Gulf Research Reports

Volume 10 | Issue 1

January 1998

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DOI: 10.18785/grr.1001.01

Gulf Research Reports Vol. 10, 1-9, 1998

Manuscript received June 1997; accepted July 31, 1997

FEEDING OF SCIAENID (PISCES: SCIAENIDAE) LARVAE IN TWO COASTAL LAGOONS OF THE GULF OF MEXICO

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ABSTRACT Stomach contents analyses showed that *Leiostomus xanthurus* (8.50-12.90 mm SL) had a wide trophic spectrum (15 food categories) with copepods and eggs of invertebrates as main components. In contrast, *Micropogonias undulatus* (6.65-12.20 mm SL) ingested only six food categories (copepods, eggs of invertebrates, crustacean nauplii, barnacle nauplii, amphipods and other crustaceans). There is an overlap of 73.2 to 83.0% in the diet of these two species. *Bairdiella chrysoura* (1.17-1.92 mm SL) fed primarily on juvenile pelecypods, crustacean nauplii, eggs of invertebrates, including gasteropods and copepods. *Cynoscion nebulosus* (1.50-2.42 mm SL) ingested juvenile pelecypods, copepods, crustacean nauplii, eggs of invertebrates and tintinnids, variability in overlap (47.4 to 79.5%) between these species was affected by size of the larvae.

Introduction

Species of the family sciaenidae are abundant on sandy-muddy bottoms of shallow tropical and subtropical seas (Castro-Aguirre 1978). Most sciaenids spawn at sea and their larvae enter estuarine-lagoon systems which provide nursery habitat for postlarval and juvenile life stages (Chao and Musick 1977; Powles 1981; Shlossman and Chittenden 1981; Taniguchi 1981; Holt et al. 1981; Govoni et al. 1983; Cowan and Shaw 1988; Ditty et al. 1988; Hook 1991). *Cynoscion nebulosus*, *C. arenarius*, *C. regalis*, *Sciaenops ocellatus*, *Pogonias cromis*, *Micropogonias undulatus* and *Leiostomus xanthurus* support important commercial and recreational resources along the Atlantic coast of the United States and the northern coast of the Gulf of Mexico (Ditty 1989). Sciaenid fishes also constitute a fishery in the coastal lagoons of the southern Gulf of Mexico, with the two most important species being *Bairdiella chrysoura* and *C. nebulosus* (Reséndez-Medina 1970, 1973, 1981).

Studies of sciaenid larvae in the southern Gulf of Mexico have been conducted primarily in Laguna de Términos, Campeche and the adjacent coastal zone. Sánchez-Iturbe and Flores-Coto (1986) measured some population parameters of *B. chrysoura* larvae, and estimated the adult biomass using the annual production of eggs. Flores-Coto and Pérez-Argudín (1991) analyzed tidal effects on the passage of sciaenid larvae through Boca del Carmen in this lagoon, and Rivera-Elizalde (1988) studied the distribution and abundance of sciaenid larvae in the coastal zone of southern Gulf of Mexico.

Our study, which was conducted in Laguna de Tampamachoco, Veracruz and Laguna Madre, Tamaulipas, compared diet of sciaenid larvae and analyze dietary overlap. Little is known about the early life history of sciaenids in these two lagoons.

Study area

The Laguna Madre (Figure 1) is located in northern Tamaulipas, a Mexican state that borders Texas. The study area within this lagoon lies between the area affected by the Río San Fernando and the area between Boca de Catan and Punta Piedras. This lagoon, which is 41.5 km long and up to 14.3 km wide, has approximately nine other inlets, some of which are closed and some which are opened by dredging or by meteorological effects.

The Laguna de Tampamachoco (Figure 1) is located in northern Veracruz, a state that borders Tamaulipas. This lagoon, which is 11.0 km long and up to 1.3 km wide, is separated from the sea by the Barra Norte de Tuxpan. To the north, it has two water-links, one with Laguna de Tamiahua through a channel and another with the sea through Boca de Galindo, and to the south it is joined with the Río Tuxpan by a channel.

