera, are used as a scale to estimate fish size.

**Growth, mortality and reproduction of kole,
*Ctenochaetus strigosus***

Final Report

Prepared for

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July 2009

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EXECUTIVE SUMMARY

Kole (*Ctenochaetus strigosus*) is one of the most numerous and conspicuous reef fishes in Hawaii. It is important both in commercial aquarium collecting as well as recreational and subsistence fisheries. Despite this, little is known of its life history. In this paper we provide information on morphometric relationships, growth, size-at-maturity, sex ratios, size-fecundity relationships, age structure, and mortality estimates.

We measured the lengths and weights of specimens collected on O‘ahu, Lana‘i, and Hawai‘i to describe morphometric relationships. Most important for fishery modeling is the length-weight relationship, which for kole is: $W = 0.000065064(FL)^{2.8499}$. We examined histological sections of kole gonads to describe sex-ratio and size at maturity (L_{50}). The populations we studied had an overall physical sex-ratio of 1:1.2 (M:F), although it varied predictably by size class, becoming male-biased beyond 130 mm FL. Size at 50% maturity was 84 mm FL for females and 100 mm FL for males. Kole have group-synchronous oocyte development and spawn repeatedly over a lengthy spawning season (confirmed spawning in February-May). The relationship between size and batch fecundity was best described by a power function $BF = 1.2766 \cdot 10^{-5}(FL)^{4.1663}$. Age estimates from otolith microincrements (assumed daily) and macroincrements (assumed annual) produced conflicting estimates of growth rate and longevity. The relationship between the two increment types was linear: $\# \text{ Microincrements} = 217.04 + \# \text{ macroincrements}(40.8174)$. Assuming macro-increments are deposited annually, the relationship between length and age can be described by the vonBertalanffy growth equations: $L_{t(\text{Males})} = 145.95(1 - e^{-0.509896(t+1.0415)})$ and $L_{t(\text{Females})} = 114.64(1 - e^{-0.655296(t+1.2811)})$. Males and females mature by 15 months and 9 months, respectively. Females initially grow faster, but attain a smaller size than males, which dominate size-classes beyond 130 mm FL. Both males and females may live 18 years or more. We compared mortality estimates obtained from a series of marine reserves with those from comparable fished sites to determine forces of natural (M) and fishing (F) mortality. Annual natural mortality up to 9 years is 0.4425 for males and 0.5334 for females. Annual fishing mortality through the same period is 0.2399 for males and 0.00583 for females. Despite the lack of minimum size limits, female kole incur little fishing pressure whereas fishing accounts for 35% total mortality for males.

INTRODUCTION

Ctenochaetus strigosus (or kole) is one of, if not the, most common non-cryptic reef-fish species in Hawaii (Hourigan, 1986; Walsh, 1987). It is commercially important, ranking second in aquarium catch records (Tissot, 1999). It also important in recreational and subsistence fishing, and was the most commonly speared fish in Waikiki creel surveys (Meyer, 2003). Among native Hawaiians, the kole is particularly esteemed as luau fare due to its abundance and ease of capture. As with most surgeonfishes, this species is fried whole until crispy. Fishing for this species is currently unregulated.

Some fragmentary life-history information is reported for *C. strigosus*. However, a recent revision of the genus by Randall and Clements (2001) recognized *Ctenochaetus strigosus* as a Hawaiian endemic, making studies from the South Pacific and Indian oceans irrelevant to kole.

In this study we estimate the following life-history descriptors: length-weight relationship, sex ratio, size at 50% maturity (L_{50}), and size-fecundity relationship, growth rate, age structure and mortality. These data are essential to estimating biomass production and reproductive output. The latter estimates should provide the least ambiguous means of evaluating various management strategies.

METHODS

Study Sites

Morphometric, reproductive, and growth analysis was performed on specimens collected opportunistically from various locations on the islands of Oahu, Lana'i, and Hawai'i. Natural and fishing mortality was estimated by comparing the total mortality estimate generated in a combination of two marine reserves with that from two fished areas that contain, at least superficially, similar habitat types and depth distributions (Figure 1). On Maui, Honolua Bay is part of the Honolua-Mokulē'ia Marine Life Conservation District (N 21° 00'52.77", W 156° 38'22.23"); it encloses approximately 110,469 m² and fishing has been prohibited for 30 years. Our comparison fished site was approximately 3 km to the southwest in Kapalua Bay (N 21° 00'08.35", W 156° 40'02.69"), and enclosed approximately 24,992 m². On Hawai'i, we surveyed Kealakekua Bay, an MLCDD established in 1969. We worked exclusively in sub-zone A (N°19'28 51.12" W°155°55' 44.29"), which encloses approximately 597,216 m². All forms of fishing are prohibited in this area. Our comparison fished site was Paaoao Bay (N 19° 31'27.45", W 155° 57'24.60"), 5.3 km to the northwest. The area surveyed enclosed approximately 89,544 m². Datum for the above coordinates is WGS84.

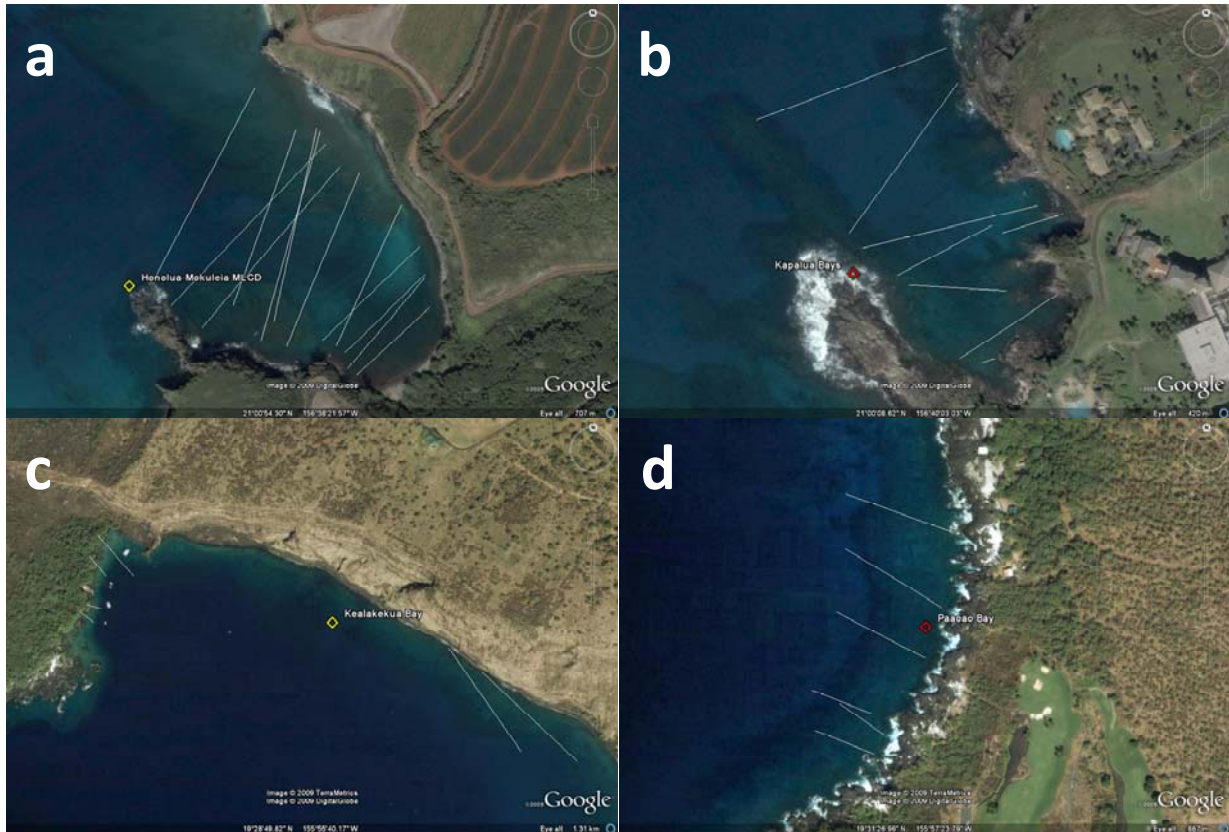


Figure 1 Survey sites on two main Hawaiian Islands. Sites on Maui were: a) Honolua (reserve), and b) Kapalua (fished) Bays. Sites on Hawaii island were: c) Kealahou (reserve), and d) Paoao (fished) Bays.

