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EARLY LARVAL DEVELOPMENT, GROWTH AND SPAWNING ECOLOGY OF THE BLACK DRUM, *POGONIAS CROMIS* L. (PISCES: SCIAENIDAE)

by

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Abstract

Early larval development and growth of the sciaenid species *Pogonias cromis* L., from the Indian River Lagoon, Florida (U.S.A.), were studied during the winter/spring spawning season 1992. Surface ichthyoplankton tows were taken to collect sciaenid eggs adjacent to known spawning sites. Black drum produce sounds which are known to be associated with spawning. Hydrophones were used to record vocalizing adult black drum and to isolate estuarine spawning sites which then allowed characterization of estuarine spawning and larval/juvenile nursery areas. In addition, the developmental stages of black drum eggs and laboratory-reared larvae were studied under controlled conditions. It was shown, that newly hatched larvae have a characteristic pigmentation pattern which consists of three chromatophore bands. Variations in pigmentation pattern were observed, with pigment concentrated into little spots or expanded across the body to form a web-like pattern. Growth measurements have shown, that *Pogonias cromis* larvae hatch at a mean total length of 2.66 mm. Lengths are very short at hatching, compared to day one larvae which are 3.04 mm mean TL. Black drum larvae, reared at a temperature of 20°C and 27‰ salinity, start feeding at an age of five days at a mean total length of 3.17 mm. Furthermore, growth is very slow until one or two days after larvae start feeding (up to 0.088 mm day^{-1}) and then growth increases rapidly (0.135-0.546 mm day^{-1}).

INTRODUCTION

Black drum (*Pogonias cromis*) are the largest multiple spawning estuarine sciaenid species distributed throughout the Indian River Lagoon of Florida. They spawn from early fall to late spring (MOK and GILMORE 1983). In the Gulf of Mexico, most spawning occurs in winter or spring (CODY et al.1984, PETERS and McMICHAEL 1990), whereas in Chesapeake Bay, later spawning peaks in March, May or June, have been reported (e.g. THOMAS and SMITH 1973). Also, in the Gulf of Mexico, a separate spawning has been reported in summer, when water temperatures would be quite high (e.g. ROSS et al.1983). The seasonal variation in spawning is caused by several as yet undefined biotic and abiotic factors which may also influence juvenile recruitment, the survivors of the larval period.

A variety of methods exist to obtain information on spawning seasonality of black drum. For example, larval collection data and juvenile surveys can be used when growth rates are known to backcalculate spawning time in addition to oocyte development of adults by histological analysis (PETERS and McMICHAEL 1990; MURPHY and TAYLOR 1989). A somewhat new method to get information about spawning ecology of sciaenid species is the acoustic recording and sound analysis of the adults (MOK and GILMORE 1983). