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# BIOLOGY OF PARROTFISH IN HAWAII

A Report prepared for the Western Pacific Regional Fishery Management Council
by the
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Cover Photo: Redlipped  parrotfish (*Scarus rubroviolaceus*). Photo courtesy of John E. Randall.

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## INTRODUCTION

Parrotfish (Scaridae) play a significant role in coral reef ecosystems throughout the tropics, functioning ecologically as bioeroders and algal consumers (Mumby 2006, Bellwood et al. 2004), and economically valuable in local fisheries (Smith 1993, Jennings et al. 1999b, Page 1998). Scaridae is a diverse family, with 83 species world-wide, from 9 genera. The family exhibits a broad size range, with maximum sizes of individual species from 20 cm (Leptoscarus vaigiensis) to 150 cm (Bolbometopon muricatum).

Scarids have complex socio-sexual systems that are key to their life histories and demographic structures. Parrotfish are sequential protogynous hermaphrodites. The dominant reproductive mode for individuals is to begin life as females, with the capability to change gender later in life (Thresher 1984, Choat & Robertson 1975). This general pattern involves three morphological phases: a juvenile phase, an initial phase, and a terminal phase (Figure 1). The juvenile phase includes newly recruited individuals that are sexually undifferentiated. After a brief period post-settlement, juveniles transition from a typically striped morphology into initial phase individuals, which exhibit drab red and brown coloration. The vast majority of these initial phase fish are female. After reproductive maturation, initial phase individuals are physiologically capable of transitioning into terminal phase individuals, which often have blue and green coloration and are always mature males (usually arising from sex-changed females). The transition between phases seems to be dependent upon individual physiological status (health, size, etc.) and environmental conditions (social and abiotic) (Choat & Robertson 2002).

Depending on the species and even on local environmental conditions, several variations of this pattern may arise. Among the variations are instances of diandry, in which some individuals begin life male and do not change sex (Thresher 1984, Robertson & Warner 1978). Also, pre-maturational sex change, in which immature females change sex without leaving the initial phase, occurs (Choat & Robertson 1975). In diandric species and species with pre-maturational sex change, mature initial phase males are present in the population.

Behaviorally, it is typical for terminal phase individuals to exhibit territorial behavior and protect their territories, which encompass the home ranges of groups of females (termed harems), from intrusion by other males. These territories may encompass preferred spawning sites and/or preferred feeding habitat attractive to females (Thresher 1984). In species and populations where initial phase males exist, these males act as "sneakers", which, because of their similar appearance to females, receive little aggression from the terminal phase males, and are able to sneak into spawning events initiated by the terminal phase male and release their sperm alongside the territorial male (Robertson & Warner 1978).

**Figure 1: Scarus rubroviolaceus, from left: juvenile phase, initial phase and terminal phase. Photo: John E. Randall**

Hawaii hosts seven species of scarids, three of which are endemic. These species are found throughout the islands. Hawaiian parrotfish range in maximum size from ~30 cm (Scarus psittacus) to over 70 cm (Scarus rubroviolaceus) total length (TL). All Hawaiian scarids are sexually dimorphic, exhibit the general scarid socio-sexual system, and at least some species have mature initial phase males. The degree to which these fish are exposed to fishing pressure depends on the human population (highest on Oahu where fishing pressure is greatest) and differs among species, with the largest species being most targeted.

## *Fishery management issues*

Despite their ecological and economic importance, very little is known about the basic life history, reproductive biology and population dynamics of Pacific scarids, and even less is known that is specific to Hawaii. In Hawaii there is growing concern over the status of scarid populations. Anecdotally, stakeholders (fisheries managers, fishermen, conservationists) are noticing declines in both the numbers and sizes of parrotfish. However, the paucity of biological information on parrotfish provides little basis for fishery management and conservation. The only source that may reflect baseline population size is the database of historical commercial catch from the Hawaii Division of Aquatic Resources (HDAR, Figure 2). These data are incomplete and difficult to interpret. Non-reporting by licensed and non-licensed commercial fishermen is a major problem. There are no adequate data on recreational or subsistence fishing for any fish species, and for inshore fishes such as parrotfish, the vast majority of the catch probably results from recreational fishing (Smith 1993).

Existing fisheries management regulations in Hawaii include a minimum size limit for catch, covering all parrotfish species as one group, and placed at 12 inches fork length (FL). Management based on minimum size limits should be supported by reproductive data, with size limits set to ensure that at least some of the population of each species harvested attains sexual maturity before being exposed to fishing pressure. It is inappropriate to combine species of different sizes at sexual maturity, which probably have very different life history and reproductive regimes, under the same size limit management strategy. Larger, slow-growing and late-maturing species are probably more vulnerable to fishing pressures than smaller, fast-growing and early-maturing species (Jennings et al. 1999 a, b) and should therefore be managed differently. Research on the biology of scarids, particularly in terms of demographic and reproductive studies, is urgently needed to support efforts in conservation and management of exploited scarid species.

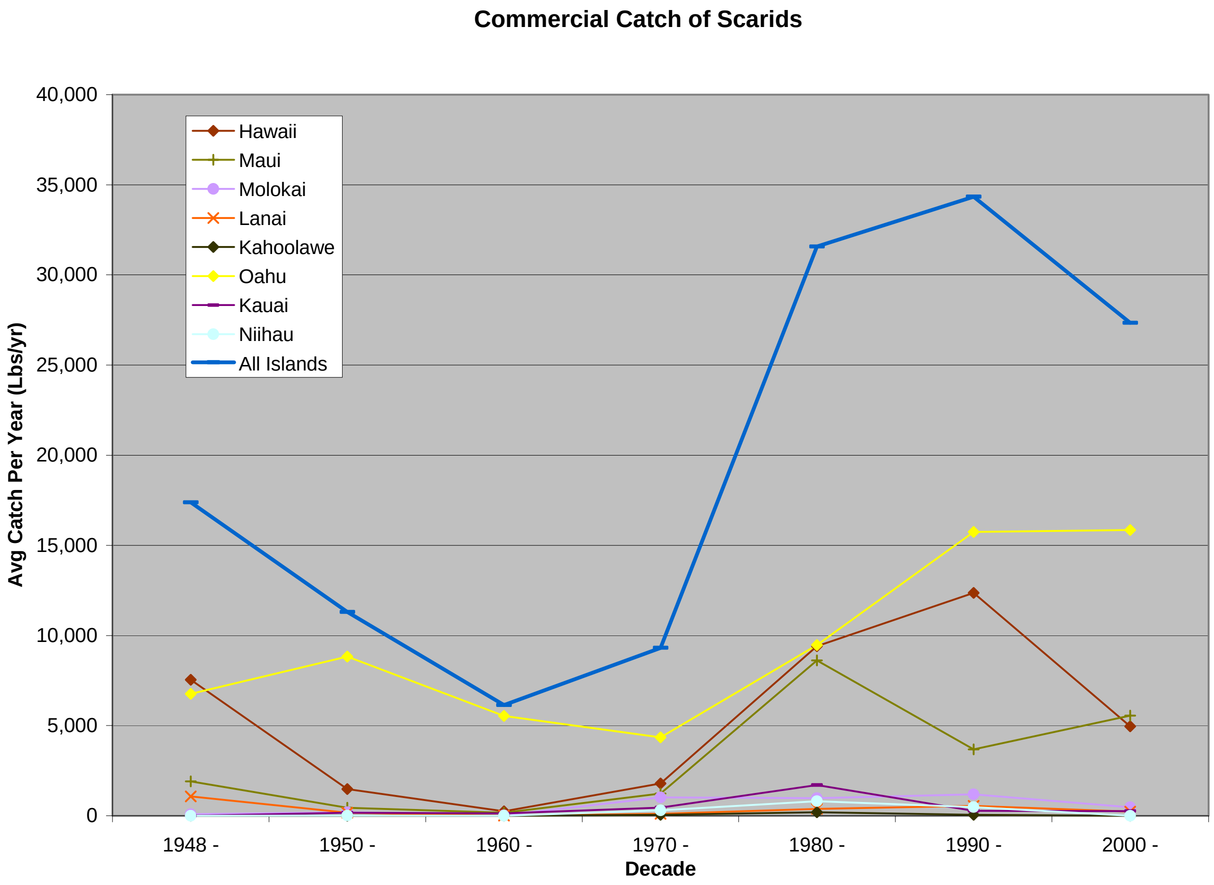

**Figure 2: Hawaii Division of Aquatic Resources commercial catch data for scarid species in Hawaii.**

### *Vulnerability of scarids to fishing pressure*

Sequential hermaphrodites such as scarids, particularly species with sexes that differ in size, may be especially sensitive to fishing pressures. Accordingly, merely identifying a single minimum size at sexual maturity, even within one species, may not be sufficient (Birkeland & Dayton 2005, Choat & Robertson 2002, Armsworth 2001). While fishing intensity has been correlated with decreased mean size and decreased number of terminal phase males for some scarid species (Hawkins & Roberts 2003), the role of fishing mortality in modifying reproductive and life history characteristics is not well known. Since fishing mortality affects primarily the largest individuals, and natural mortality is less size-specific (but overall, greater on smaller individuals), effects of fishing mortality on demographics may be different in kind and/or intensity relative to the effects of natural mortality. However, no comprehensive reproductive studies have been conducted, either in Hawaii or elsewhere in the Pacific, on the scarid species that occur in Hawaii.

## MATERIALS AND METHODS

### 1. Distribution, Density and Habitat Associations

For demographic investigations, we use GIS-based benthic habitat maps prepared by the National Oceanic and Atmospheric Administration's National Ocean Service (NOAA/NOS), which were developed using orthorectified aerial photographs and hyperspectral imagery, to identify coarse-scale habitat types (Coyne et al. 2003). Using these maps, we randomly selected points, stratified by habitat type, for three major bottom types representing potential parrotfish habitat: hard bottom colonized by coral (CH), uncolonized hard bottom (UH), and macroalgae (MA). This strategy enables us to collect in environments diverse enough for our data not to be confounded with such factors as habitat quality, reef zone, and variable fishing intensity. Each of these randomly generated geographic locations represents a starting point for an underwater visual census transect (Samoilys & Carlos 2000). Censuses on these transects were conducted in coastal habitats around Oahu from November 2005 through March 2007. More than 130 transects were conducted during this time. The numbers, sizes, and phases of scarids, combined with their habitat data, permit examination of density of individuals, distribution patterns, sex ratios, size structure, and other demographic characteristics of parrotfish populations.