Life History Analysis

We collected specimens using nets or spears. We measured, to the nearest 0.5 mm, standard length, total length, the distance between the origins of the dorsal and pelvic fins, and the length from the anterior-most part of the head to the end of the middle caudal rays. The latter measurement is referred to as fork length throughout this report. We then measured total body mass (to 0.1 g), removed saccular otoliths (sagittae), and fixed gonads in Dietrich's fixative (60% distilled water, 28% absolute ethanol, 10% formaldehyde, and 2 % glacial acetic acid). Morphometric relationships were described using linear regression for lengths and a 2-parameter power function for length vs. weight. Growth and reproduction were described following the methods in Longenecker and Langston (2006), summarized below.

Growth

Annual Rings

We prepared a single, transverse section of each sagitta by mounting the otolith, lateral side down, on a glass microscope slide in thermoplastic glue (Crystal Bond #509 from Electron Microscopy Sciences, Hatfield, PA) then removing a section containing the core using an Isomet 11-1180 low-speed saw (Beuhler, Lake Bluff, IL). We affixed this section to a glass microscope

slide, a cut side down, with thermoplastic glue; ground close to the core using a series of 600 and 1500 grit sandpaper; then polished the section with 0.3 and 0.05 μm alumina slurry on felt. We counted the number of macro-increments (presumed annual rings) using light microscopy (40-100X).

Daily Rings

Otoliths used for micro-increment analysis were prepared as above, then etched with a 2.5% solution of unbuffered EDTA for 4-7 min followed by a rinse with distilled water. We dissolved the thermoplastic glue with acetone and mounted prepared otolith sections on aluminum stubs. We coated these sections with a gold-palladium film in a Hummer II sputtercoater (Technics, Alexandria, VA), and viewed them on a field emission scanning electron microscope at 700X.

We used Photoshop Elements (Adobe Systems, San Jose, CA) to examine digital images of the otolith sections (see Figure 2). Otolith preparations rarely included the primordium, so total number of rings was estimated by counting the number of increments past an easily identifiable settlement mark, and adding an assumed number of days for the region inside the mark. Analysis of four otoliths including the primordium yielded a mean 76 days to the presumed settlement mark.

We assumed that each otolith microincrement represented one day and that each macroincrement represented one year. We used these to construct vonBertalanffy growth curves using Simply Growth version 2.1.0.48 (Pisces Conservation, Lymington, Hampshire, UK).

Reproduction

We removed a small tissue biopsy from each of the Dietrichs'-preserved gonads, dehydrated in a graded ethanol series and embedded it in glycol methacrylate (JB-4 Embedding Kit from Electron Microscopy Sciences, Hatfield, PA). Embedded gonads were then sectioned at 2 - 5 μm on a rotary microtome (Sorvall Products, Newtown, CT) fitted with a glass knife. We affixed these sections to glass microscope slides, stained them in toluidine blue or hematoxylin and eosin and examined them for evidence of reproductive maturity. We classified ovaries according to Wallace & Sellman (1981) and testes according to Nagahama (1983). We considered female fish mature with the onset of vitellogenesis, and males mature when the testes contained visible spermatozoa. We report size at sexual maturity as the size at which a regression equation (3-parameter, sigmoidal) of percent mature individuals in each 12 mm size class versus standard length indicates 50% of individuals are mature. We also described size-specific sex ratios by plotting the percent of each sex in 10 mm size classes.

Ovaries selected for batch fecundity were weighed to the nearest 0.001 g on a digital microbalance. We collected 3 subsamples (chosen randomly from right or left lobe of ovary) of tissue (8-15 mg each) from the anterior, middle, and posterior of the gonad and weighed these to the nearest 0.01 mg on a CAHN 28 electrobalance. We estimated batch fecundity by determining the mean number of oocytes per unit weight, and multiplying that value by the total weight of the ovary.

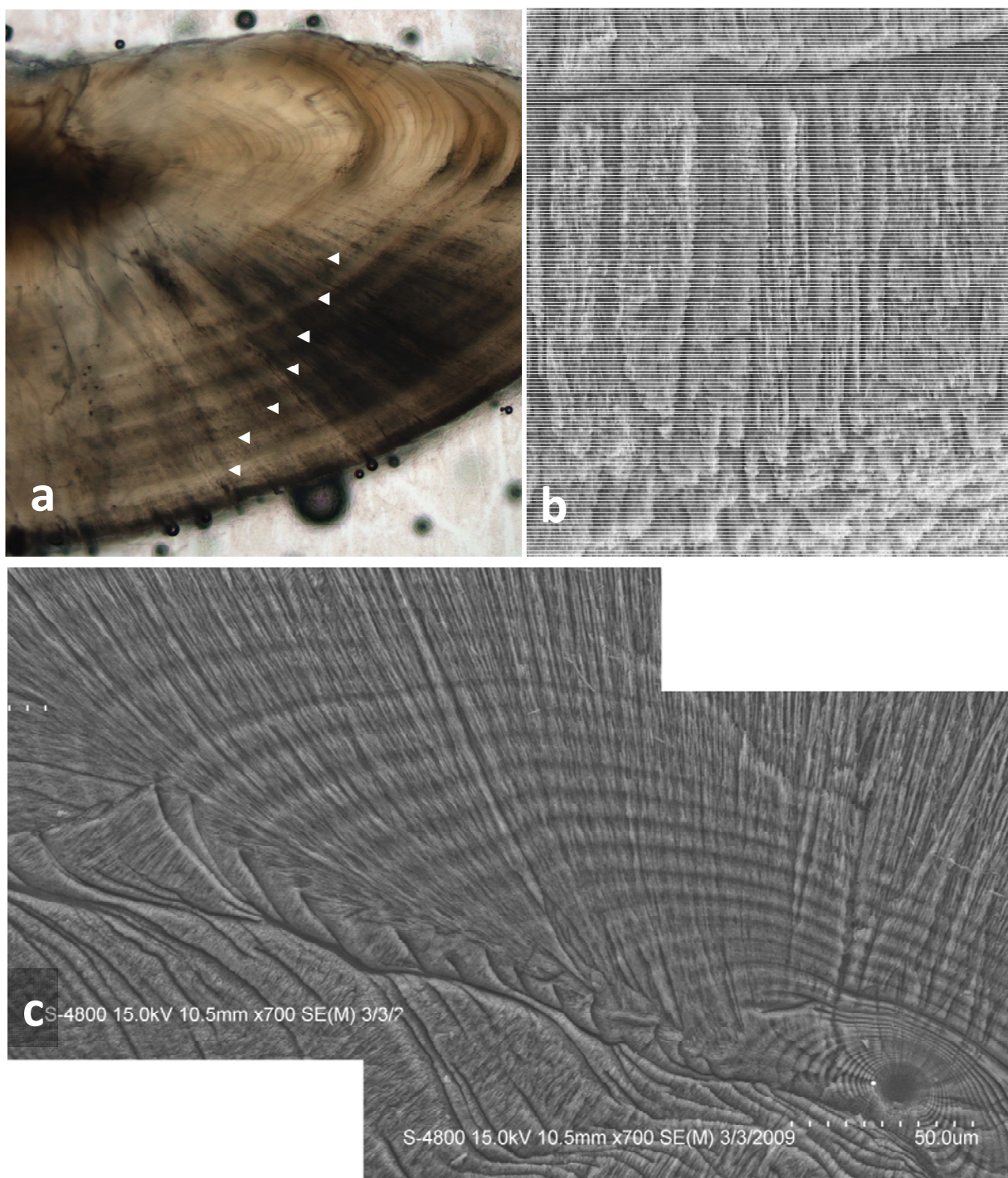


Figure 2 Otolith microstructure for *C. strigosus*. a) light micrograph of sectioned otolith. Arrowheads indicate assumed annual increments (magnification is approx. 100X). b & c) Scanning electron micrographs of an otolith etched with EDTA (700x). b) Microincrements at otolith margin. c) Pre-settlement increments within the otolith core.

Mortality

We used laser videogrammetry to describe the size distribution of kole in marine reserves and nearby, comparable fished habitats (Figure 3). Here, we used closed-circuit rebreathers (Maui) or open-circuit SCUBA (Hawaii) to swim two-meter-wide belt transects along a compass heading. A high-definition video camera fitted with parallel laser beams was used to capture images of individuals when they were oriented perpendicular to the laser beam axes. We then reviewed the video with Sony Picture Motion Browser® and captured 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. Still images were analyzed using ImageJ (National Institutes of Health). In most cases, we were able to estimate fork length. However on occasion, the only reliable length estimate was “body depth” (the distance between the origins of the dorsal and pelvic fins). In these cases, we used morphometric relationships to convert this measurement to fork length. Longenecker & Langston (2008) demonstrated a nearly 1:1 relationship between fish length estimated from laser videogrammetry versus actual fish length. Further, the prediction interval suggested 95% of estimates will be within 0.5 cm of the actual fish length (Figure 4).

