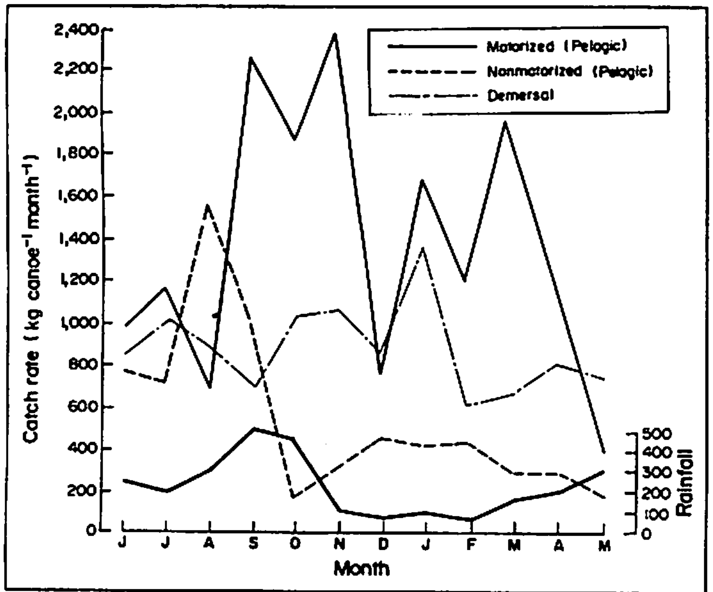


**Fig. 2.** *Comparisons of catch rates for pelagic motorized, nonmotorized and demersal fisheries with total monthly rainfall (mm), June 1990 - May 1991.*

of the pelagic fishing canoes should also be encouraged. The earnings of the fishers (20% of net revenue) gives values of US$284 for motorized pelagic fishing, US$108 for nonmotorized pelagic fishing and US$367 per month, respectively, for demersal motorized fishing. These figures underline the advantages of motorization.

**Acknowledgements**

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# Growth and Mortality of *Ctenochaetus striatus*, *Stegastes nigricans* and *Sargocentron microstoma* in Tiahura Reef, Moorea Island, French Polynesia

J.E. ARIAS-GONZÁLEZ, R. GALZIN and F. TORRES, JR.

## Abstract

Growth parameters and mortality rates were estimated from length-frequency data sampled in 1982, using the FiSAT software, for three coral reef fish species, the surgeonfish (*Ctenochaetus striatus*), the damselfish (*Stegastes nigricans*) and the squirrel fish (*Sargocentron microstoma*) in Tiahura Reef, Moorea Island, French Polynesia.

## Introduction

Moorea island is situated 25 km northwest of Tahiti, French Polynesia, at latitude 17°30' South and longitude 149°50' West. It belongs to the Windward islands (eastern group) of the Society archipelago (Fig. 1).

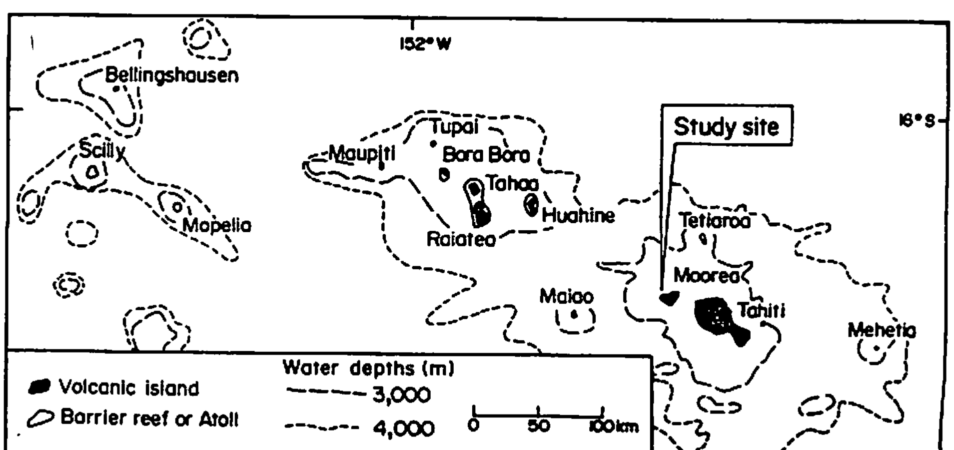


**Fig. 1.** *Location map of Society Archipelago, showing the location of the study site.*

Tiahura is located in the northwest part of Moorea, bounded by Tepee Point in the east and Tehau Point in the west (Galzin and Pointer 1985).

The surgeonfish (*Ctenochaetus striatus*), locally known as *maito*, the damselfish (*Stegastes nigricans*) or *atoti*, and the squirrelfish (*Sargocentron microstoma*) or *araoe*, are the most common species of the reef flat of Moorea island (Galzin 1987).

*Maito* occurs over coral or rubble substrates of reef flat, and feeds on the surface film of bluegreen algae and diatoms. It is a key link in the ciguatera food chain and is one of the few herbivorous fishes which is occasionally toxic (Myers 1991).

*Atoti* is extremely abundant in fringing reefs, where it hides in crevices and holes and pugnaciously holds to its territory (Allen 1975). Its favorite habitats consist of dead coral colonized by filamentous algae, which forms the bulk of its diet, with annelids and crustaceans constituting the remainder.

*Araoe* occurs in virtually all coral reef zones (Myers 1991) and is the most abundant of the large nocturnally active fishes in the lagoon. It feeds on crustaceans, mainly brachyuran crabs, which represent by far the most important item of its diet.

The biology and ecology, including growth, of these three species has been studied by Galzin (1985); the present account is to revise the growth parameters presented therein.

## Materials and Methods

The length-frequency data used here were sampled from January to December 1982 (Table 1A, B and C).

The ELEFAN I program as incorporated in the FiSAT software (Gayanilo et al., in press) was used to fit growth curves to the restructured length-frequency data, based on preliminary estimates of $L_\infty$

**Table 1. Length-frequency (total length) data of *Ctenochaetus striatus*, *Stegates nigricans* and *Sargocentron microstoma* caught in 1982 by rotenone sampling at Moorea, French Polynesia.**

A. *Ctenochaetus striatus*

| Mid-length (cm) | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | - | 4 | - | - | - | - | - | - | - | - | - | 2 |
| 5 | - | 5 | 1 | 4 | - | - | - | - | - | - | - | 2 |
| 6 | - | 0 | 0 | 6 | 2 | - | - | 1 | - | - | - | 0 |
| 7 | - | 2 | 0 | 2 | 0 | - | - | 3 | 1 | - | - | 0 |
| 8 | - | 15 | 0 | 0 | 1 | - | - | 3 | 4 | - | - | 0 |
| 9 | - | 14 | 3 | 7 | 1 | 1 | 1 | 0 | 5 | - | - | 0 |
| 10 | - | 14 | 5 | 14 | 7 | 2 | 3 | 5 | 7 | 2 | 1 | 0 |
| 11 | - | 4 | 3 | 19 | 1 | 1 | 7 | 2 | 8 | 2 | 3 | 0 |
| 12 | 2 | 4 | 2 | 8 | 1 | 0 | 3 | 5 | 7 | 1 | 3 | 0 |
| 13 | 5 | 11 | 2 | 6 | 5 | 3 | 4 | 8 | 4 | 3 | 2 | 3 |
| 14 | 11 | 5 | 5 | 9 | 8 | 3 | 6 | 13 | 2 | 12 | 8 | 12 |
| 15 | 16 | 17 | 7 | 6 | 7 | 7 | 5 | 10 | 4 | 7 | 7 | 14 |
| 16 | 18 | 23 | 6 | 8 | 3 | 3 | 6 | 5 | 1 | 10 | 8 | 12 |
| 17 | 4 | 25 | 16 | 2 | 2 | 7 | 2 | 4 | 0 | 6 | 6 | 4 |
| 18 | 8 | 15 | 16 | 16 | 6 | 16 | 4 | 14 | 6 | 6 | 1 | 3 |
| 19 | 8 | 7 | 12 | 33 | 11 | 19 | 9 | 19 | 8 | 20 | 9 | 1 |
| 20 | 3 | 5 | 9 | 18 | 5 | 5 | 5 | 25 | 26 | 14 | 5 | - |
| 21 | 0 | 3 | 3 | 14 | 6 | 7 | 4 | 11 | 14 | 13 | 5 | - |
| 22 | 3 | - | 5 | 14 | 6 | 7 | 4 | 7 | 8 | 11 | 8 | - |
| 23 | 5 | - | - | 3 | 1 | 2 | 3 | 2 | 7 | 6 | 2 | - |
| 24 | - | - | - | - | - | - | - | - | 3 | - | - | - |