The divers were trained to estimate fish size under water using fish models of known length (Bell et al. 1985). A team of two divers conducted 5 m x 100 m transect surveys, at relatively constant depth, within a habitat type. Diver 1 would begin at the start of the transect, swimming slowly and recording parrotfish data (number, species, total length (TL), and color phase) while Diver 2 would unroll the transect tape. Once the fish survey was completed, Diver 2 would record benthic habitat data using a one-meter square quadrat. Recorded benthic data include species or substrate identification at 25 point intercepts within the quadrat. Meanwhile, Diver 1 would conduct rugosity measurements of the substrate using a chain made of small links (1.3 cm per link) draped carefully to follow the contours of the substrate (McCormick 1994). The distance along the substrate contour divided by the linear horizontal distance yields a rugosity index (ranging 0-1) that can be used to compare habitats at different sites. On more rugose substrates, the chain will extend a shorter linear horizontal distance than on less rugose substrates. The index of more rugose surfaces, then, is actually a smaller number (shorter chain distance compared to the linear horizontal distance). The benthic habitat data and rugosity measurements were made at 10, 30, 50, 70, and 90 meter distances along the tape.

This protocol was chosen because it corresponds closely with that of the Fish Habitat Utilization Study surveys conducted by Friedlander & Brown (2003). We intended for our data to complement data from that more spatially extensive study and add to our knowledge base of parrotfish demography and reef fish community ecology.

Demographic and habitat-related data were analyzed using one-way Analysis of Variance, and PRIMER (Plymouth Routines in Multivariate Ecological Research) multivariate software to identify environmental trends in the demographic characteristics of this species.

## 2. Species Life History and Reproductive Biology

We collected specimens of all scarid species, and in particular, the five most abundant scarids in Hawaii: Scarus psittacus, Chlorurus spilurus (previously Chlorurus sordidus), Calotomus carolinus, Chlorurus perspicillatus and Scarus rubroviolaceus. Collections ranged from March 2005 through April 2007 and were obtained from fish markets, spearfishing tournaments, fish traps, and by spearing in the field. For each fish we determined whole body wet weight, length, phase (juvenile, initial, terminal), liver wet weight, and gonad wet weight. When possible, we removed otoliths for age and growth studies. The gonads were examined macroscopically to determine sex and preserved in Dietrich’s fixative (10 % formalin, 30 % ethanol, 2 % glacial acetic acid in distilled water, Gray 1954).

Length-weight relationships for each species were determined using standard length (SL) in centimeters and wet weight in grams. The following table indicates the range of specimens used for this analysis:

**Table 1: Range of species covered in this study and Min/Max length and weight estimates**

| Species | Number collected | Minimum Fork Length (FL) | Maximum Fork Length (FL) | Minimum Weight | Maximum Weight |
|---|---|---|---|---|---|
| Scarus psittacus | 121 | 4.6 cm | 31.3 cm | 1.7 g | 732.0 g |
| Scarus rubroviolaceus | 499 | 15.0 cm | 64.8 cm | 70.0 g | 5443.1 g |
| Chlorurus spilurus | 98 | 11.1 cm | 33.3 cm | 28.3 g | 872.0 g |
| Chlorurus perspicillatus | 81 | 20.0 cm | 60.0 cm | 178.0 g | 4295.0 g |
| Calotomus carolinus | 93 | 9.4 cm | 45.5 cm | 12.0 g | 2299.7 g |

Length-length expressions were also calculated for each species to determine the relationships between total length (TL), fork length (FL) and standard length (SL).

The gonadosomatic index (GSI = gonad weight*100/somatic weight) was used to investigate spawning seasonality. Native Hawaiian traditional knowledge indicates that the peak spawning season occurs from May through July (Poepoe et al. 2003). Measuring GSI permits plotting the relative energy invested in reproduction over time. A higher GSI indicates greater reproductive investment (greater weight of gonads relative to somatic weight) and therefore greater reproductive activity.
While GSI may also give some indication of size at reproductive maturity, estimates obtained with this index are usually imprecise and may be problematic for fish such as scarids with complex sexual dynamics (West 1990). To accommodate for this, we are currently following up on research done through this contract by utilizing histological techniques to better estimate length at maturity. In this process, the tissue is embedded in paraffin so that it can be sliced thinly, placed on a slide and stained for better visualization of microscopic physical structures.

Otoliths were removed, washed, stored dry, and then weighed and sectioned following standard procedures used on other parrotfish species (Choat et al. 1996, Gust et al. 2002). This process includes grinding the otolith on both sides until a thin cross-section including the centrum is exposed. Rings were counted by two independent observers. Because of the large number of otoliths collected (see table below) and the time required for other aspects of this study, only a few otoliths have currently been sectioned for each species. All otoliths are prepared and available for further processing.

**Table 2: Number of otoliths obtained by species**

| Species | Number of individuals from which otoliths obtained | Length range of fish corresponding to otolith samples (SL) |
|---|---|---|
| Scarus psittacus | 91 | 4.6 cm – 31.3 cm |
| Scarus rubroviolaceus | 142 | 15.0 cm – 64.8 cm |
| Chlorurus spilurus | 86 | 11.1 cm – 33.3 cm |
| Chlorurus perspicillatus | 54 | 20.0 cm – 60.0 cm |
| Calotomus carolinus | 56 | 12.2 cm – 45.5 cm |

Age validation was conducted by injecting live fish with oxytetracycline (OTC), a chemical that becomes incorporated into calcium-rich structures. These fish were kept in tanks on Coconut Island, monitored, and reared for 15 months after injection with OTC. To maximize the number of individuals raised in each tank, we collected small juvenile fish for all species feasible. We had difficulty obtaining S. rubroviolaceus and C. perspicillatus specimens in good condition, and the C. carolinus specimens collected did not survive the rearing period. Therefore, we have validated results only for C. spilurus and S. psittacus - species that represent the two dominant genera in Hawaii. Thirteen S. psittacus and 7 Chlorurus spilurus survived the full rearing period, and their otoliths were collected for processing. Otoliths were processed using the same techniques mentioned above and examined microscopically with UV light to identify the OTC marks and subsequent periodic marks (Campana 2001, Campana & Neilson 1985).

## RESULTS

### 1. Distribution, Density and Habitat Associations

More than 130 underwater visual census transects were conducted around Oahu (Figure 3). The benthic habitat data collected confirmed that the a priori habitat delineations indicated by the NOS benthic habitat maps were appropriate. In comparing the three major habitat types, coral-colonized hard bottom was significantly more rugose than other habitat types (Figure 4) using one-way ANOVA, p = 0.017.

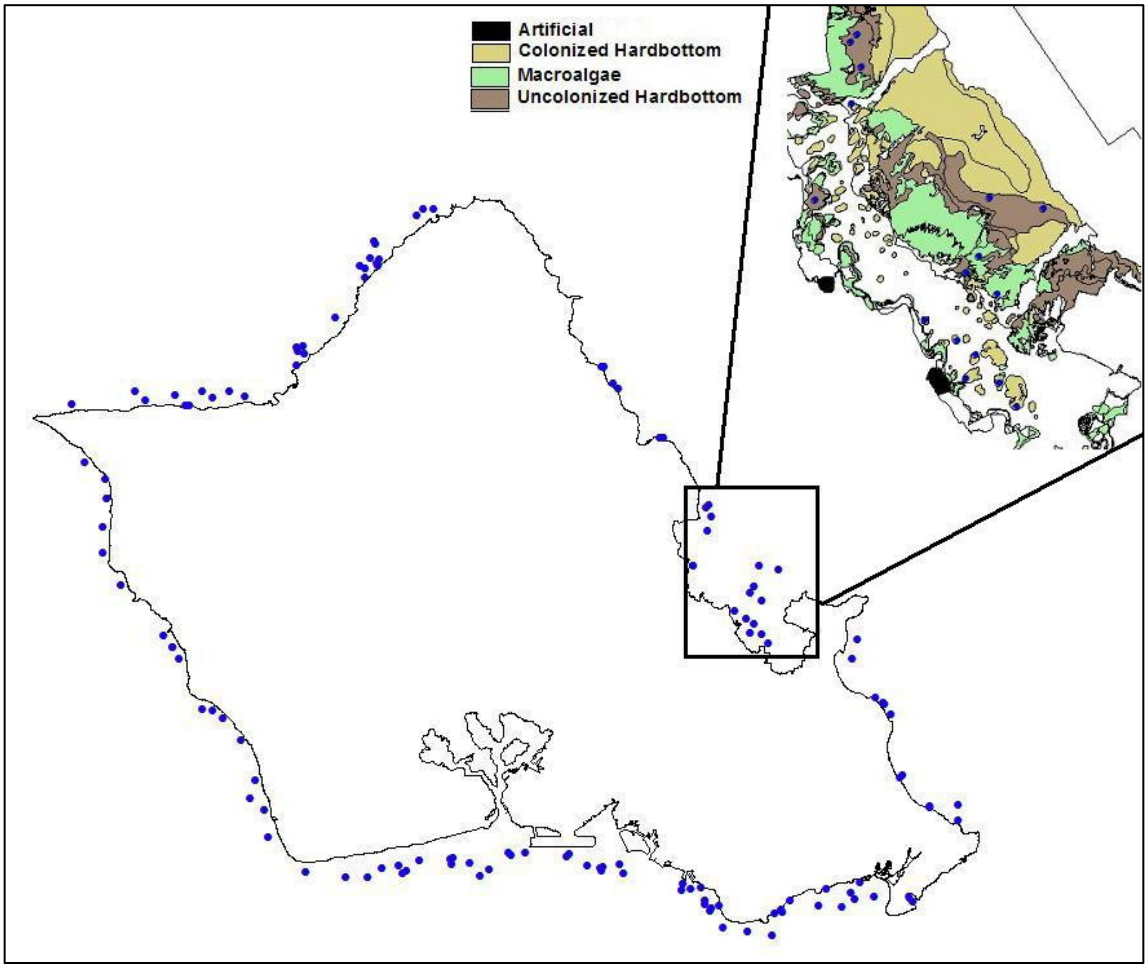

**Figure 3: Locations of underwater visual surveys of parrotfish around Oahu. The inset illustrates habitat delineations on the NOS digital benthic habitat map (legend of substrate types to the left).**

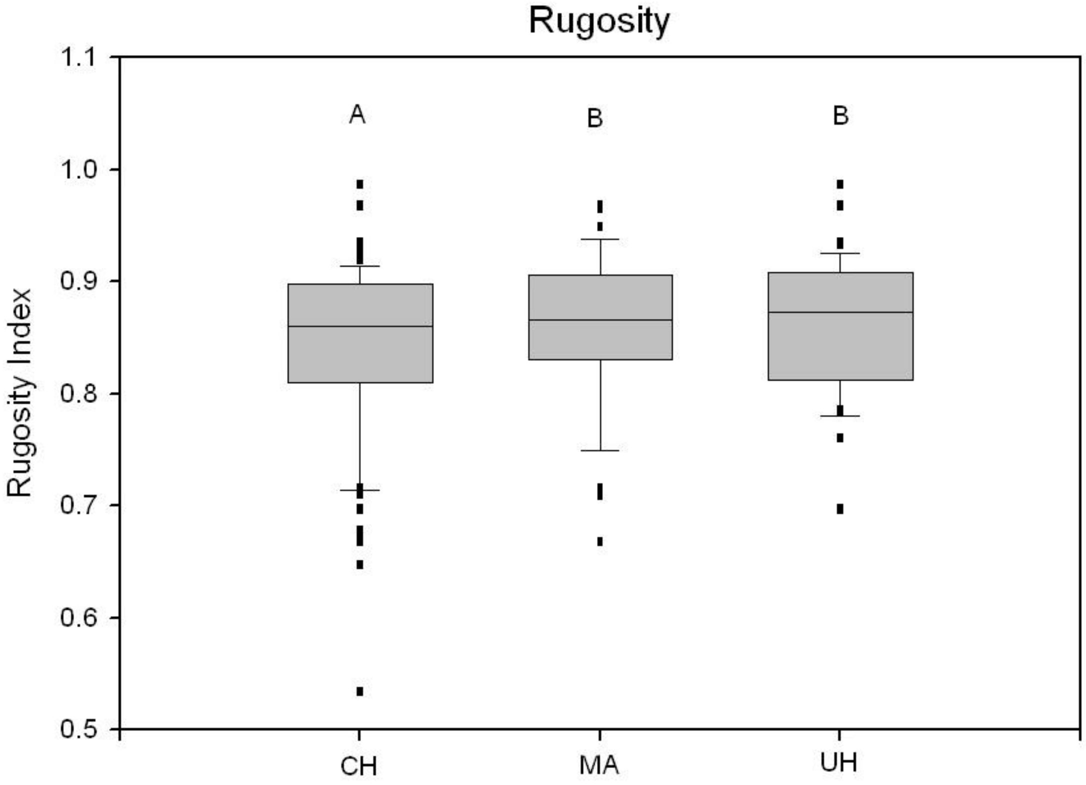

**Figure 4: Analysis of variance for rugosity among habitat types, p = 0.017. A smaller number on the rugosity index indicates a more rugose benthic structure.**

Six of the seven scarid species found in Hawaii were observed during our surveys. Fifty-four percent of the surveys revealed no parrotfish of any species. The three main fishery species (S. rubroviolaceus, C. perspicillatus, and C. carolinus) made up only a small part of the overall scarid community. Scarus psittacus occurred on 36%, Scarus dubius on 7%, Chlorurus spilurus on 17%, Scarus rubroviolaceus on 14%, Chlorurus perspicillatus on 1%, and Calotomus carolinus on 6% of all transects.

The estimated numerical abundance of all scarid species combined is 277.3 scarids/ha ± 82.6 fish/ha. Based on the potential reef area around Oahu (24,127 ha), we extrapolate that there are approximately 6,690,417 ± 1,992,890 scarids in the water surrounding this island. The biomass of all scarid species combined is estimated at 13.07 ± 4.05 kg/ha. The potential area around Oahu predicts a combined biomass of 315,340 ± 97,714 kg of scarids. Estimates for S. rubroviolaceus, the primary target species within the scarid fishery, are 226,794 ± 63,213 individuals and a biomass of 169,613 ± 69,486 kg. Numerical abundance for the other species is estimated at: 4,955,686 ± 1,551,366 for Scarus psittacus, 72,140 ± 32,571 for Scarus dubius, 86,375 ± 33,054 for Calotomus carolinus, 1,324,572 ± 33,054 for Chlorurus spilurus, and 24,213 ± 17,951 for Chlorurus perspicillatus. The biomass around Oahu is estimated to be: 64,298 ± 12,281 kg of Scarus psittacus, 3,901 ± 1,653 kg of Scarus dubius, 8,637 ± 4,874 kg of Calotomus carolinus, 43,911 ± 13,101 kg of Chlorurus spilurus, and 25,116 ± 23,756 kg of Chlorurus perspicillatus.

The Oahu scarid community structure is dominated by small fish. The most numerically abundant species are two of the smallest species, Scarus psittacus and Chlorurus spilurus, (Figure 5). Within species, the relative size of individuals is small, and the majority of individuals are reproductively immature.

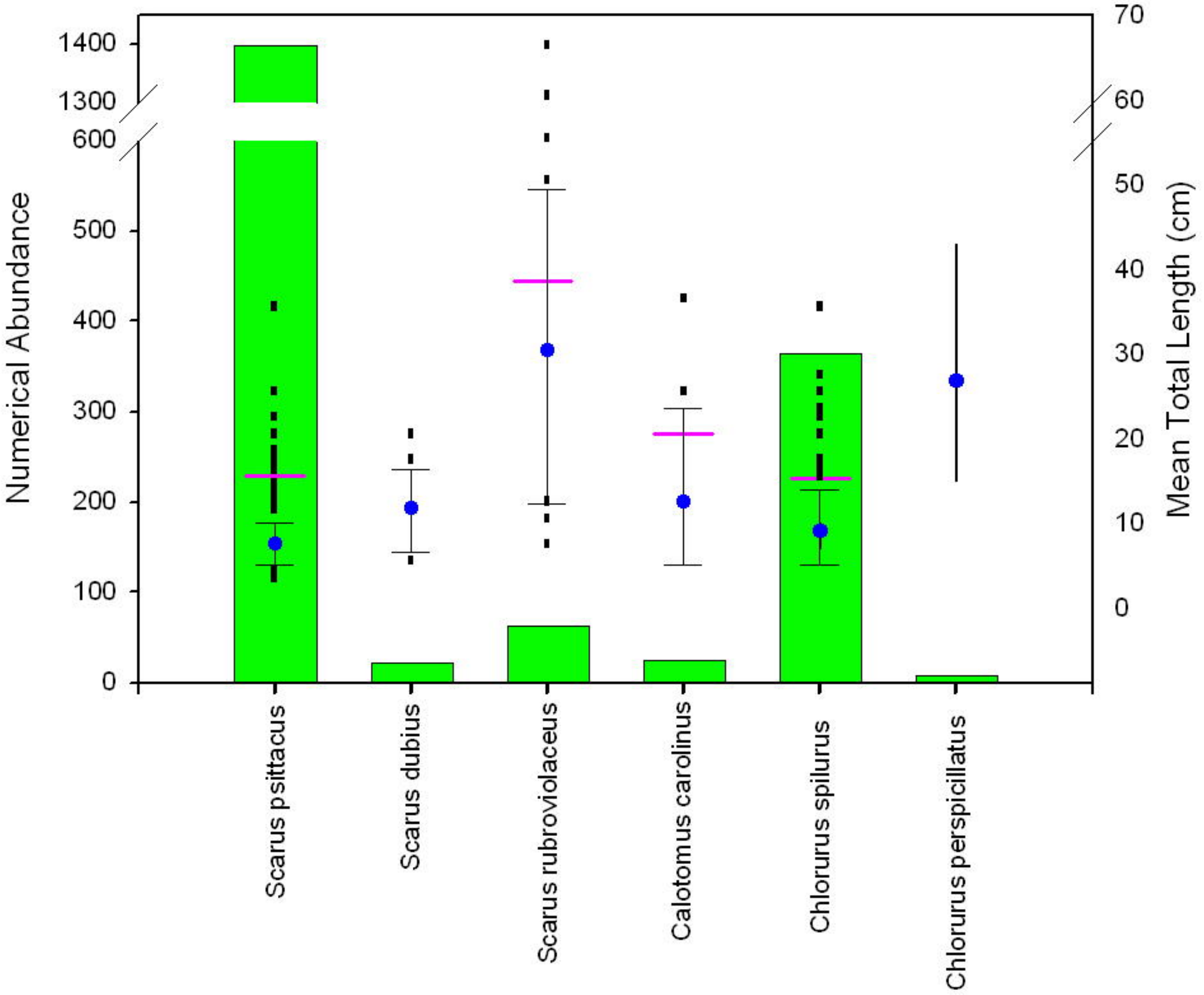

**Figure 5: Relative abundance (in numbers of scarids) on Oahu in green bars. Confidence intervals indicate mean total length (±1 s.d.): blue dots represent mean length, and pink lines represent the size at sexual maturity (Lm) for that species obtained from Fish**

**Table 3: Summary of the relative abundance of mature scarids observed**

| | **Total individuals observed** | **Length at maturity Lm (TL, cm)*** | **% Observed at or above Lm** | **Initial: terminal phase ratio** |
|---|---|---|---|---|
| **Scarus psittacus** | 1397 | 15 cm | 2.5% | 77:1 |
| **Scarus dubius** | 22 | Unknown | n/a | 22:0 |
| **Scarus rubroviolaceus** | 62 | 37.5 cm | 34.4% | 6.8:1 |
| **Calotomus carolinus** | 24 | 20 cm | 25% | 23:1 |
| **Chlorurus spilurus** | 364 | 15 cm | 10.4% | 120:1 |
| **Chlorurus perspicillatus** | 7 | Unknown | n/a | 2.5:1 |

*** Length at maturity is taken from references provided by FishBase since no Hawaii datasets presently exist. The gonads collected in the present study are currently being used to obtain maturity information on these species, and these preliminary data are confirming FishBase estimates as being close to the results for these species in Hawaii.**

One-way Analysis of Variance indicates some association between coarse-scale habitat type and scarid community characteristics (Figure 6). Coral-colonized hard bottom is associated with significantly more numerically abundant scarids present, greater biomass, greater species richness and greater species diversity than the other habitat types investigated.