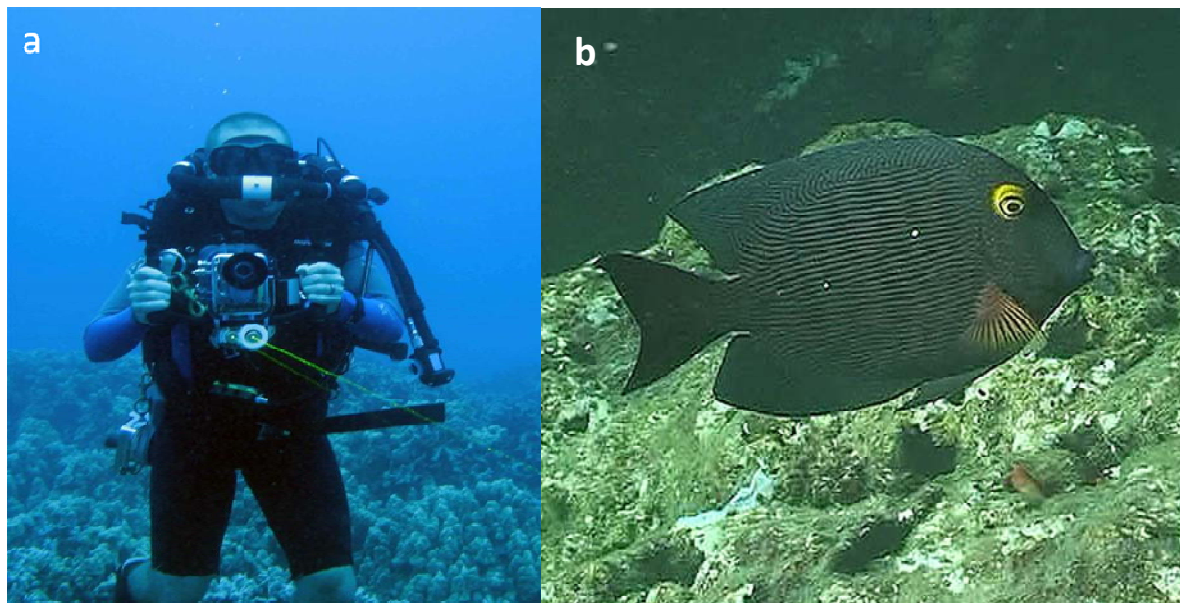


Figure 3 Laser videogrammetry, a non-destructive technique to estimate fish length. (a) a diver operates a video camera fitted with two parallel laser beams. (b) the laser beams superimpose a measurement scale on the side of *C. strigosus*.

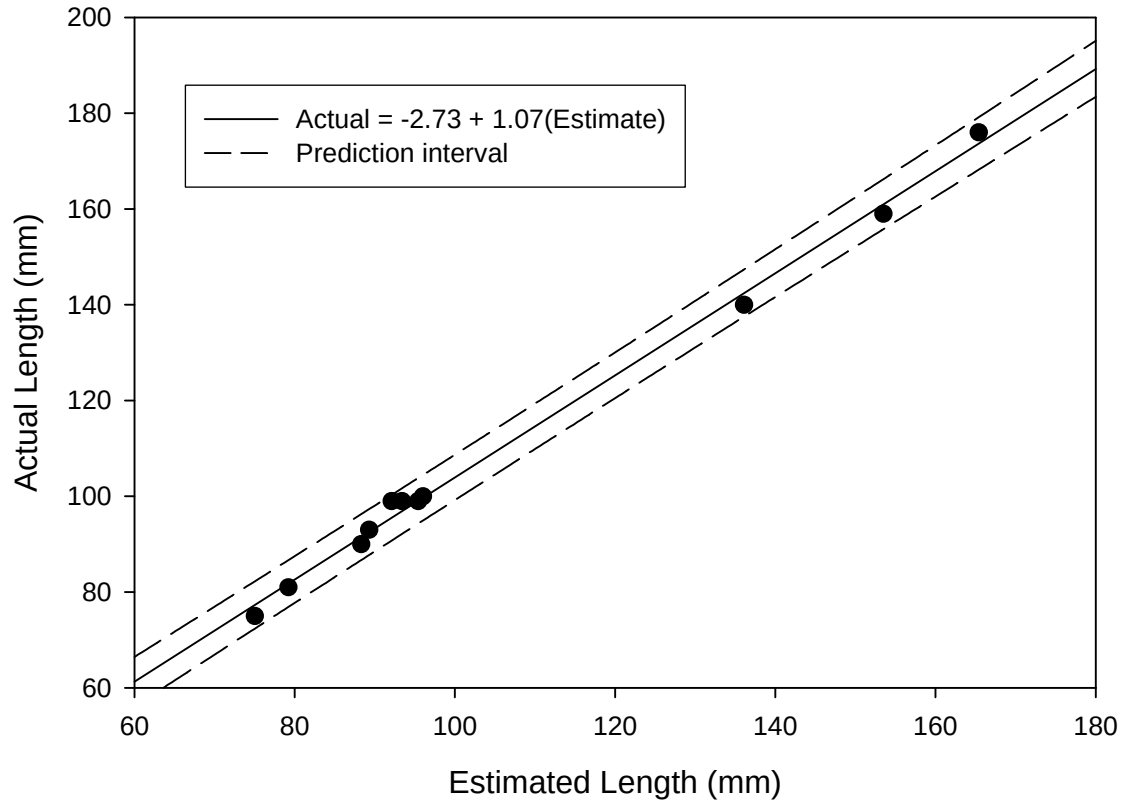


Figure 4 The relationship between estimated and actual lengths of specimens “captured” on videotape for laser videogrammetry and subsequently speared. The prediction interval suggests that 95% of length estimates will be within 0.5 cm of actual fish length (from Longenecker & Langston 2008).

We used the equation for size-specific sex ratios (Figure 11) to estimate the number of males and females represented in each 1 mm size class captured on video. For each sex-specific size class, we used sex-specific vonBertalanffy growth equations (Figure 6) to convert lengths to age estimates and constructed a cumulative age distribution for each sex in all marine reserves surveyed and in all fished sites surveyed. We then used regression analysis to describe the natural logarithm of the frequency of each age class as a function of age, and obtained total mortality (Z) from the negative slope of the line (Everhart & Youngs 1992). Because fishing is prohibited in Marine Life Conservation Districts, total mortality at these sites is equivalent to natural mortality (M). At comparison fished sites, total mortality is the sum of natural (M) and fishing mortality (F). A fishery-independent estimate of fishing mortality was estimated by subtracting total mortality in marine reserves from total mortality at fished sites. That is:

$$\begin{aligned} Z_{\text{reserves}} &= M \\ Z_{\text{fished}} &= F + M \end{aligned}$$

Therefore:

$$Z_{\text{fished}} - Z_{\text{reserves}} = (F + M) - M = F$$

RESULTS

Morphometric relationships

We collected 164 kole for life history analysis. The length-weight relationship was best described by a two-parameter power function where weight was an approximately cubic function of length (Figure 5). All length-to-length relationships were linear (Table 1).

Growth

We obtained 172 readable otolith preparations (109 for macroincrements and 63 for microincrements). The relationship between age and size was described by vonBertalanffy growth equations.