Materials and Methods

Zooplankton was sampled at nine stations in the Laguna de Tampamachoco during November 1987 and February, June and August 1988, and at eleven stations in the Laguna Madre during September and December 1989, and February and April 1990 (Figure 1). Samples were collected with a 505 µm mesh zooplankton net at both lagoons, additionally a 250 µm mesh net was also used in Laguna de Tampamachoco, in order to obtain a larger quantity of organisms. Both nets had a 50 cm diameter opening and were equipped with a flowmeter. Tows, which followed a circular track, were taken at the surface for a duration of 5 minutes. Samples were preserved in a 4% formaldehyde solution neutralized with sodium borate.

Measurements of larvae included standard length (SL), head length (HL), and length of both the upper and lower

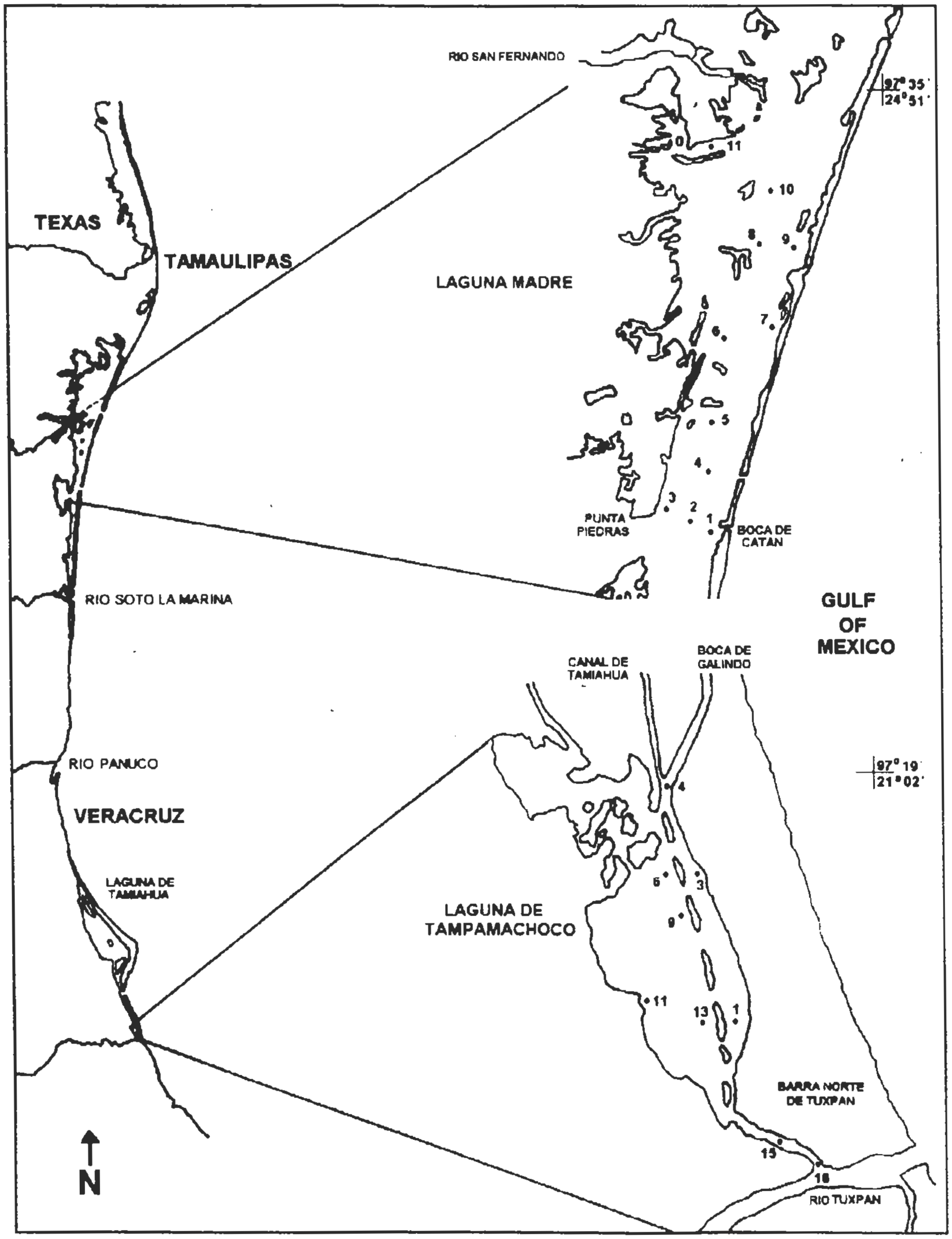

Figure 1. Study area and sampling stations. Laguna de Tampamachoco, Veracruz and Laguna Madre, Tamaulipas, Mexico.