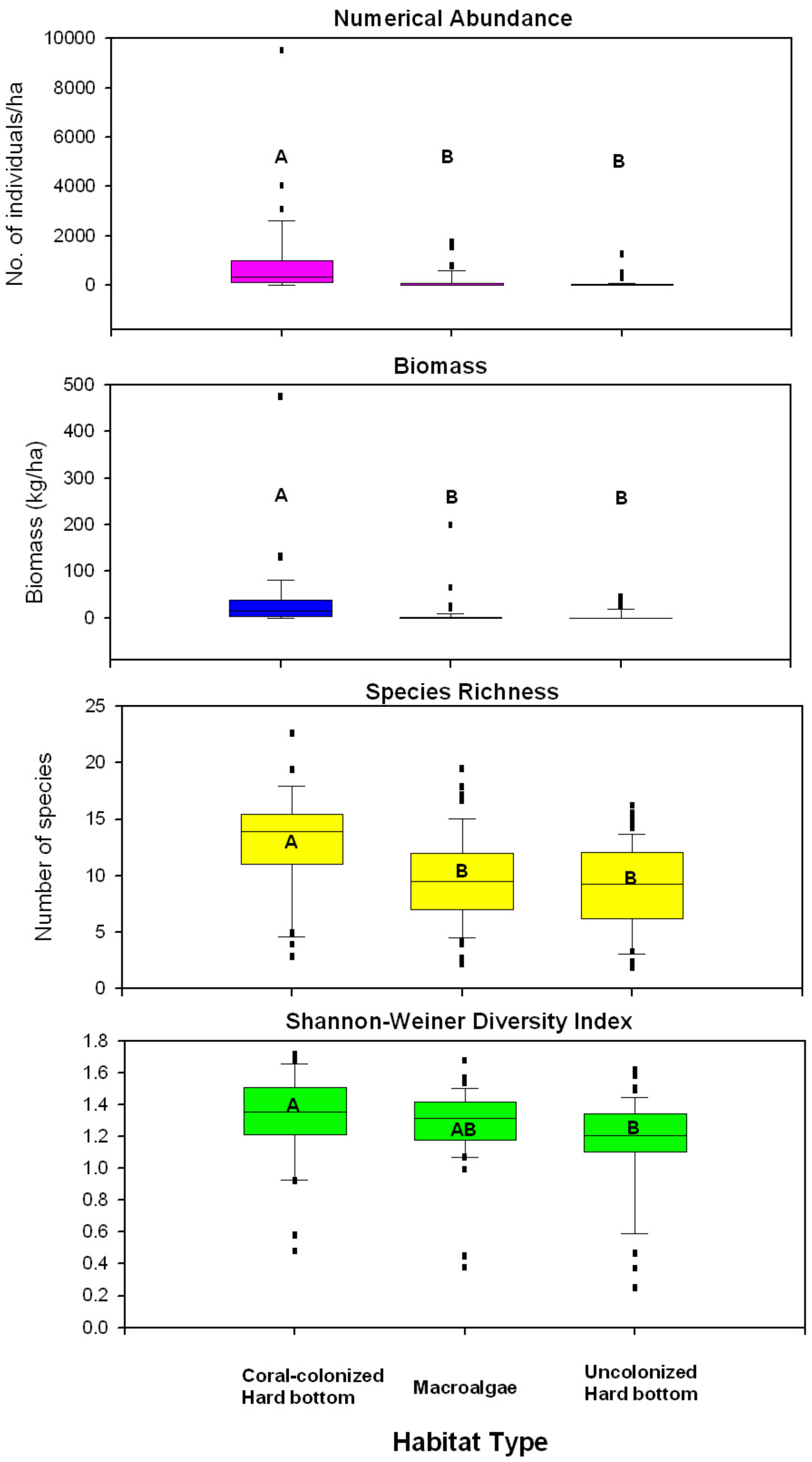

**Figure 6: Scarid community structure characteristics associated with coarse-scale habitat type.**

PRIMER (Plymouth Routines in Multivariate Ecological Research) multivariate statistical software was used to determine whether specific habitat characteristics (such as depth and exposure of shoreline, and rugosity and cover of substrate as measured with quadrats) were associated with scarid community characteristics, including the size structure of fish communities. None of these analyses resulted in any statistically significant relationship among fine-scale environmental characteristics and scarid communities. Our inability to distinguish specific habitat associations is probably a result of the patchiness of parrotfish encounters. Even in habitats that appeared to be “good” coral-colonized habitat, we often encountered no scarids on our transects or found only smaller individuals and/or smaller species.

### 2. Life History, Species Biology and Reproductive Studies

Length-weight relationships were obtained for the five main species encountered in this study (Figures 7-11).

**Table 4: Length-weight equations for scarid species.**

| Species | Equation |
|---|---|
| Scarus rubroviolaceus | Weight (g) = 0.0683 * SL(cm)2.810 |
| Scarus psittacus | Weight (g) = 0.03934 * SL (cm)3.005 |
| Chlorurus spilurus | Weight (g) = 0.04989 * SL(cm)2.934 |
| Chlorurus perspicillatus | Weight (g) = 0.07631 * SL (cm)2.828 |
| Calotomus carolinus | Weight (g) = 0.02916 * SL (cm)3.112 |