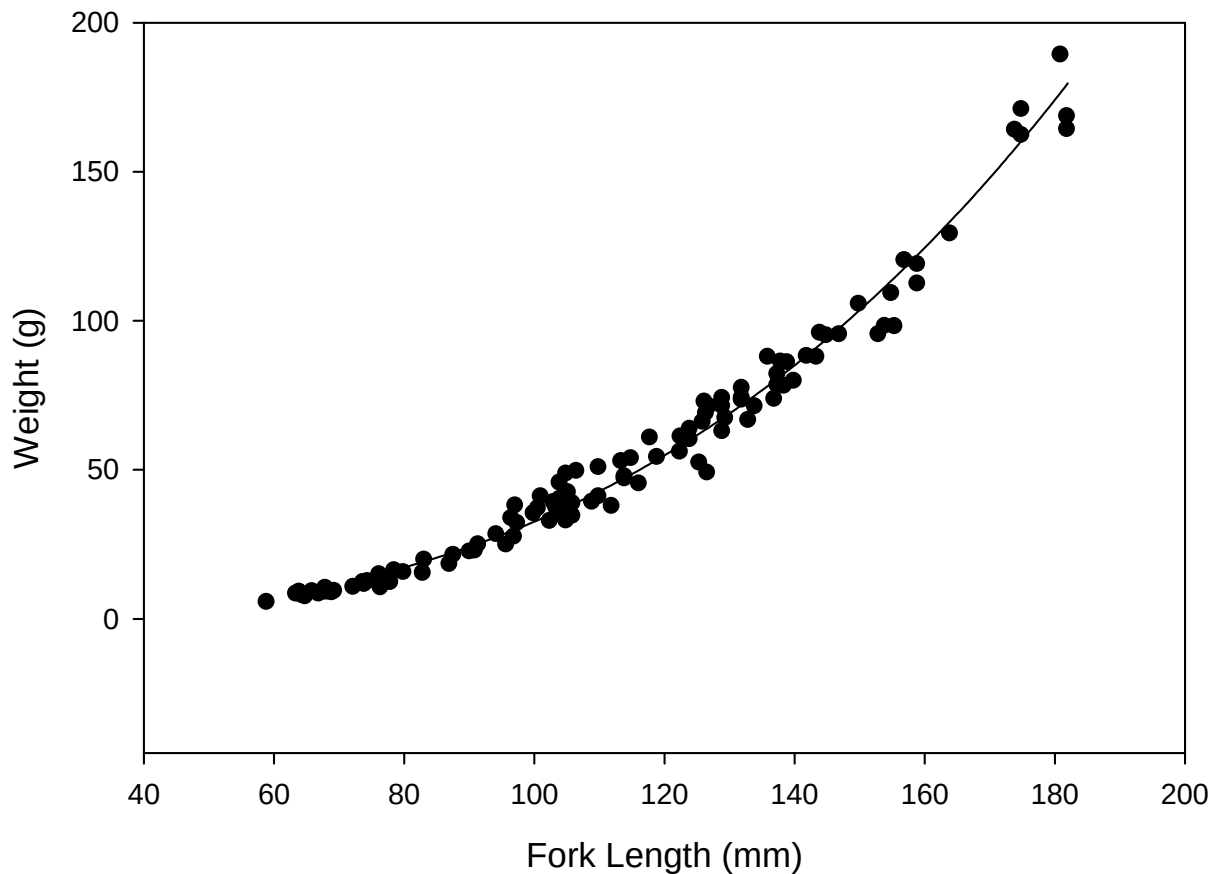


Figure 5 Length-weight relationship for *C. strigosus*. $W = 0.000065064(FL)^{2.8499}$; $n = 160$; $r^2 = 0.97$.

Table 1 Linear regressions predicting fork length (FL) of *C. strigosus*. $FL = a + (X)b$, where X is a linear distance in mm. TL = total length; SL = standard length; BD = the distance between dorsal and pelvic fin origins.

Variable	N	a	B	r ²
TL	117	8.0661	0.8324	0.991
SL	117	0.9706	1.2158	0.992
BD	114	-3.5093	2.2356	0.975

Obvious differences in growth rate were evident in growth curves generated from both macroincrements (Figure 6) and microincrements (Figure 7). Growth approaches an asymptote between 115-120 mm FL for females and 146-154 mm FL for males. Estimates of L_{∞} (Table 2) were well below the maximum reported size for the species (180 mm FL; Randall and Clements, 2001). Estimates of longevity and age at maturity differed markedly depending on the type of increment used and its assumed periodicity.

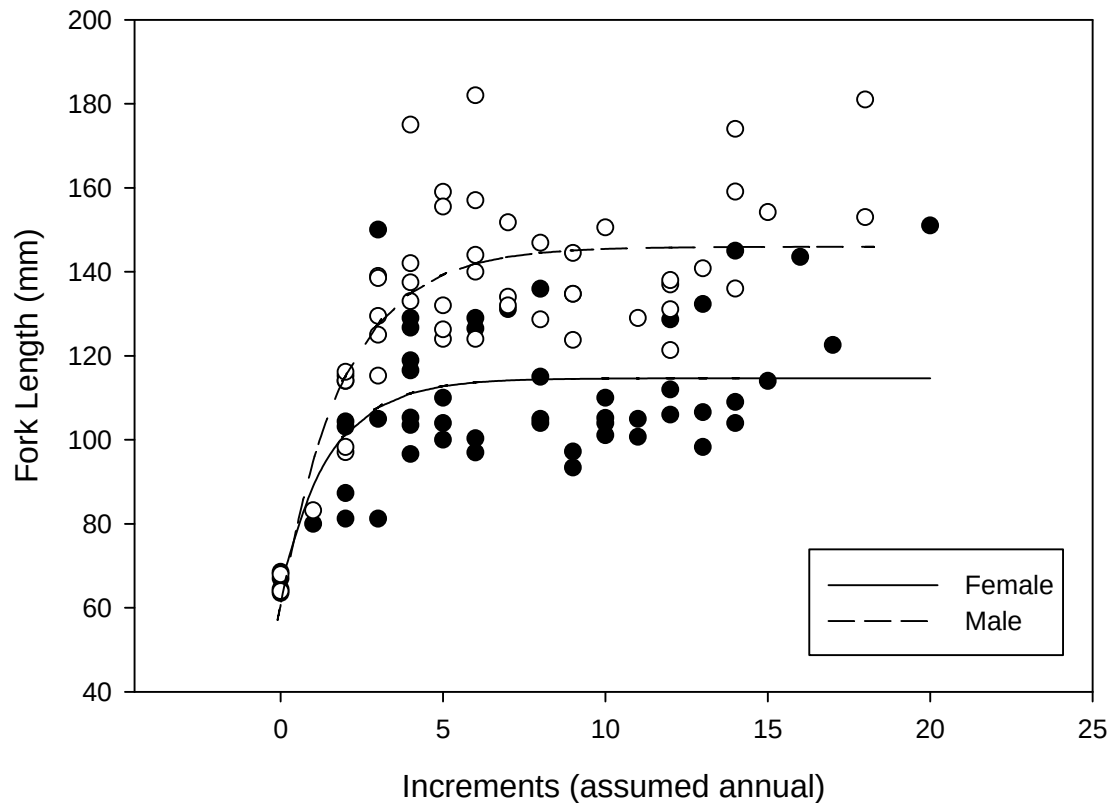


Figure 6 A scatterplot of age (assuming each otolith increment is equivalent to one year) versus fork length for kole, *Ctenochaetus strigosus*. The curves represent vonBertalanffy growth equations for males (open circles) and females (closed circles). Growth parameters are located in Table 2.

Plots based on macroincrements (which are assumed to be deposited annually) indicate that males will reach L_{50} at 1.21 years (ca. 15 months) and females at 0.73 years (9 months). Maximum lifespan may exceed 20 years. In contrast, plots based on microincrements (assumed daily deposition) indicate both males and females will reach maturity in six months and that the longest-lived fish in our collections would have been just over three years old at the time of capture.