B. *Stegastes nigricans*

| Mid-length (cm) | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.2 | - | 1 | 9 | - | 7 | - | - | 1 | - | - | 3 | - |
| 1.8 | - | 7 | 24 | 1 | 15 | 94 | 77 | 70 | 42 | 10 | 13 | - |
| 2.4 | - | 12 | 20 | 2 | 12 | 10 | 6 | 24 | 42 | 23 | 5 | - |
| 3.0 | - | 16 | 20 | 2 | 12 | 10 | 15 | 24 | 40 | 10 | 9 | - |
| 3.6 | - | 20 | 19 | 4 | 8 | 17 | 22 | 28 | 36 | 8 | 11 | - |
| 4.2 | - | 8 | 14 | 9 | 5 | 8 | 18 | 30 | 30 | 9 | 11 | - |
| 4.8 | - | 12 | 10 | 3 | 5 | 12 | 10 | 12 | 22 | 2 | 7 | - |
| 5.4 | - | 6 | 2 | 4 | 3 | 12 | 14 | 16 | 30 | 4 | 6 | - |
| 6.0 | - | 4 | 4 | 7 | 6 | 6 | 6 | 14 | 20 | 3 | 2 | - |
| 6.6 | - | 1 | 1 | 4 | 5 | 6 | 7 | 9 | 19 | 0 | 1 | - |
| 7.2 | - | 4 | 1 | 5 | 7 | 12 | 5 | 12 | 20 | 0 | 3 | - |
| 7.8 | - | 3 | 3 | 3 | 7 | 5 | 5 | 10 | 18 | 0 | 1 | - |
| 8.4 | - | 2 | 2 | 3 | 5 | 5 | 7 | 5 | 20 | 3 | 3 | - |
| 9.0 | - | 1 | 3 | 4 | 1 | 5 | 7 | 8 | 18 | 1 | 5 | - |
| 9.6 | - | 5 | 5 | 1 | 2 | 7 | 18 | 22 | 26 | 1 | 4 | - |
| 10.2 | - | 6 | 6 | 4 | 3 | 9 | 10 | 29 | 32 | 2 | 5 | - |
| 10.8 | - | 13 | 4 | 5 | 1 | 6 | 11 | 22 | 38 | 6 | 10 | - |
| 11.4 | - | 16 | 4 | 11 | 1 | 6 | 26 | 55 | 60 | 6 | 11 | - |
| 12.0 | - | 15 | 10 | 7 | 8 | 20 | 37 | 72 | 106 | 21 | 11 | - |
| 12.6 | - | 13 | 21 | 12 | 12 | 24 | 44 | 78 | 108 | 17 | 16 | - |
| 13.2 | - | 16 | 15 | 7 | 6 | 17 | 51 | 50 | 88 | 12 | 14 | - |
| 13.8 | - | 15 | 16 | 6 | 7 | 10 | 43 | 29 | 34 | 7 | 7 | - |
| 14.4 | - | 11 | 4 | 3 | 1 | 2 | 13 | 8 | 4 | 2 | - | - |
| 15.0 | - | 3 | - | 4 | - | 2 | 7 | 2 | 2 | - | - | - |
| 15.6 | - | - | - | 1 | - | - | 2 | - | 2 | - | - | - |

C. *Sargocentron microstoma*

| Mid-length (cm) | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | - | 1 | 3 | 2 | 1 | - | - | - | - | - | - | - |
| 7 | - | 2 | 1 | 5 | 2 | 2 | - | 3 | 2 | - | - | - |
| 8 | - | 0 | 1 | 0 | 1 | 2 | 5 | 1 | 2 | - | - | - |
| 9 | - | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | - | - | - |
| 10 | - | 1 | 0 | 0 | 1 | 1 | 1 | 3 | 0 | - | 1 | - |
| 11 | 1 | 1 | 0 | 3 | 1 | 2 | 0 | 1 | 1 | - | 1 | 1 |
| 12 | 0 | 4 | 0 | 8 | 2 | 1 | 1 | 0 | 2 | - | 0 | 0 |
| 13 | 4 | 2 | 0 | 5 | 10 | 3 | 1 | 6 | 5 | 1 | 1 | 1 |
| 14 | 5 | 3 | 1 | 7 | 8 | 3 | 4 | 6 | 3 | 0 | 1 | 3 |
| 15 | 7 | 3 | 1 | 10 | 15 | 9 | 2 | 11 | 10 | 5 | 6 | 3 |
| 16 | 6 | 1 | 1 | 14 | 6 | 3 | 3 | 4 | 11 | 10 | 4 | 1 |
| 17 | 1 | - | - | 6 | 1 | 1 | - | 3 | 1 | 2 | 3 | 1 |
| 18 | - | - | - | - | - | 1 | - | 1 | 2 | - | - | - |