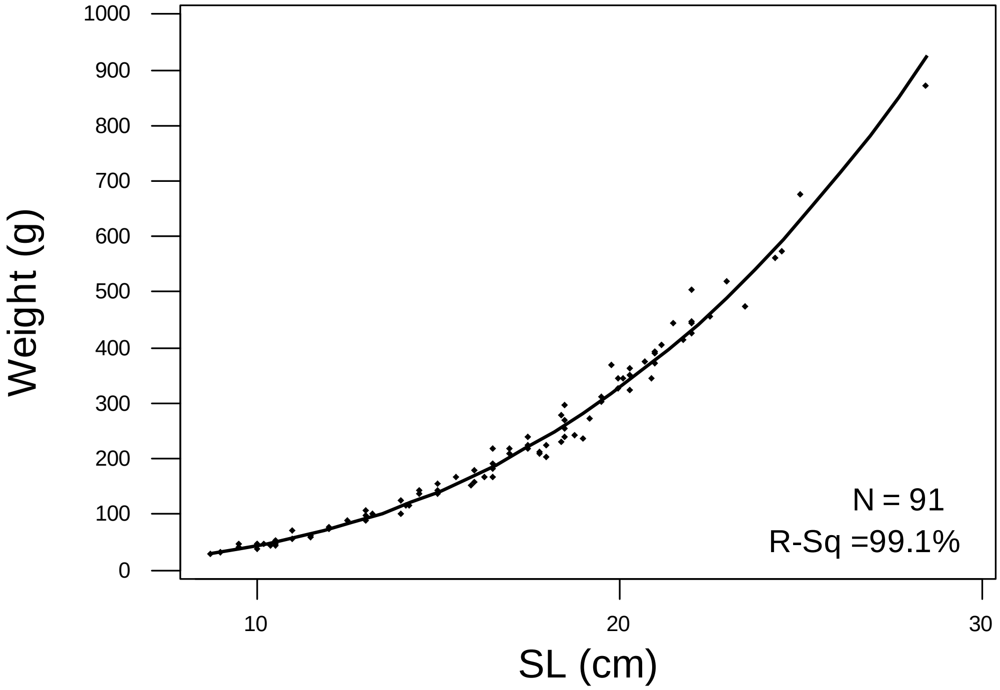

**Figure 7: Chlorurus spilurus length-weight regression.**

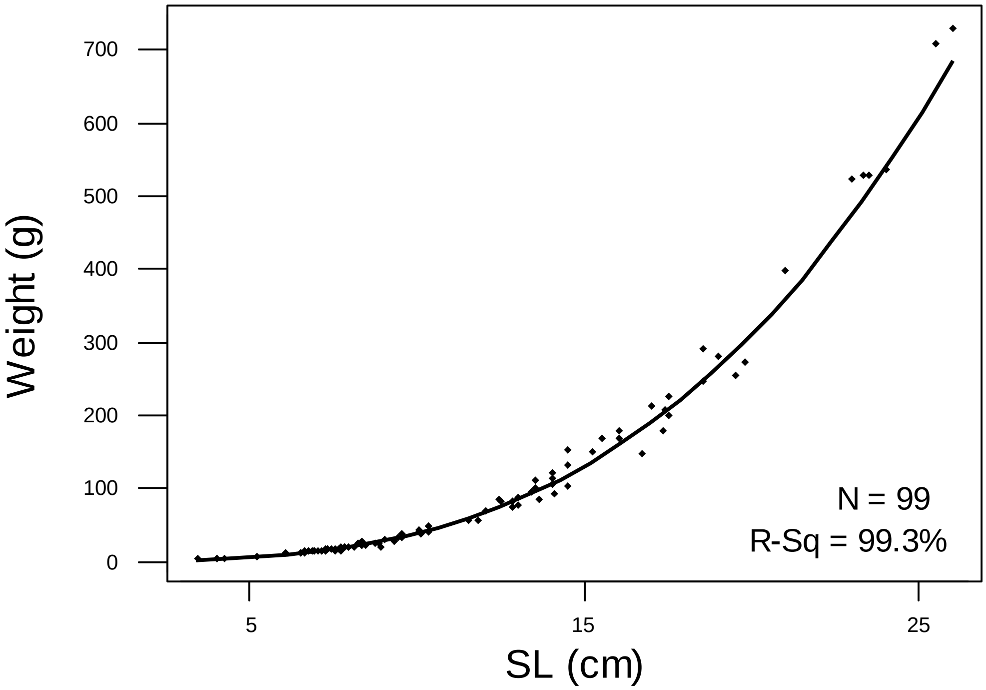

**Figure 8: Scarus psittacus length-weight regression.**

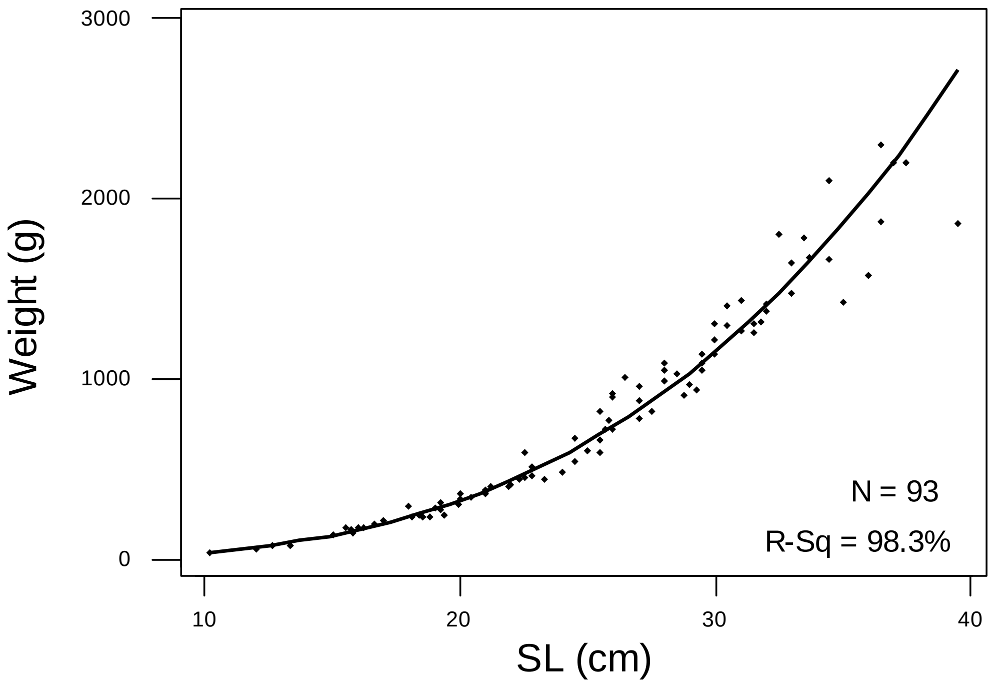

**Figure 9: Calotomus carolinus length-weight regression.**

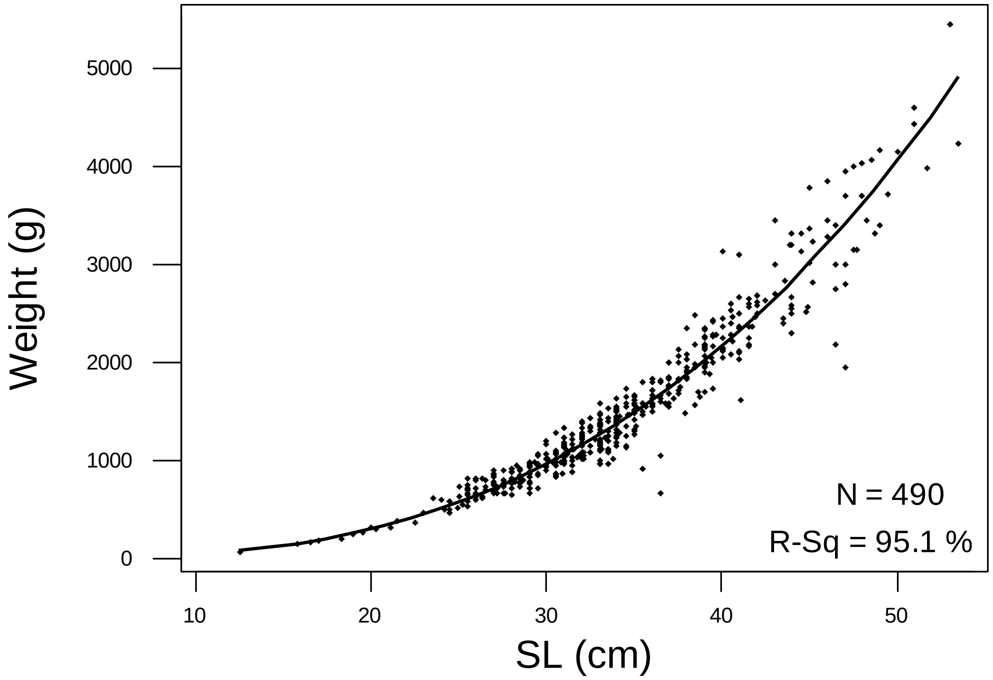

**Figure 10: Scarus rubroviolaceus length-weight regression.**

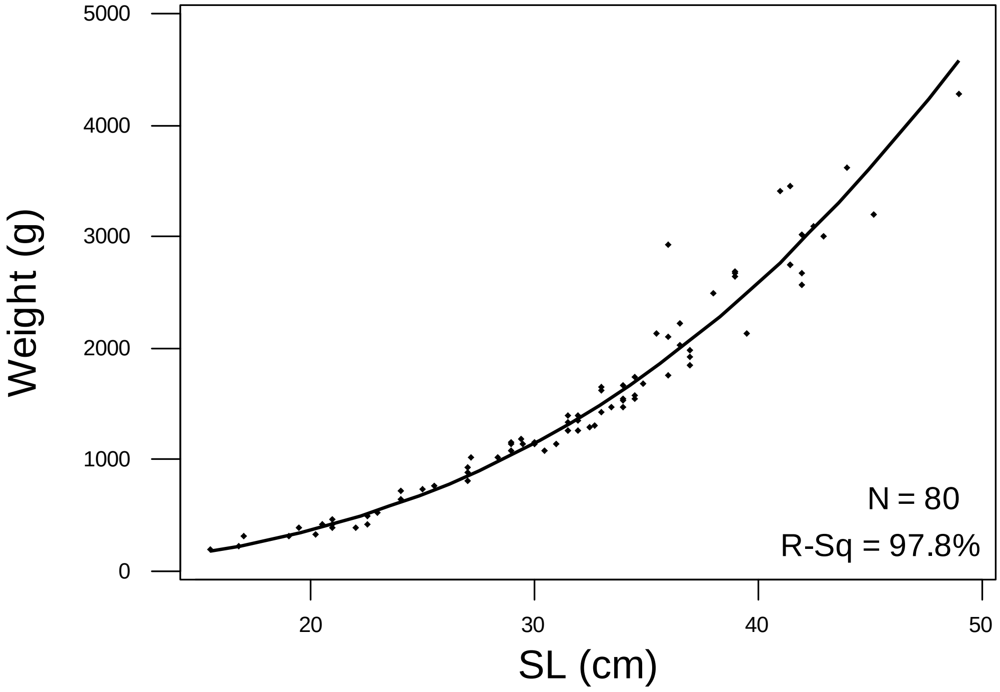

**Figure 11: Chlorurus perspicillatus length-weight relationship.**

**Table 5: Length-length relationships obtained for the five main species encountered in this study.**

| Species | Sample Size | FL-TL Regression Equation | SL-TL Regression Equation | SL-FL Regression Equation |
|---|---|---|---|---|
| *Scarus rubroviolaceus* | 487 | FL (cm) = 0.911 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.772 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.848 FL (cm)<br>$p << 0.001$ |
| *Scarus psittacus* | 99 | FL (cm) = 0.957 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.784 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.819 FL (cm)<br>$p<<0.001$ |
| *Chlorurus spilurus* | 91 | N/a | SL (cm) = 0.820 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.821 FL (cm)<br>$p<<0.001$ |
| *Chlorurus perspicillatus* | 80 | N/a | SL (cm) = 0.800 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.816 FL (cm)<br>$p<<0.001$ |
| *Calotomus carolinus* | 93 | FL (cm) = 0.945 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.790 TL (cm)<br>$p << 0.001$ | SL (cm) = 0.836 FL (cm)<br>$p<<0.001$ |

### *Reproduction*

As sequential hermaphrodites, social structure and reproductive strategy are important to the life history of scarids. The proportion of initial phase males provides some indication of the degree to which alternative reproductive strategies are being employed in the population. The following are the percentages of initial phase fish that are actually male individuals: S. rubroviolaceus – 18.3%, S. psittacus – 28.6%, C. spilurus – 6.7%, C. perspicillatus – 4%, C. carolinus – 3.4%. The proportion of individuals in the initial phase that are male is quite variable among species; for the first three species, it is considerably higher than the estimates of 4-12.9% for C. spilurus in the Great Barrier Reef. In the Great Barrier Reef study, higher percentages were associated with higher mortality rates (Gust 2004). Using the GSI, we predict the spawning seasonality for scarids to peak April – July, with some species having a second, smaller peak around November (Figures 12-16). The following plots include only individuals that are presumed to be large enough to be reproductively mature, based on reference information from FishBase as well as the preliminary data using GSI and length in this study.