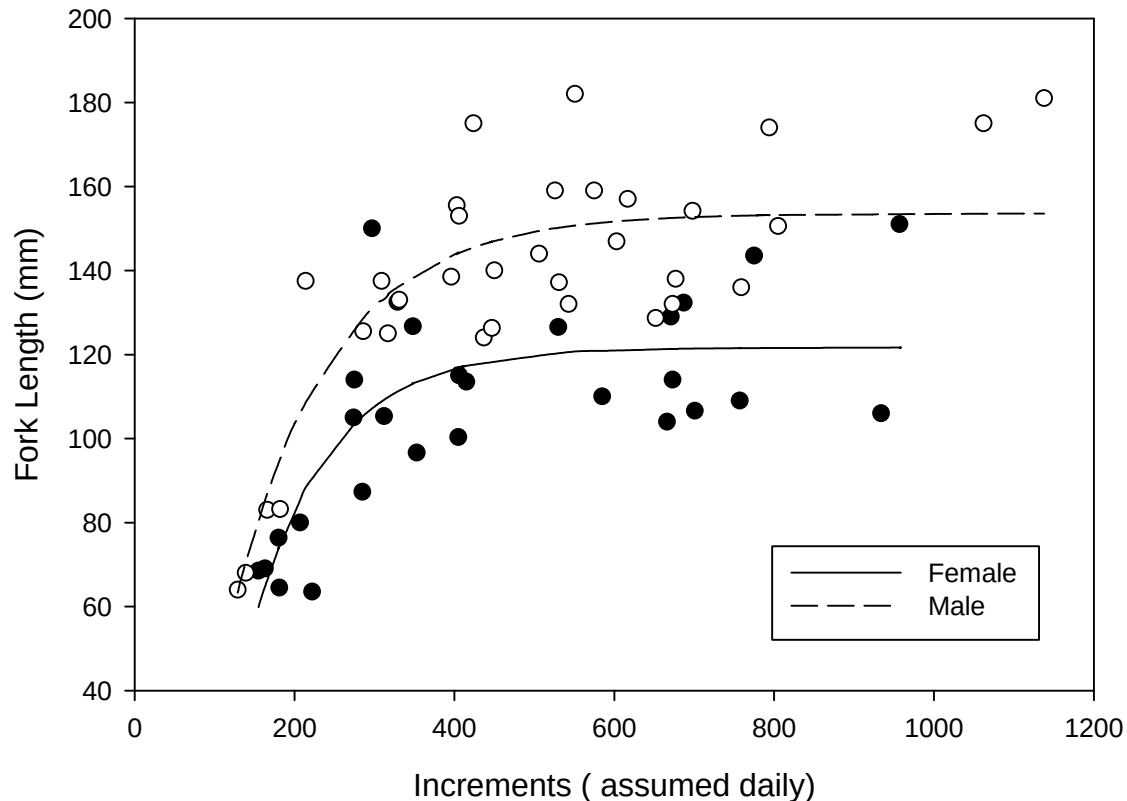


Figure 7 A scatterplot of age (assuming each otolith increment is equivalent to one day) versus fork length for kole, *Ctenochaetus strigosus*. The curves represent vonBertalanffy growth equations for males (open circles) and females (closed circles). Growth parameters are located in Table 2.

Table 2 Parameters for vonBertalanffy growth equations based on assumed annual (figure 6) and daily (figure 7) increments. $l_t = L_{\infty}(1 - e^{-k(t-t_0)})$ where l_t = length at time t , L_{∞} is the theoretical maximum length, k is the growth rate and t_0 is the theoretical time when length is zero.

Equation	L_{∞}	K	t_0
Males Annual	145.95	0.509896	-1.05415
Males Daily	153.58	0.008174	64.0383
Females Annual	114.64	0.655296	-1.28111
Females Daily	121.66	0.010208	88.6233

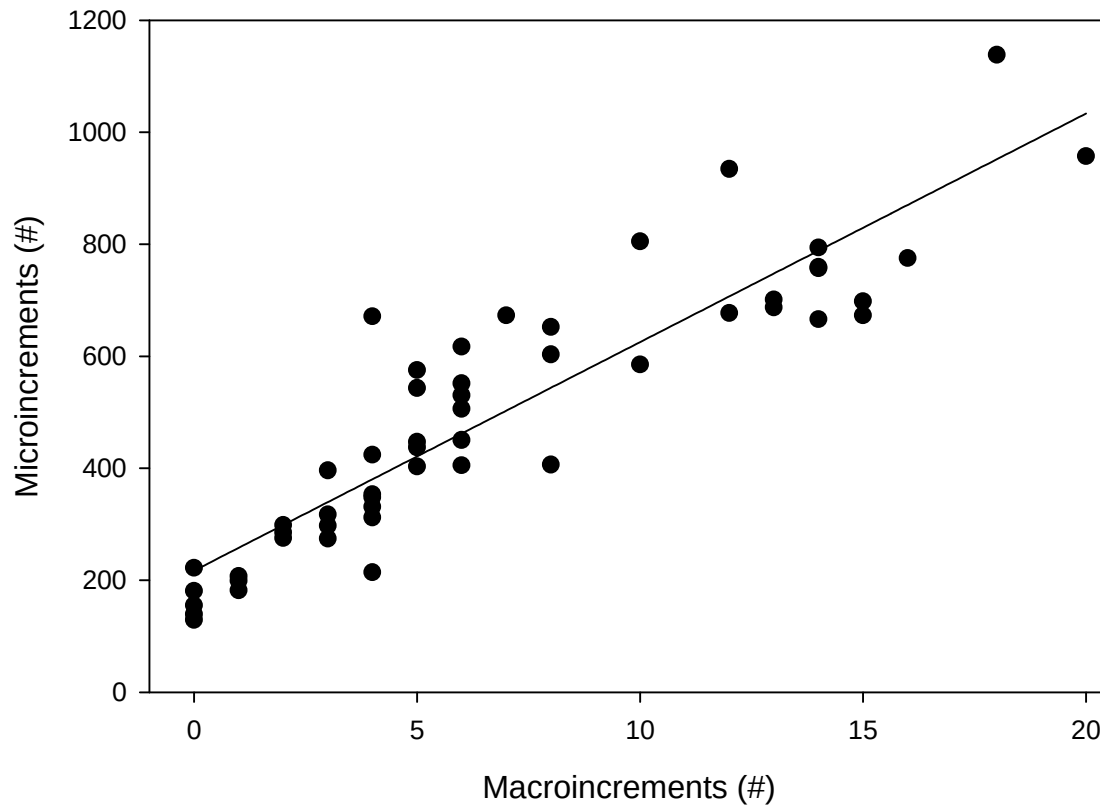


Figure 7 Relationship between counts of macro- and microincrements for *C. strigosus*. # Microincrements = 217.04 + # macroincrements (40.8174). $n = 52$; $r^2 = 0.82$.

Reproduction

We histologically examined gonads from 139 individuals and classified each as mature or immature based on the stages of gametes present (Figure 7). Of these, 76 were ovaries and 63 were testes, yielding an overall physical sex ratio of 45:55 (M:F).

Females

The ovaries of immature females (n=19) consisted of tightly packed lamellae consisting primarily of primary growth oocytes (Figure 8a) and occasional yolk vesicle oocytes. Adjacent lamellae were separated by a narrow space which presumably extended into a central lumen. .

The ovaries of reproductive females (n=57) contained various size-classes of vitellogenic (yolked) oocytes (Figure 8b), indicating that *C. strigosus* exhibits group-synchronous oocyte development (see Wallace and Sellman, 1981). Most oocytes undergoing vitellogenesis were > 250 µm in diameter. Small, light-staining yolk granules first appeared at the oocyte periphery. In larger oocytes, these migrated centrally and coalesced into larger yolk globules. These were interspersed with larger, non-staining vesicles presumed to be oil droplets.

During final maturation and hydration (Figure 8c) the oocyte grows rapidly, reaching a diameter of 500 µm or more. Yolk globules coalesce into a homogenous mass that stains more lightly and uniformly than previous stages. In unembedded ovaries, hydrated oocytes could easily be identified by their large size (usually 70% larger than vitellogenic oocytes) and wrinkled, translucent appearance.

Reproductive females (those whose ovaries contained oocytes in stage II or beyond) were present in all months in which fish were collected (February, March, May, June, August and November) with hydrated individuals present February-May. The smallest reproductive female was 81.2 mm FL. Estimated L_{50} for female *C. strigosus* is 84 mm FL.

Males

Males have an unrestricted spermatogonial testis (see Grier, 1981). In immature (n=9) males, the testis was visible as a small, roughly triangular block of tissue dorsolateral to the posterior part of the intestine. It consisted of clumps of tightly packed spermatogonia bound by stromal tissue (Figure 8d). Discrete lobules were rarely evident.

In reproductive males (n= 57; Figure 8e), the testis consisted of clearly-defined circular lobules separated by a lattice of stromal tissue. The walls of the lobules were composed of spermatocysts (spermatocytes or spermatids encapsulated by sertoli cells) in various stages of development. Spermatozoa were readily evident within the lobule lumen. In longitudinal sections, the lumens of adjacent lobules merged centrally to form sperm ducts (Figure 8f).

Spermiated males were present in all collections. The smallest mature male was 97 mm FL. The size at 50% maturity (L_{50}) was estimated at 100 mm FL (Figure 9).