jaws. The digestive tract was dissected and the contents were identified down to the lowest possible taxon using a wet chamber to obtain the number and type of prey ingested. Prey were measured for width. The index of relative importance (IRI) proposed by George and Hadley (1979) and modified by Towsend (1983) was calculated as follows:

$$IRI_a = \frac{100X_a}{\sum_{a=1}^{n} X_a}$$

where IRI_a = Index of relative importance for food item a, X_a = % frequency of occurrence + % total number for food item a, and n = total number of different food item found in the larvae from that sample.

The Schoener's index (1970) was used to evaluate diet overlap with values from 0 (no overlap) to 100 (total overlap):

$$a = 100\left[1\text{-}0.5 \sum_{i=1}^{n} /Px_i\text{-}Py_i/\right]$$

where a = Index of overlap, Px_i = proportion (percent by number) of food category i in the diet of species x, Py_i = proportion (percent by number) of food category i in the diet of species y, and n = the number of food categories.

The size of the mouth was measured using indices proposed by Shirota (1970) and Chao and Musick (1977) as follows:

$$D = \sqrt{2} \cdot AB$$

where D = mouth size (Shirota 1970), and AB = length of upper jaw.

$$RMS = \frac{uj \cdot lj}{h}$$

where RMS = relative mouth size (Chao and Musick 1977), uj = length of the upper jaw, lj = length of the lower jaw, and h = head length.

RESULTS AND DISCUSSION

Stomach contents of 35 *L. xanthurus* larvae from Laguna Madre were analyzed for larvae that measured from 8.50 to 12.20 mm SL. Larvae were collected between 1330 and 1410 hrs in December 1989 and at 1230 hrs in February 1990. *Leiostomus xanthurus* larvae fed on eleven different prey types. Copepods were the main diet component in December, and values of IRI ranged from 56.7 to 90.7% (Table 1). Sizes of copepods ingested ranged between 80 and 360 µm ($\bar{x}$ = 207; SD = 49) and between 60 and 320 µm ($\bar{x}$ = 148; SD = 55) in two different sample stations. The number of copepods per fish at this time of the year ranged from 14 to 27 (Table 2). This is lower than that reported by Kjelson et al. (1975) in the Newport River Estuary where larvae had 21.3 to 26.3 copepods/fish in their digestive tubes with a maximum of 36.5 copepods/fish at 1200 hrs. Kjelson et al. (1975) reported that this species had the highest food content in their digestive tracts during daylight hours, which has been observed in many marine fish larvae which are visual feeders (Hunter 1981). Copepods decreased in number in February (IRI=37.5%) (Table 1) to five copepods/fish and at the same time increased in size from 220 to 400 µm ($\bar{x}$=314; SD=50) (Table 2). The numerically dominant prey at this time of the year were non-identified eggs of invertebrates (46.2%) (Table 1).

Thirteen prey types were found in the stomach of 18 *L. xanthurus* larvae collected from Laguna de Tampamachoco in February 1988 at 1900 hrs. Larvae ranged in length from 9.10 to 12.90 mm SL and fed primarily upon copepods (IRI = 29.9%). The second most abundant prey items were appendicularians, which had an IRI of 16.7% (Table 1). The width of the ingested copepods ranged between 90 and 400 µm ($\bar{x}$ =180; SD=54) and the mean number of copepods per fish was 11 (Table 2). In general, the number of copepods ingested per fish was inversely proportional to the size of the prey. Kjelson et al. (1975) found that 99% of the food consumed by this species in the Newport River Estuary, North Carolina, were copepods, the remaining 1% was comprised of diatoms, amphipods, ostracods, barnacle larvae and crab zoea. Govoni and Chester (1990), working in the vicinity of the Mississippi River plume, found that flexion-postflexion *L. xanthurus* also eats a great diversity of prey items (11-15).