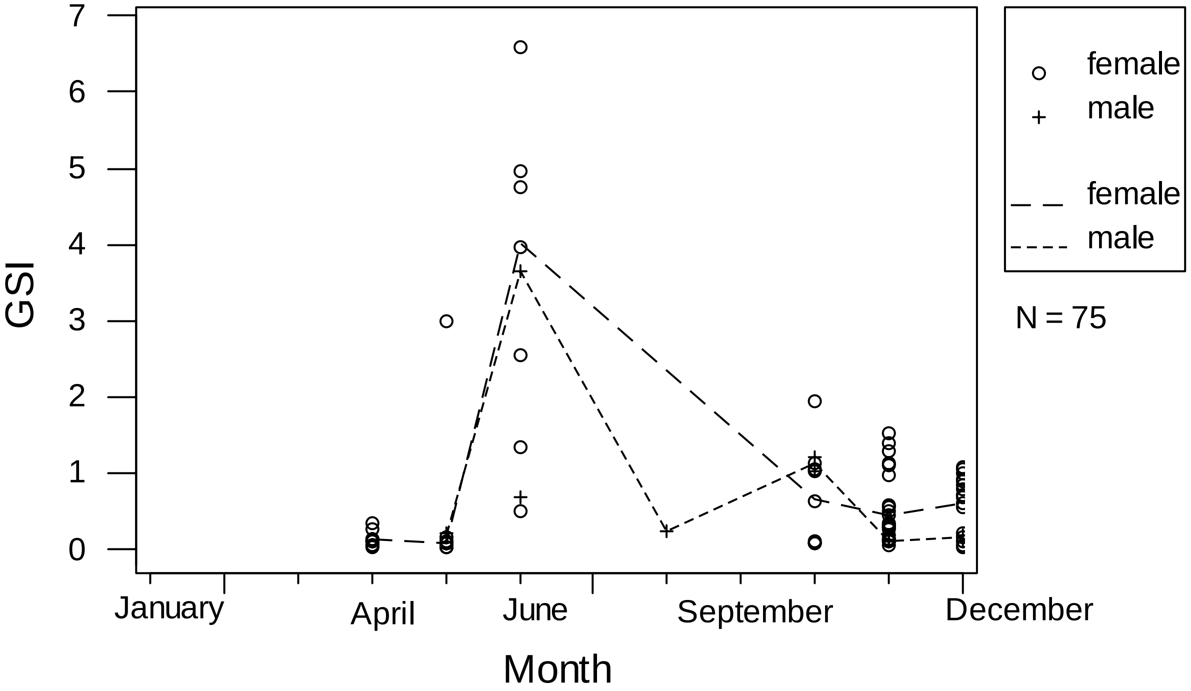

Figure 12: Chlorurus spilurus spawning seasonality.