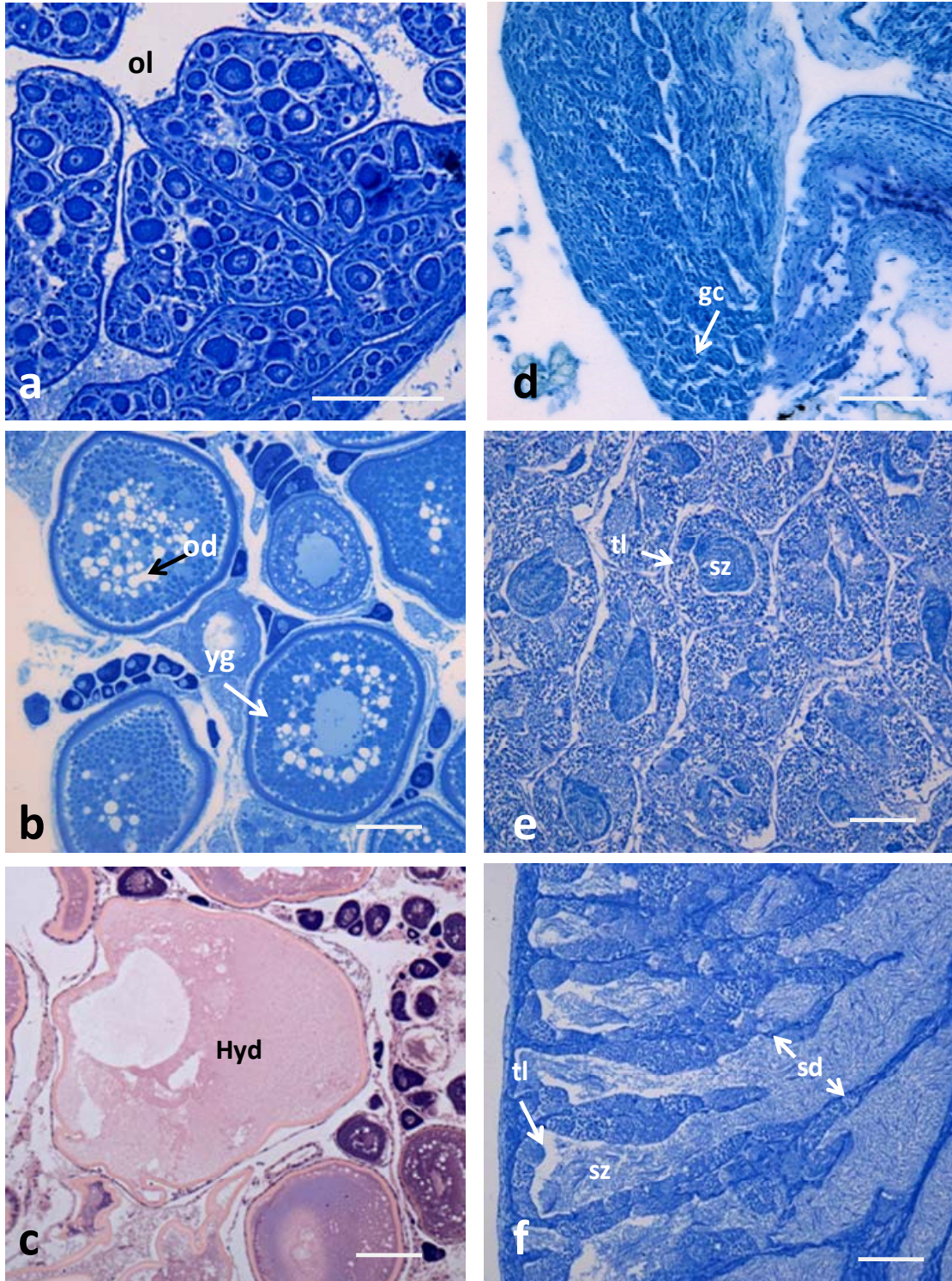


Figure 8 Gonad structure of *C. strigosus*. A) Ovary of an immature female containing primary growth oocytes B) ovary of a mature female containing vitellogenic oocytes C) ovary of a mature female containing hydrated oocytes d) testis of a juvenile male containing clumps of gonial cells D) Transverse section of a mature testis E) longitudinal section of a mature testis. gc= spermatogonia, Hyd= hydrated oocyte; od= oil droplet; sd= sperm duct; sz= spermatozoa; tl= testis lobule; yg = yolk granule. Bar is 100 μm.

Size-specific Sex Ratios

Males grow to a significantly larger size than females (Figure 10). Mean size for females was 106.8 mm FL and males was 133.8 mm FL. Growth of females approaches an asymptote between 115-120 mm FL whereas that of males approaches an asymptote at 146-154 mm FL. As a result, the proportion of females in the population varies predictably by size-class (Figure 11). Size classes below 120 mm FL are more likely to be female biased whereas those above 130 mm FL are likely to be male biased.

Table 2 Oocyte diameters measured from histological sections of *C. strigosus* gonads. Oocyte classification follows Wallace and Sellman (1981). Females were considered mature when their ovaries contained oocytes in stage III or later. n= # of oocytes measured.

Oocyte Stage	Size Range (μm)	Mean Size (μm)	Standard Deviation	n
I Primary Growth	25-95	48.2	16.7	42
II Yolk Vesicle Stage	75-225	138.0	34.3	36
III Vitellogenesis	175-430	327.7	45.7	90
IV Mature/Hydrated	300-700	558.0	81.7	76

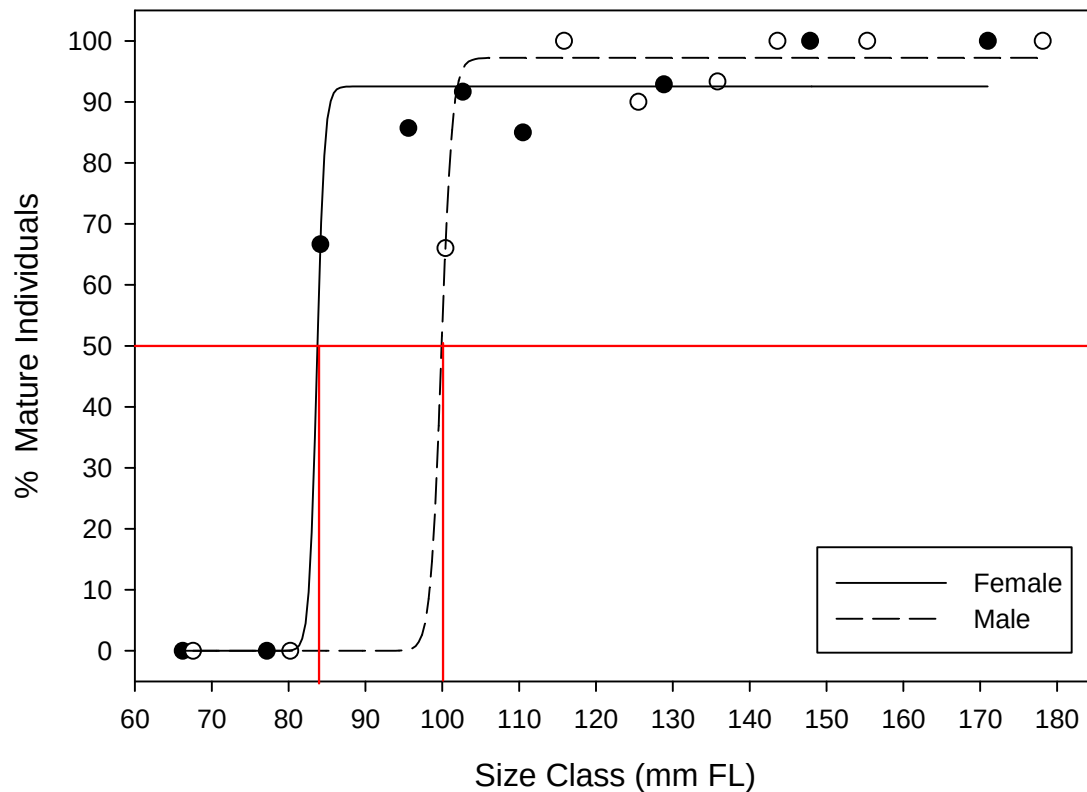


Figure 9 Size at maturity (L_{50}) for kole, *Ctenochaetus strigosus*. Open circles represent males, closed circles represent females.