In the present study a total of 23 digestive tracts from 6.65 to 12.20 mm SL *M. undulatus* larvae were analyzed. Larvae were collected from Laguna Madre in December 1989 and February 1990 at 1410 and 1230 hrs, respectively. Similarly to *L. xanthurus*, this species fed primarily upon copepods (IRI = 44.7 to 67.0%), although the number prey types (6) was much lower for *M. undulatus* than for *L. xanthurus* (Table 3). Govoni et al. (1983) found high percentages of copepodites and copepods in larvae of both species in the northern Gulf of Mexico. These authors found that pteropods *(Limacina trochiformis)* and copepod

TABLE 1

Index of relative importance (IRI) of food items for larval *Leiostomus xanthurus* in Laguna de Tampamachoco, Veracruz and Laguna Madre, Tamaulipas, Mexico. N = number of food items, FO = frequency of occurrence, n = number of larvae examined, n′ = number of larvae with empty guts.

Diet Items	Laguna Madre, Station 8 (December-1989) Range: 9.21-12.22 mm SL (n=11, n′=0)			Laguna Madre, Station 7 (December-1989) Range: 8.50-11.40 mm SL (n=12, n′=2)			Laguna Madre, Station 2 (February-1990) Range: 9.95-12.10 mm SL (n=12, n′=0)			Laguna de Tampamachoco Station 16 (February-1988) Range: 9.10-12.90 mm SL (n=18, n′=0)		
	N	FO	IRI	N	FO	IRI	N	FO	IRI	N	FO	IRI
Copepods	293	11	56.7	166	9	90.7	55	12	37.5	200	16	29.9
Appendicularia										26	14	16.7
Barnacle nauplii	3	3	8.4				1	1	2.7	20	10	12.0
Pelecypods (Juveniles)	5	2	5.9	1	1	4.7				12	8	9.4
Pseudodiaptomus pelagicus	2	2	5.6									
Detonula sp	1	1	2.8									
Zoea							5	3	8.3	9	6	7.0
Crustacean nauplii	2	1	2.9							9	6	7.0
Crustaceans				1	1	4.7				5	5	5.7
Invertebrate eggs	15	4	12.2				189	9	46.2	16	3	4.2
Invertebrate clutch										2	2	2.3
Barnacle cypris	1	1	2.8							2	2	2.3
Amphipods	1	1	2.8				2	2	5.4	1	1	1.1
Chaetognaths										1	1	1.1
Navicula sp										1	1	1.1

TABLE 2

Size and number of copepods/fish eaten by *Leiostomus xanthurus* in two coastal lagoons of the Gulf of Mexico. S = Station, TAMPA = Laguna de Tampamachoco, Veracruz, LAMA = Laguna Madre, Tamaulipas, IRI = Index of relative importance, N = number of larvae examined, n = number of copepods; COP/FISH = copepods/fish, n′ = number of copepods measured, SD = standard deviation.

	Standard Length (mm)	N	n	COP/ FISH	IRI (COPEPODS)	Width Range (COPEPODS) (μm)	Mean Width (COPEPODS) (μm)	n′	SD	Sample Hour
TAMPA S-16 Feb-88	9.10-12.90	18	200	11.11	29.9	90-400	180	161	54	1900
LAMA S-7 Dec-89	8.50-11.40	12	166	13.83	90.6	80-360	207	160	49	1410
LAMA S-8 Dec 89	9.21-12.22	11	293	26.64	56.7	60-320	148	94	55	1330
LAMA S- 2 Feb-90	9.95-12.10	12	55	4.6	37.5	220-400	314	55	50	1230

nauplii were important in the diet of *L. xanthurus*, whereas eggs of invertebrates constituted a high percentage of the diet of *M. undulatus.*

Larvae of *B. chrysoura* and *C. nebulosus* used for feeding analyses were collected in September 1989 at 1310 hrs in Laguna Madre. Nineteen digestive tracts of *B. chrysoura* larvae between 1.17 and 1.92 mm SL contained mainly pelecypods (IRI=54.2-59.2%) and crustacean nauplii (IRI=21.7-22.9%). Larvae smaller than 1.5 mm SL also ate gastropods and eggs of invertebrates, whereas gastropods were substituted by copepods in larvae between 1.52 and 1.92 mm (Table 4). Chao and Musick (1977) found that specimens smaller than 40 mm SL fed mostly on copepods and changed to *Neomysis americana*, amphipods and other crustaceans as they grew.