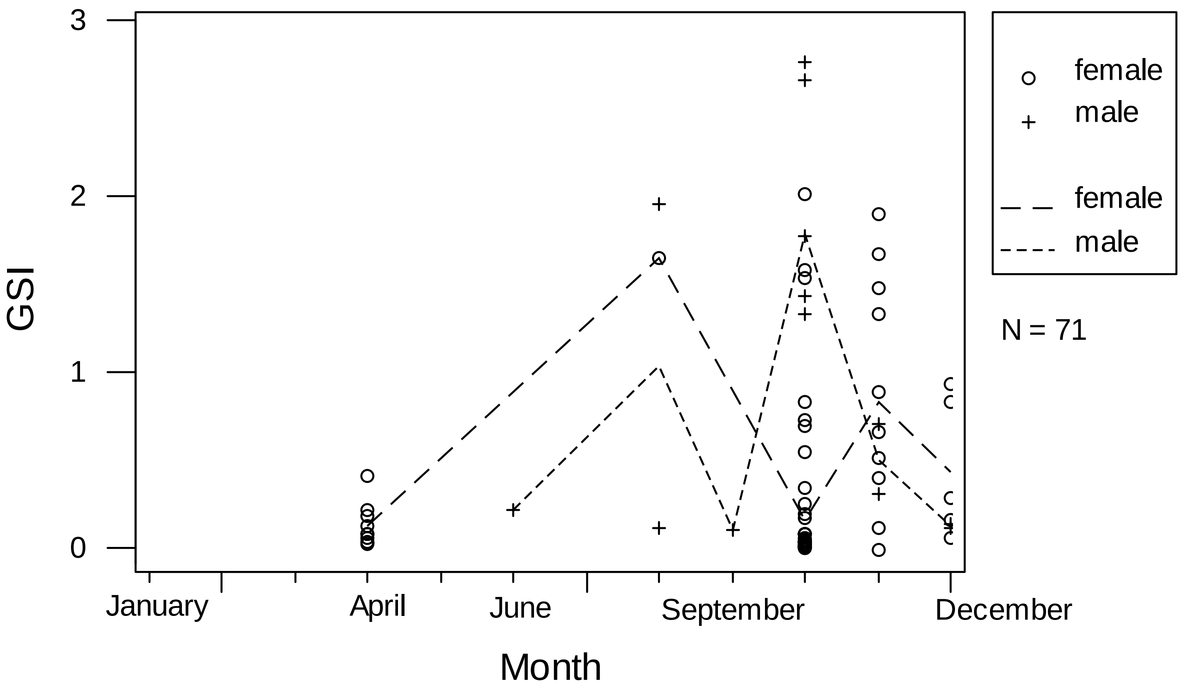

**Figure 13: Scarus psittacus spawning seasonality.**

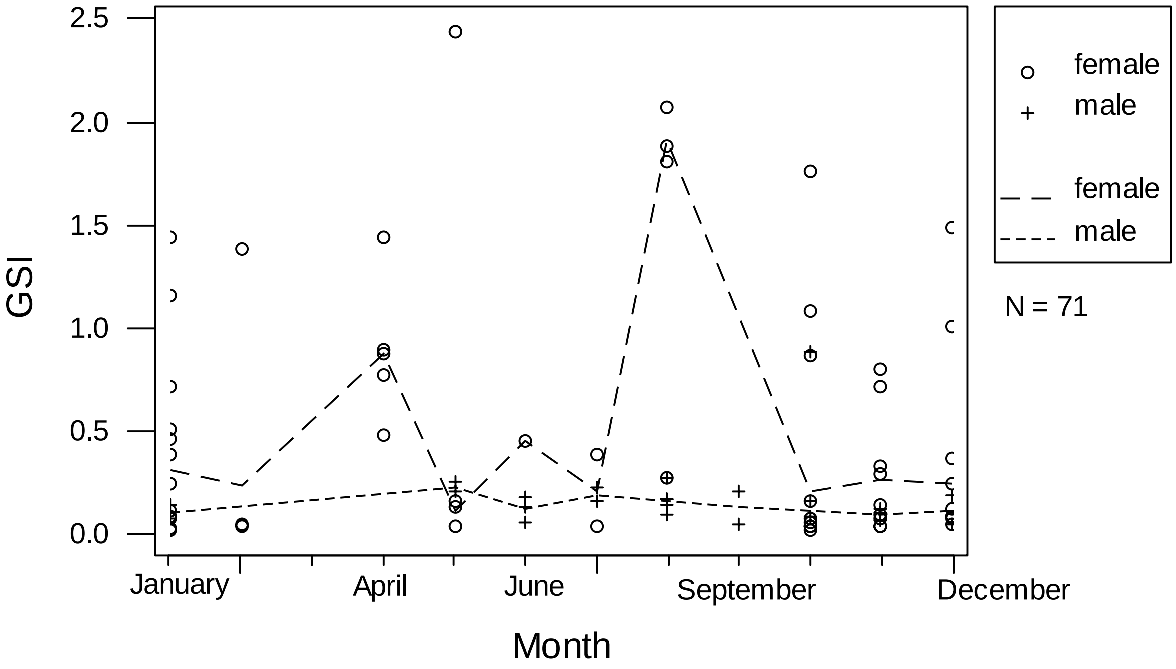

**Figure 14: Calotomus carolinus spawning seasonality.**

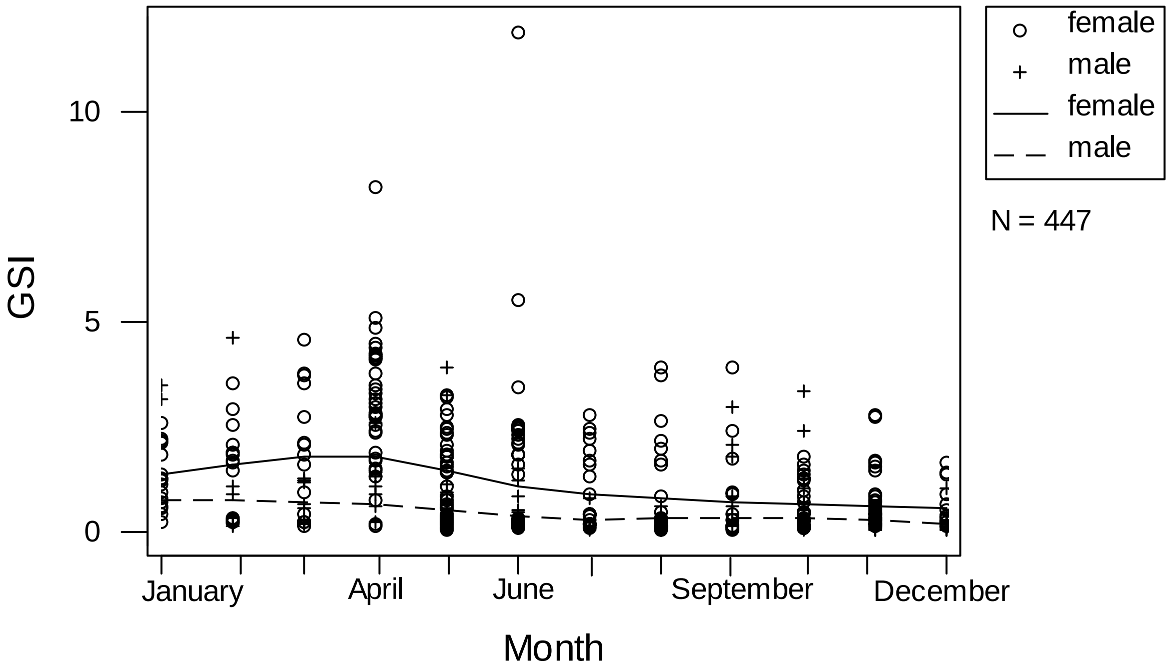

**Figure 15: Scarus rubroviolaceus spawning seasonality.**

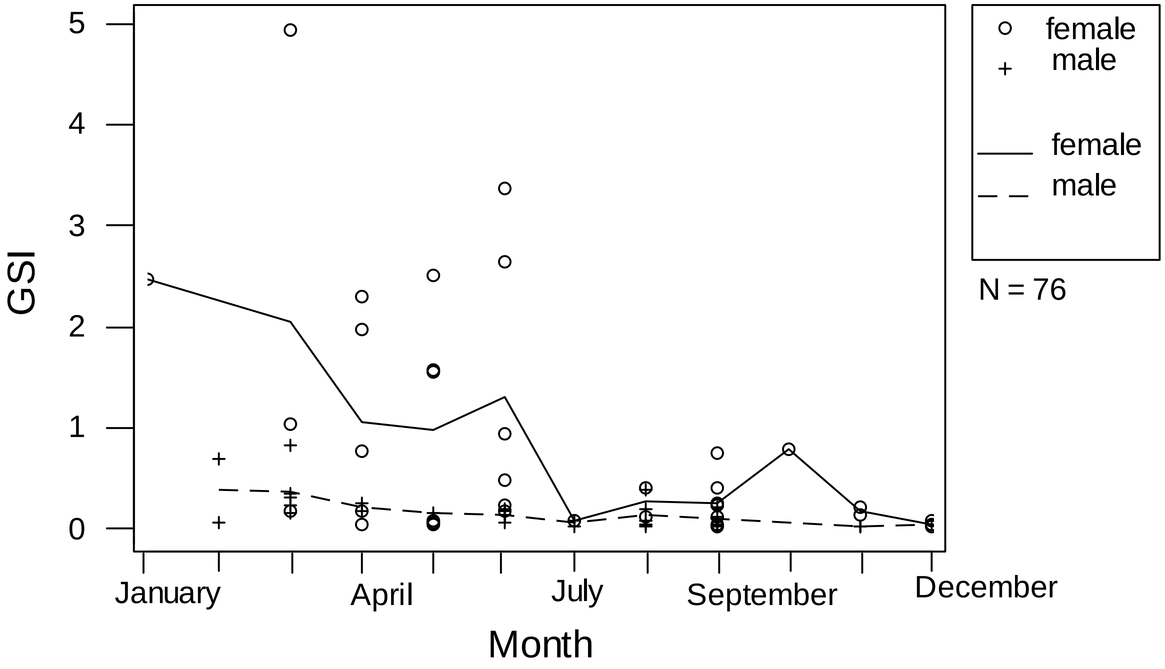

**Figure 16: Chlorurus perspicillatus spawning seasonality.**

The relationship between reproductive investment (in terms of GSI) and length of fish is shown in Figures 17-21. Since our sample size for Scarus rubroviolaceus was large, and spawning seasonality is most clearly defined for this species, we only compared individuals of different sizes during the peak spawning months of April through July.