obtained using the method of Wetherall (1986) also incorporated in FiSAT, while the value of K was obtained by using a new routine of ELEFAN I, wherein for a fixed value of $L_\infty$, values of K ranging from 0.1 to 10.0 are scanned in small steps, and the value of K selected is that associated with the highest value of the goodness of fit index. In one case where this routine did not show a clear peak, the method of Shepherd (1987) was used, as also incorporated in the FiSAT software.

Natural mortality (M) was estimated from Pauly's empirical formula:

$$\log_{10}M=-0.0066-0.279\log_{10}L_\infty+0.6543\log_{10}K+0.4634\log_{10}T$$

where $L_\infty$ is the asymptotic size (total length, in cm), K is expressed on an annual basis and T is the mean environmental temperature (Pauly 1980), taken as 28.7°C (Delesalle 1990).

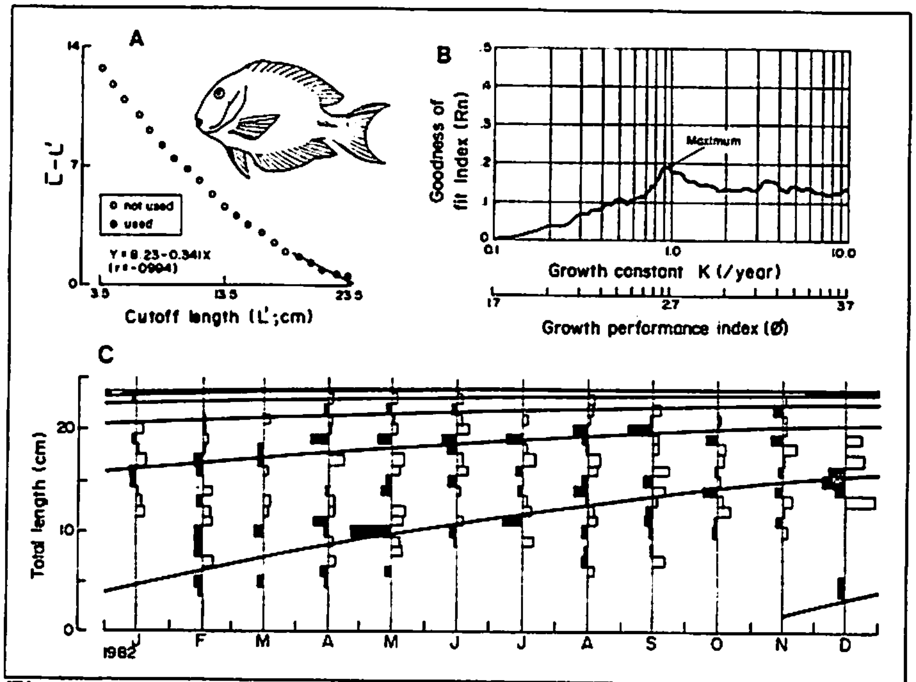


**Fig. 2.** *Summary of results for* Ctenochaetus striatus; *A) Wetherall plot leading to $L_\infty$ = 24.1 cm; B) Scan of K values using ELEFAN I showing location of "best" estimate of K = 0.9·year$^{-1}$ (see φ' scale below); C) Restructured L/F data (from Table 1A), with superimposed growth curve.*