Nineteen *C. nebulosus* larvae measuring 1.5 to 1.95 mm SL were found to eat mainly pelecypods (IRI=42.8%), whereas for sizes from 2.00 to 2.42 mm SL the proportion of prey changed with copepods being more abundant (IRI=34.2%) (Table 5). Reared larvae older than eight days consumed a greater dry weight of copepods than rotifers (Taniguchi 1981). This greater proportion of copepods was observed by Houde and Lovdal (1984) for larvae of this species collected in Biscayne Bay, Florida. They found that 80.9% of the food consisted of copepod nauplii, copepodites and adult copepods, with pelecypods making up a very small portion of the diet. In addition, McMichael and Peters (1989) found that copepods were the dominant prey in larvae of this species collected in Tampa Bay, Florida. Apparently larvae of this species smaller than 2.0 mm feed on prey types with low motility (pelecypods), as was also observed in laboratory cultured specimens (Taniguchi 1981).

The diet of *C. nebulosus* and *B. chrysoura* larvae did not include phytoplankton and they are consequently considered carnivorous. In contrast, the diet of *L. xanthurus* included diatoms (*Navicula* sp and *Detonula* sp), although these prey items were small and were found infrequently (Table 1). No phytoplankters were observed in the guts of *M. undulatus* in our study, whereas Govoni et al. (1983) reported the dinoflagellates (*Dinophysis* spp. and *D. caudatum*) in the youngest stages of this species.

Diet overlap was analyzed for the *M. undulatus* and *L. xanthurus* larvae collected in Laguna Madre in December. A high degree of diet overlap was found with 73.2%, which increased to 83.0% in February. Govoni et al. (1986) considers that fish larvae eat prey suitable for mechanical ingestion only; therefore food selection is restricted by prey size as well as by the perception and catching ability of the larvae. There was no significant difference between mouth size of *M. undulatus* and *L. xanthurus* (t-test, $p > 0.01$). This could be the main reason for the great diet overlap between these two species.

TABLE 3

Index of relative importance (IRI) of food items for larval *Micropogonias undulatus* Laguna Madre, Tamaulipas, Mexico. N = number of food items, FO = frequency of occurrence, n = number of larvae examined, n′ = number of larvae with empty guts.

Diet Items	Laguna Madre, Station 7 (December-1989) Range: 9.80-12.20 mm SL (n=12, n′=7)			Laguna Madre, Station 2 (February-1990) Range: 6.65-10.67 mm SL (n=11 n′=1)		
	N	FO	IRI	N	FO	IRI
Copepods	8	4	67	21	8	44.7
Barnacle nauplii				3	3	13.5
Crustacean nauplii	2	2	22.0			
Crustaceans				1	1	4.5
Invertebrate eggs				39	3	37.3
Amphipods	1	1	11.0			

TABLE 4

Index of relative importance (IRI) of food items for larval *Bairdiella chrysoura* in Laguna Madre, Tamaulipas, Mexico. N = number of food items, FO = frequency of occurrence, n = number of larvae examined, n′ = number of larvae with empty guts.

Diet Items	Laguna Madre, Station 9 (September-1989) Range: 1.17-1.47 mm SL (n=12, n′=0)			Laguna Madre, Station 9 (September-1989) Range: 1.52-1.92 mm SL (n=7, n′=0)		
	N	FO	IRI	N	FO	IRI
Copepods				4	2	12.1
Pelecypods (juveniles)	66	10	59.2	40	6	54.2
Crustacean nauplii	8	6	21.7	6	4	22.9
Gasteropods	1	1	3.5			
Invertebrate eggs	8	4	15.6	2	2	10.8

TABLE 5

Index of relative importance (IRI) of food items for larval *Cynoscion nebulosus* in Laguna Madre, Tamaulipas, Mexico. N = number of food items, FO = frequency of occurrence, n = number of larvae examined, n′ = number of larvae with empty guts.