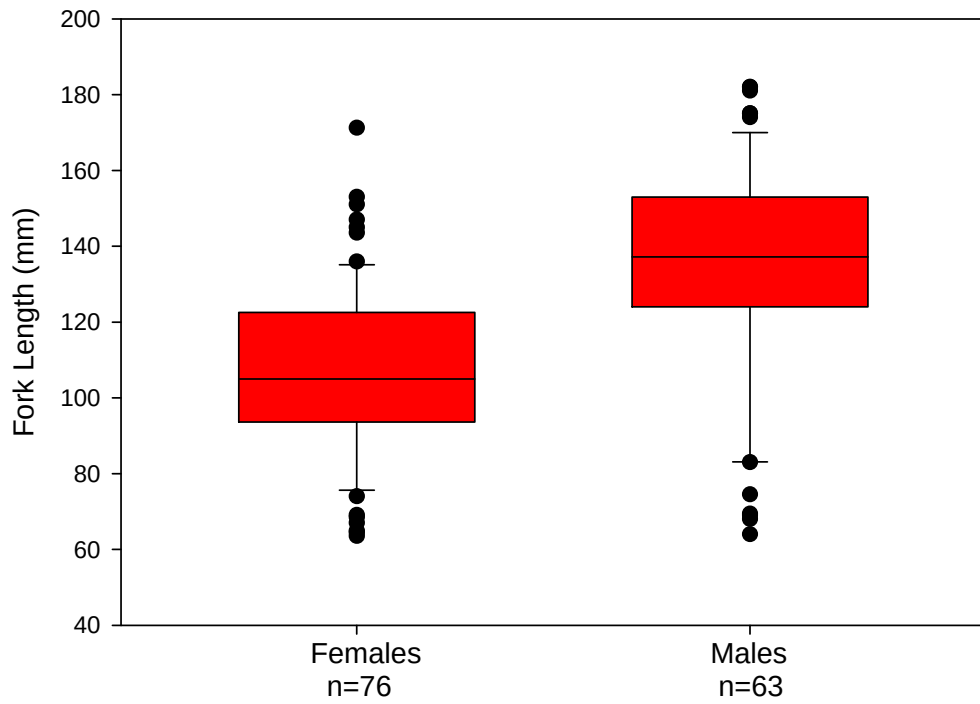


Figure 10 Box plot of females and males by Fork Length. Males reach a significantly larger size than females (Mann-Whitney U statistic = 978.5; $P < 0.001$).

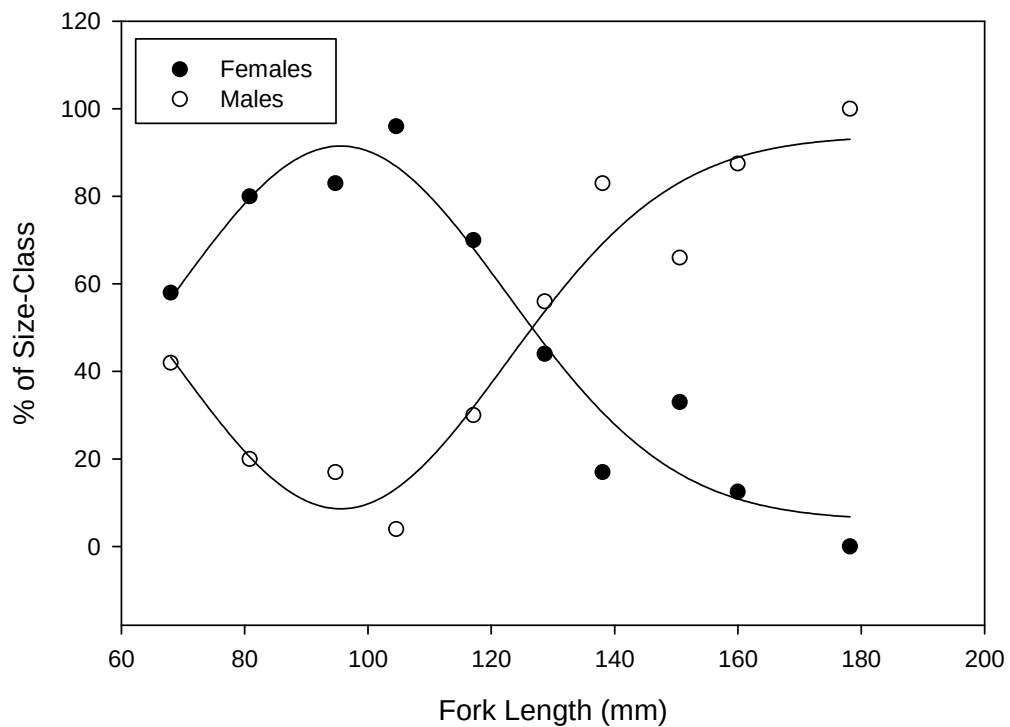


Figure 11 Proportion of males and females by size class. The proportion of females in the population can be described by the equation $\% \text{ Females} = 5.99 + 85.49 \cdot (-.5 * ((x - 95.58) / 26.92)^2)$; $r^2 = 0.932$.

Fecundity

Twenty seven ovaries were selected for batch fecundity analysis. Counts of maturing or hydrated oocytes yielded fecundity estimates ranging from 1,410 eggs/spawn for a 110 mm FL specimen to 35,262 eggs/spawn for a 171 mm FL specimen (mean = 7,424). The relationship between size and fecundity was best described by a power function (Figure 12).

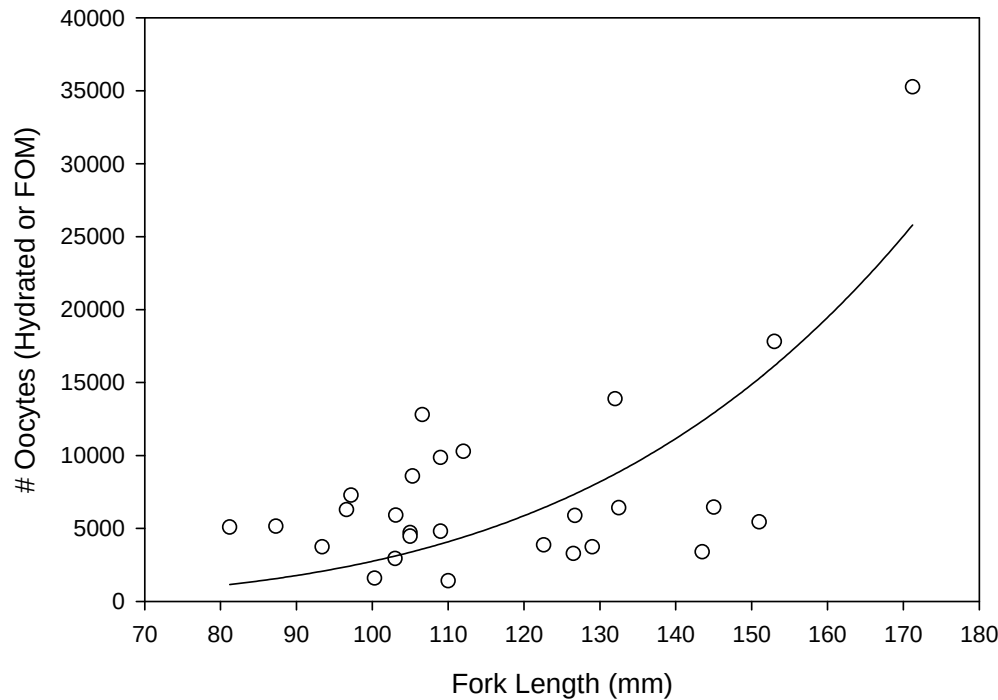


Figure 12. Scatterplot of size vs. batch fecundity for kole, *Ctenochatus strigosus*. $BF = 1.2766E^{-005}(FL)^{4.1663}$. $r^2 = 0.44$,

Mortality

We surveyed a total 21,368 m², 69% of this area was in marine reserves and 31% was in fished habitat (Table 3). We captured on video a total 845 individuals suitable for size estimation, 520 of these were in marine reserves and 325 were in fished habitat.

Table 2 Area surveyed in marine reserves and nearby comparison sites.

Reserve Site	Area Surveyed (m ²)	Fished Site	Area Surveyed (m ²)
Honolua Bay	10,991	Kapalua Bay	3,065
Kealakekua Bay	3,783	Paoao Bay	3,529
Total	14,774		6,594