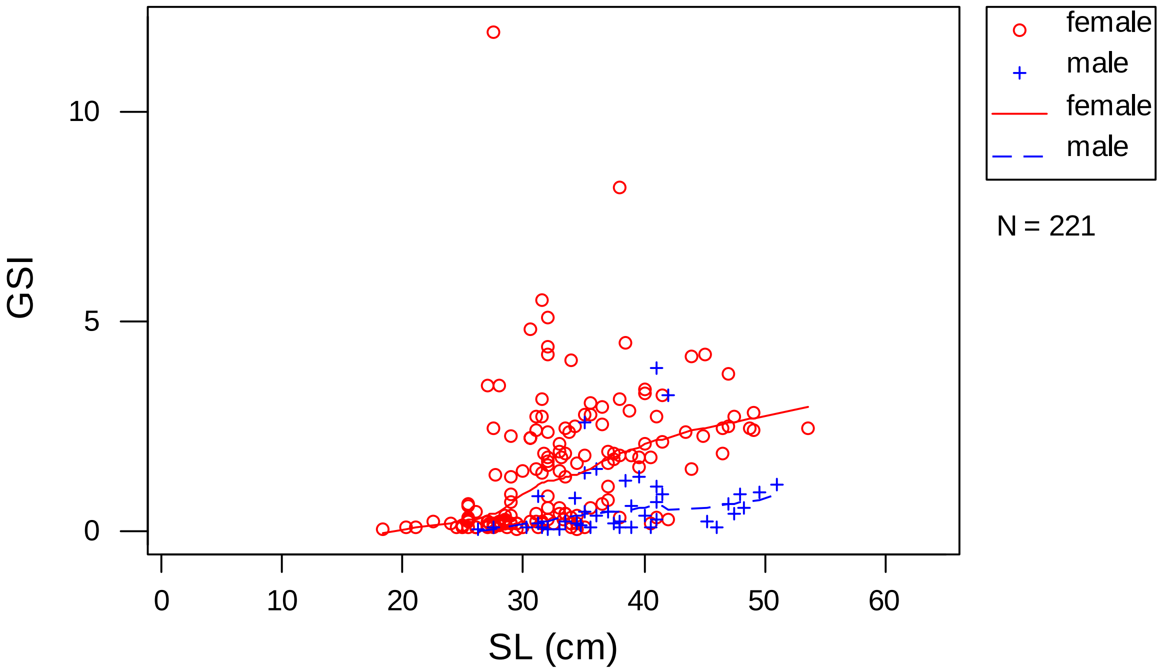

**Figure 17: GSI and length relationship of Scarus rubroviolaceus.**

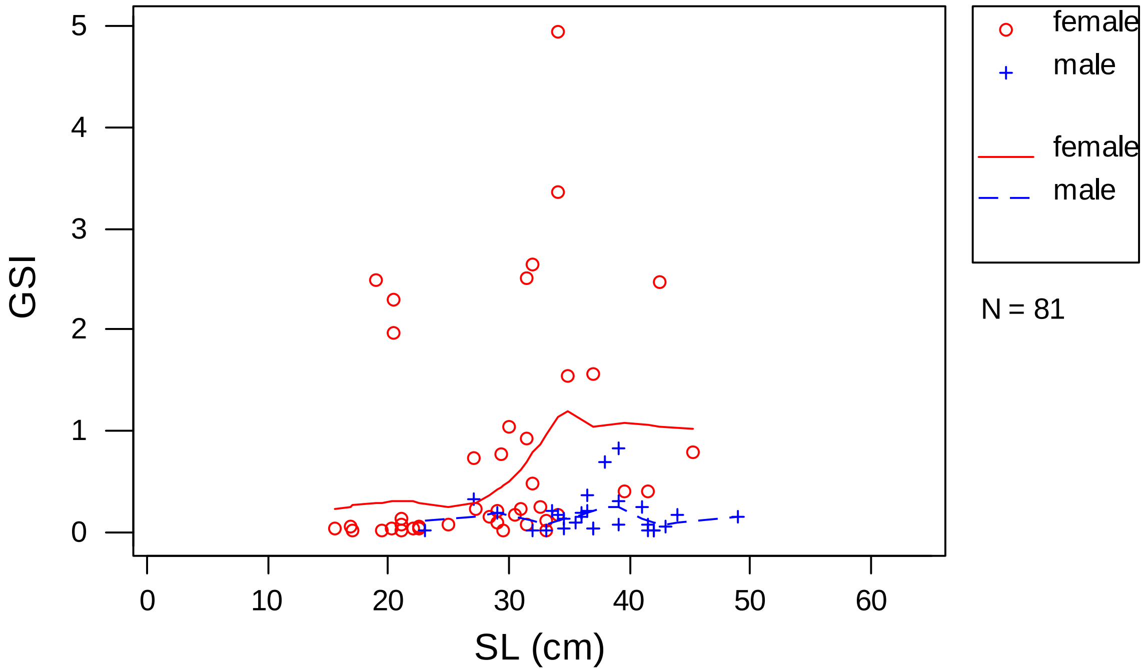

**Figure 18: GSI and length relationship of Chlorurus perspicillatus.**

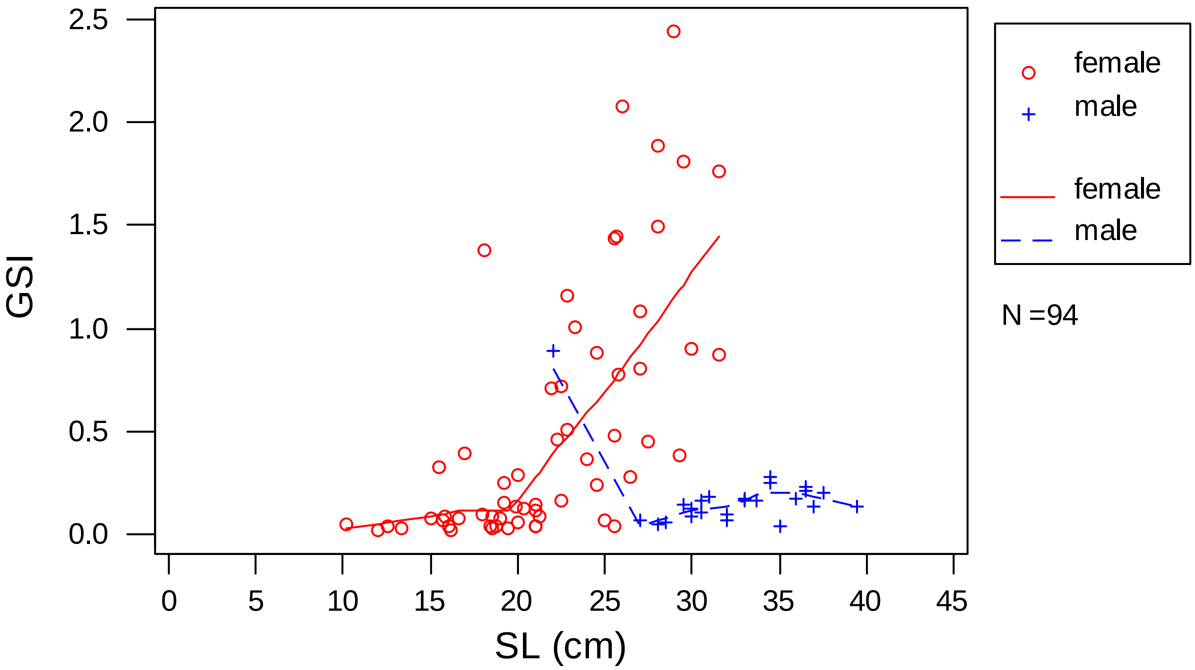

**Figure 19: GSI and length relationship of Calotomus carolinus.**

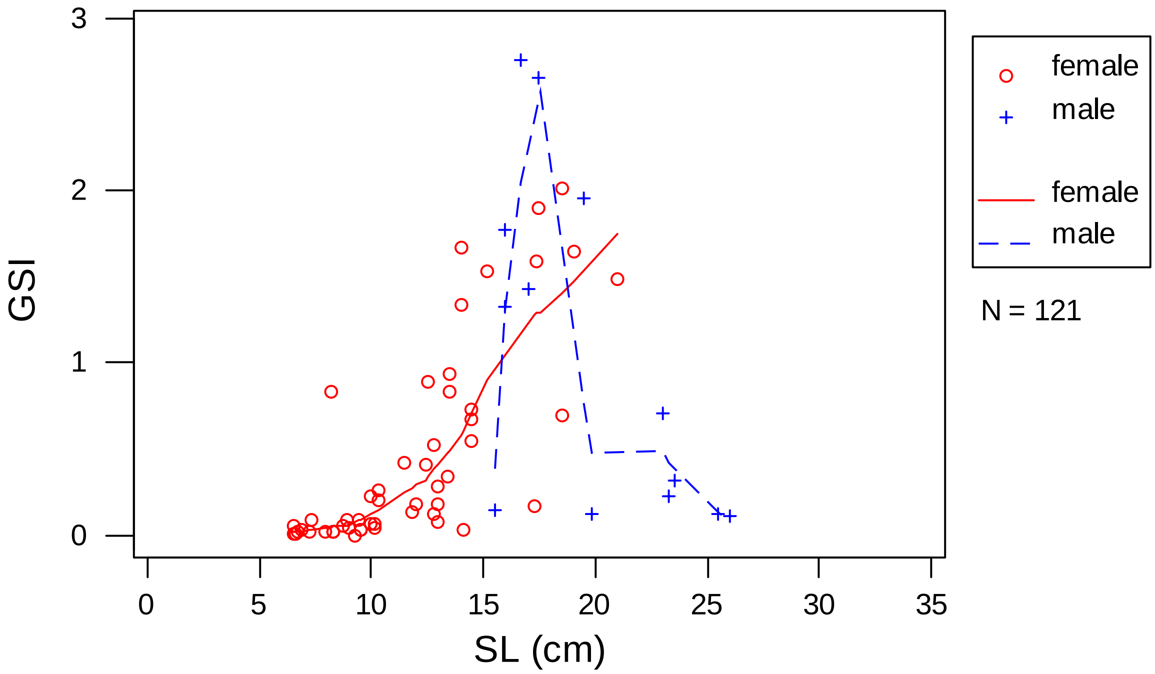

**Figure 20: GSI and length relationship of Scarus psittacus.**

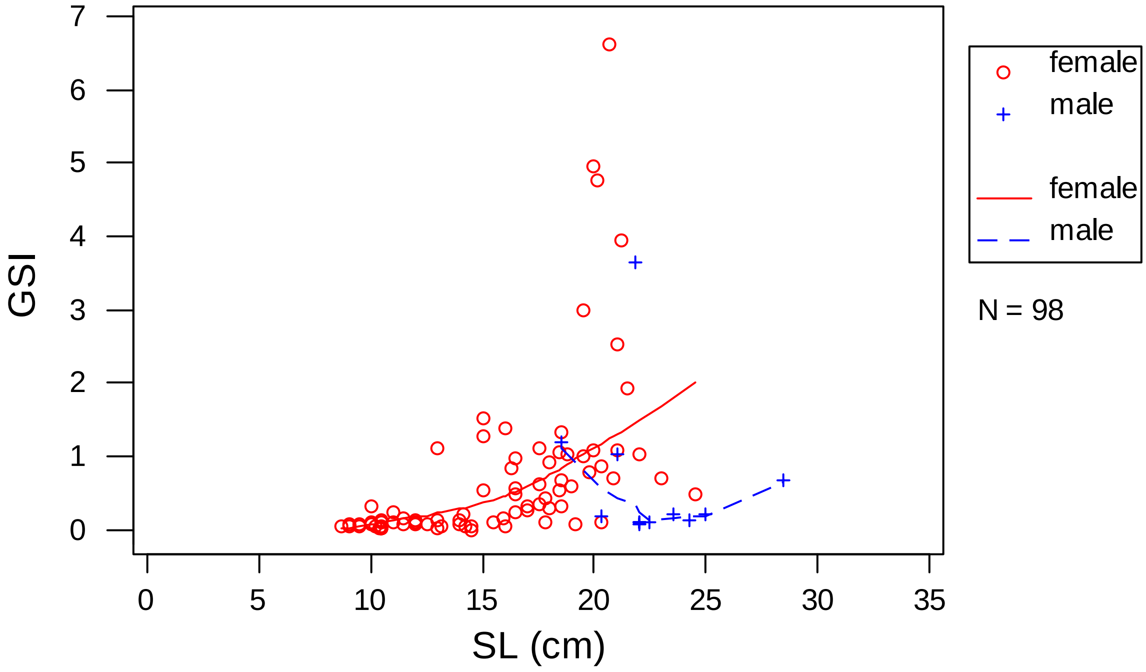

**Figure 21: GSI and length relationship of Chlorurus spilurus.**

## *Age and Growth*

With time and labor constraints, and the vast number of otoliths collected in this study, we can only present here some of the data on age and growth at this time. While some otoliths have been processed and read for the five target species of this study, our efforts have been focused on the age and growth of Scarus rubroviolaceus and on validating ring increments for scarids in Hawaii. Figure 22 illustrates some of these data.

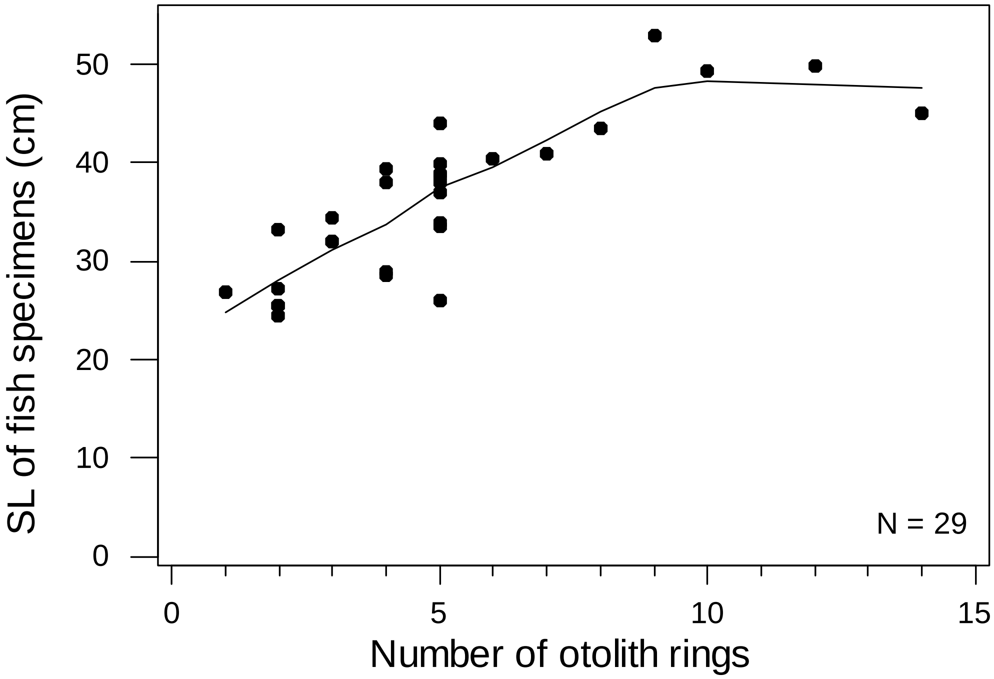

**Figure 22: Preliminary associations of the number of otolith rings with standard length of Scarus rubroviolaceus.**

### *Age Validation*

Growth of fish in tanks was variable. Over the period of captivity, Scarus psittacus individuals showed a small but significant increase in both length and weight (mean growth of 2.79 cm and 18.23 g) in 2-sample t-tests. Chlorurus spilurus did not show a significant change in either length or weight during the rearing period. For both species, otoliths contained a tetracycline mark near the outer edge of the otolith, followed by an opaque ring, and then a translucent area. This implies that the otolith rings are forming on an annual basis and permits important age data such as that on the x-axis in figure 22 to be expressed in years.

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# CONCLUSIONS

## 1. Distribution, Density and Habitat Associations

This project has provided a descriptive account of scarid communities around Oahu. What appears to be one of the most important trends is that scarids are patchily distributed. This patchiness prevents much detailed analysis at this scale, but coarse scale habitat associations with coral-colonized hard bottom are obvious. Another trend worth noting is the frequent absence of scarids from our surveys. It is difficult to determine whether this absence is due purely to low densities of fish present, or if it can be partially explained by skittish behavior in the presence of divers. While conducting other scarid research on the Big Island, scarids appeared to be much less disturbed by diver presence than on Oahu surveys.

## 2. Life History, Species Biology and Reproductive Studies

In this report we have presented valuable life history, reproductive and basic biological data that can be used in fishery management. The fish collected in this study, however, are primarily from Oahu and may not fully represent parrotfish populations as a whole, since stocks on Oahu are under heavier fishing pressures than elsewhere in Hawaii.

Scarids appear to be reproductively active throughout the year with a peak spawning period in late spring/early summer and, for some species, a second smaller peak in late fall/early winter. The gonadosomatic index (GSI) provides a rough estimate of when these species are maturing. It is interesting that in the smaller species, such as Scarus psittacus and Chlorurus spilurus, there are small males with relatively large GSI. This is probably characteristic of these sequential hermaphrodites. These males may represent either group spawning individuals or “sneaker” males, both of which have a reproductive strategy of investing their energy into producing large testes and large quantities of sperm rather than into growth. These characteristics allow them to produce significantly more sperm than the territorial males, giving them a reproductive advantage when competing with either territorial males or other small males.

Ageing scarids does not produce results as easily or clearly as in many temperate fishes, or even in other taxa of tropical reef fishes. However, otolith ageing procedures can produce useful results, and we have been able to acquire ages for some individuals of the five main species studied.

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