Diet Items	Laguna Madre, Station 9 (September-1989) Range: 1.50-1.95 mm SL (n=10, n′=1)			Laguna Madre, Station 9 (September-1989) Range: 2.00-2.42 mm SL (n=9 n′=0)		
	N	FO	IRI	N	FO	IRI
Copepods	4	4	15.9	22	8	34.5
Pelecypods (juveniles)	31	7	42.8	17	5	23.2
Crustacean nauplii	16	7	33.4	11	9	32.0
Tintinnids	1	1	4.0			
Invertebrate eggs	1	1	4.0	3	3	10.3

An overlap in diet of 62.3% was recorded in September in the northern inlet of the study area (station 9) for *C. nebulosus* larvae measuring from 1.50 to 1.95 and 2.00 to 2.42 mm SL. The intraspecific diet overlap increased to 90.4% for *B. chrysoura* larvae from 1.17 to 1.47 and 1.52 to 1.92 mm SL. The percentage of overlap between *C. nebulosus* (1.50 to 1.95 mm SL) and *B. chrysoura* (1.17 to 1.47 and 1.52 to 1.92 mm SL) during September was 70.0 and 79.5%; however, the degree of overlap between larvae of *C. nebulosus* (2.00 to 2.42 mm SL) and both size ranges of *B. chrysoura* was lower (47.4 and 55.2%) (Table 6). This reduction may have been caused by an increase in length and consequently increase in mouth size of *C. nebulosus* compared to *B. chrysoura* (Table 7). It is evident that as *C. nebulosus* increased in size, copepods replaced pelecypods as the primary prey item (Table 5).

The diets of *L. xanthurus* and *M. undulatus* clearly overlapped due to two reasons: they are recruited into lagoons at the same time of the year (December-February) and they both have the same mouth size. On the other hand, although *C. nebulosus* and *B. chrysoura* coexist in space and time, they had a lower diet overlap that could be caused by a larger size mouth of *C. nebulosus* (t-test, $p < 0.01$). The different degrees of food preferences is reflected in a decrease of the diet overlap that is inversely proportional to the size.

ACKNOWLEDGMENTS

We would like to thank Samuel Gómez-Aguirre for his critical review and valuable comments to the manuscript of this work, Fernando Mondragón-Galicia for his assistance in the working field, and to Andrea Raz-Guzmán Macbeth for helping us with the translation of the original work into English. We are especially grateful to J. Lyczkowski-Shultz and B. H. Comyns for their professional critical review which greatly contributed to the improvement of the final version.

TABLE 6

Dietary overlap measured by Schoener's index for *Cynoscion nebulosus* and *Bairdiella chrysoura* September-1990, Laguna Madre, Tamaulipas, Mexico.

Species/size (mm SL)	*C. nebulosus* 1.50-1.95	*C. nebulosus* 2.00-2.42	*B. chrysoura* 1.17-1.47	*B. chrysoura* 1.52-1.92
C. nebulosus 1.50-1.95	100.0	62.3	70.0	79.5
C. nebulosus 2.00-2.42		100.0	47.4	55.2
B. chrysoura 1.17-1.47			100.0	90.4
B. chrysoura 1.52-1.92				100.0

TABLE 7

Relative size of the mouth of larval sciaenids in Laguna Madre, Tamaulipas, Mexico. SL = standard length, HL = head length, n = number of larvae, RMS = relative mouth size (Chao and Musick 1977), D = mouth size of fish (Shirota 1970), SD = standard deviation.

Species	SL (mm)	HL (mm)	n	RMS			D		
				Range	$\bar{x}$	SD	Range	$\bar{x}$	SD
Cynoscion nebulosus	1.50-2.52	0.42-0.90	21	0.07-0.18	0.13	0.03	0.28-0.64	0.41	0.08
Bairdiella chrysoura	1.17-1.92	0.35-0.67	19	0.05-0.16	0.09	0.04	0.20-0.45	0.29	0.09
Micropogonias undulatus	6.65-12.20	2.07-3.70	23	0.37-1.20	0.79	0.22	1.29-3.11	2.24	0.49
Leiostomus xanthurus	8.50-12.22	2.50-3.80	35	0.48-0.88	0.69	0.12	1.72-2.67	2.12	0.24

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