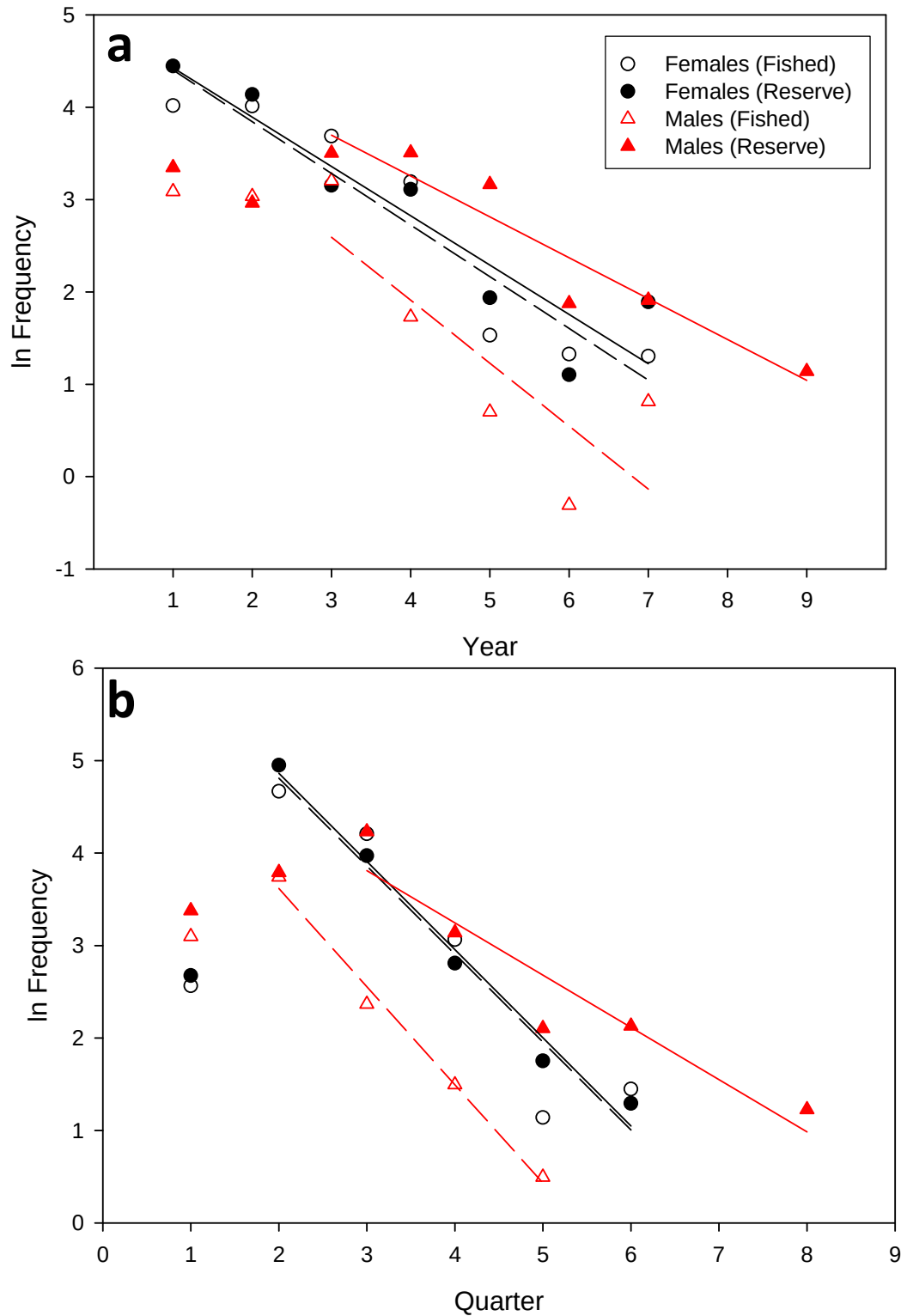


Figure 13 Annual (a) and quarterly (b) mortality estimates for kole, *Ctenochaetus strigosus*, in reserves (solid lines) and areas open to fishing (dashed lines). Mortality was estimated separately for females (black) and males (red). Using assumed annual increments (a), female annual mortality was 0.55923 and 0.5334 in fished and reserve areas, respectively. Male annual mortality was 0.6824 and 0.4425. Using assumed daily increments (b), female quarterly mortality was 0.9513 and 0.9534. Male quarterly mortality was 1.0608 and 0.5650.

In marine reserves 75 females and 16 males exceeded the asymptotic length of the vonBertalanffy daily growth equation, preventing back-calculation to age. The same is true for 20 females in fished areas. Considering the annual growth equation, 102 females and 42 males in marine reserves plus 51 females and 1 male in fished areas exceeded the asymptotic length. None of these individuals could be included in mortality estimates. Mortality plots for the remaining individuals are presented in Figure 13a. Mortality estimates for females were notably similar in both fished and reserve areas, suggesting that fishing mortality is virtually non-existent for females. However, as expected, total mortality of males in marine reserves was lower than that in areas open to fishing.

Using daily growth estimates (Figure 13b) total quarterly mortality in marine reserves, which equals natural mortality, is 0.5650. Total quarterly mortality in fished areas is 1.0608. The fishery-independent estimate of quarterly fishing mortality is 0.4958. Using annual growth estimates total annual mortality in marine reserves, which equals natural mortality, is 0.4425. Total annual mortality in fished areas is 0.6824. The fishery-independent estimate of annual fishing mortality is 0.2399. On average, fishing accounts for about 40% of all male mortality over the age classes analyzed.

DISCUSSION

This study modeled the growth of kole using micro and macro increments. Because of time constraints, the periodicity of increment deposition was not validated. In similar studies, macro increments were assumed to be deposited annually (e.g., Choat and Axe, 1996) whereas micro-increments are assumed to be deposited daily (Longenecker and Langston, 2008; Sudekum et al., 1991). Growth curves resulting from these result in conflicting estimates of growth rate and longevity, highlighting the dire need for validation in this species. Despite this, there is a linear relationship between annual and daily increments suggesting that both methods can be useful in future growth studies and management. Although obtaining counts of micro-increments is much more labor intensive, it also leads to more precise age estimates, which can be particularly useful in modeling growth during early life of the species. We suggest that both methods be validated and used in combination.

Regardless of the type of increment analysis used, growth of kole appears to approach an asymptote early in life (30 % of maximum life span). This type of growth profile is typical of many surgeonfish species (e.g., Craig et al., 1997). As such, it is difficult to predict the age of large individuals based on size alone. For this reason, we were only able to model mortality for intermediate size classes using laser videogrammetry analysis. Our results suggest that male kole, which grow to a larger size, experience significant fishing mortality whereas female kole do not. Most kole caught for human consumption are collected with spears or nets. Spearfishermen may target the largest, predominantly male, size-classes because they offer more meat for the effort (in most cases, kole are deep-fried and eaten whole). Small size-classes are targeted by aquarium fishers; however we did not capture enough video footage of small individuals to allow analysis of mortality in the smallest size-classes. That is, we could not estimate aquarium fishing mortality.

Growth of females slows at a smaller size than males, which reach a significantly larger size. Similar size differences have been reported for *A. nigrofuscus* (Dazell and Smith, 1998) and *A. triostegus sandvicensis* (Longenecker et al., 2008). As a result, the proportion of females in larger size classes (>130 mm FL) decreases predictably. Management strategies which seek to protect the largest individuals (e.g., slot limits) would disproportionately protect males and redirect fishing pressure to smaller size classes where females are more numerous.

Our histological evaluation of *C. strigosus* gonads indicate that this species has group-synchronous oocyte development, suggesting this species spawns discrete batches of eggs over an extended reproductive season. The relationship between body length and batch fecundity appears to be exponential; however, the equation is based on a small number of individuals (n=27) and includes a few highly influential points, particularly in the larger size classes. Because fecundity was estimated from hydrated oocytes, it is possible that our analysis could have underestimated the reproductive potential of this species, as some individuals may have already spawned a portion of the most recent clutch prior to capture. Although we also attempted to count the largest mode of yolked oocytes, we had difficulty resolving one size mode from another. As such, our fecundity estimates using this method were almost certainly inflated (ca. 5 times of counts of hydrated oocytes). We could find few fecundity studies on similar-sized surgeonfishes for comparison. Fecundity estimates determined for kole were similar to that observed for yellow tang, *Zebrassoma flavescens*, for which fecundity ranged from 0-28,000 eggs for fish 110-140 mm SL (Bushnell & Claisse, *In Prep*). In comparison, fecundity for the larger-bodied manini, *Acanthurus triostegus sandvicensis*, varied between 20,000-380,000 eggs/spawn (Longenecker et al., 2008).

ACKNOWLEDGMENTS

Funding for the majority of this work was provided by the Dingell-Johnson Sport Fish Restoration program through Hawaii's Fisheries Local Action Strategy, in collaboration with Hawaii's Division of Aquatic Resources. The Hawaii Institute of Marine Biology provided access to vessels and SCUBA equipment for work in Kaneohe Bay. Meghan Dailer and Celia Smith provided field assistance and lodging while on Maui. B&B SCUBA supplied air and oxygen fills at a reduced rate on Maui. The University of Hawaii at Hilo provided transportation and the use on a kayak in Hawaii. Bill Walsh provided logistical advice/support on Hawaii. Kassi Cole allowed the use of her laboratory for histology. Otoliths were examined at the Biological Electron Microscopy Facility. Tina Carvalho provided SEM training to our assistants. The Hawaii Undersea Research Laboratory provided access to closed-circuit rebreathers. This work was conducted under the DLNR Collecting Special Activities Permit 2008-15 and University of Hawaii IACUC protocol 09-665.

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