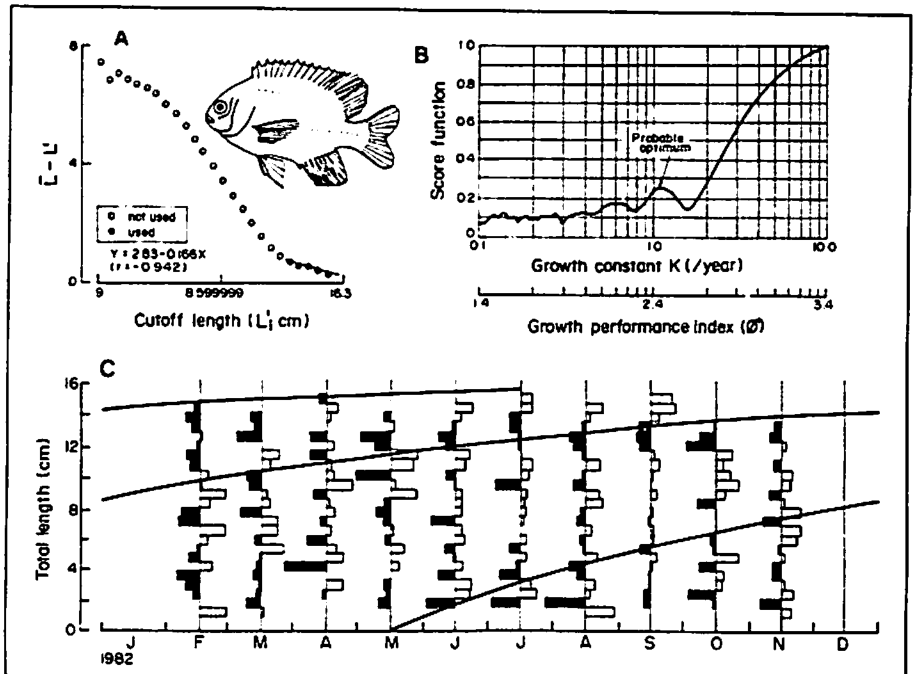


**Fig. 3.** *Summary of results for* Stegastes nigricans; *A) Wetherall plot leading to $L_\infty$ = 17.1 cm; B) Scan of K values using Shepherd's method (as incorporated in the FiSAT software) showing location of "best" estimate of K = 1.1·year$^{-1}$ (see φ' scale below); C) Restructured L/F data (from Table 1B), with superimposed growth curve.*

## Results and Discussion

The Wetherall plot for *C. striatus* (Fig. 2A) provides estimates of $L_\infty$ = 24.1 cm and Z/K = 1.9·year$^{-1}$. The corresponding estimate of K = 0.9·year$^{-1}$ (Fig. 2B) and the growth curve superimposed on the restructured length-frequency data is shown in Fig. 2C. Natural mortality is estimated at 1.8·year$^{-1}$.

The estimates derived from the Wetherall plot for *S. nigricans* are $L_\infty$ = 17.1 cm and Z/K = 5.0 (Fig. 3A). The corresponding estimate of K = 1.1·year$^{-1}$ (Fig. 3B). The growth curve superimposed on the restructured length-frequency data is shown in Fig. 3C. Natural mortality is estimated at 2.25·year$^{-1}$.

For *S. microstoma*, the Wetherall plot gives $L_\infty$ = 18.6 cm and Z/K= 2.6 (Fig. 4A) and the corresponding value of K = 1.0·year$^{-1}$ (Fig. 4B); the growth curve superimposed on the restructured length-frequency data is shown in Fig. 4C. Natural mortality is estimated at 2.1·year$^{-1}$.

The available data were difficult to interpret due to lack of clear progression of modes. Previous growth parameter estimates for the three species studied here are not available from the literature, thus preventing comparisons with populations from other areas. Our estimates of $L_\infty$ are in reasonable agreement with maximum sizes reported from the literature (Table 2), while the K values appear to be on the high side, especially for *Ctenochaetus striatus* (Table 3).

Clearly, more studies on the growth of small coral reef fishes are warranted, given their importance near the base of the trophic web of coral reefs.

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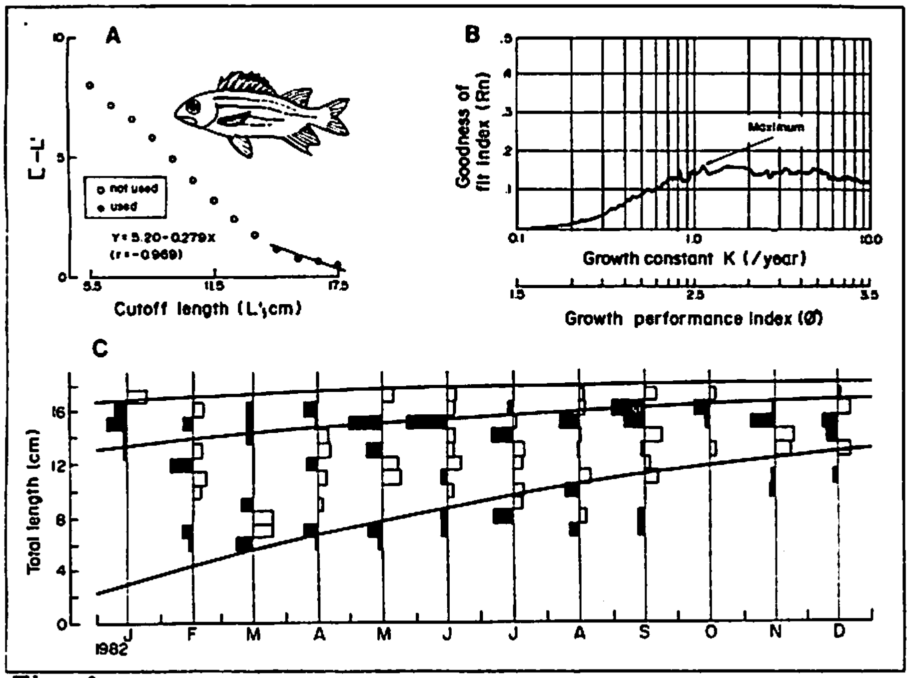


**Fig. 4.** *Summary of results for* Sargocentron microstoma*; A) Wetherall plot leading to* $L_\infty$ *= 18.6 cm; B) Scan of K values using ELEFAN I showing location of "best" estimate of K = 1.0·year*$^{-1}$ *(see* $\phi'$ *scale below); C) Restructured L/F data (from Table 1C), with superimposed growth curve.*

Table 2. Maximum reported lengths for the three coral reef fish species presented.

| | *Ctenochaetus striatus* | *Stegastes nigricans* | *Sargocentron microstoma* |
|---|---|---|---|
| Maximum length | 27.3[a,b] | 14.4[a,b] | 20.6[a,b] |
| (TL, cm) | 26.0[c] | 14.0[d] | 20.0[e] |
| | 20.3[f] | 14.3[a,g] | |
| $L_\infty$ (TL, cm) | 24.1[h] | 17.1[h] | 18.6[h] |

[a]values originally given as Standard Length
[b]from Myers (1991)
[c]from Randall (1986)
[d]from Allen (1986)
[e]from Randall and Heemstra (1986)
[f]from Bagnis et al. (1972)
[g]from Allen (1975)
[h]this study (see Table 1)

Table 3. Growth parameters for three families of reef fishes[a]

| | $L_\infty$ (TL, cm) | K (year$^{-1}$) | $\phi'$ |
|---|---|---|---|
| ACANTHURIDAE | | | |
| *Acanthurus gahm* | 31.9 | 0.40 | 2.61 |
| *A. coeruleus* | 36.9 | 0.11 | 2.29 |
| *A. chirurgus* | 31.6 | 0.14 | 2.25 |
| *A. bahianus* | 19.3 | 0.45 | 2.32 |
| *Ctenochaetus striatus*[b] | 24.1 | 0.87 | 2.70 |
| POMACENTRIDAE | | | |
| *Chromis ternatensis* | 8.0 | 4.02 | 2.41 |
| *C. ternatensis* | 9.0 | 2.09 | 2.23 |
| *Stegastes planifrons* | 15.5 | 0.58 | 2.14 |
| *S. planifrons* | 15.5 | 0.33 | 1.90 |
| *S. nigricans*[b] | 17.1 | 1.10 | 2.51 |
| HOLOCENTRIDAE | | | |
| *Holocentrus diadema* | 15.3 | 1.47 | 2.54 |
| *H. diadema* | 17.6 | 1.05 | 2.51 |
| *H. ascensionis* | 23.0 | 0.39 | 2.31 |
| *Sargocentron microstoma*[b] | 18.6 | 1.00 | 2.56 |

[a]from Munro and Williams (1985)
[b]this study


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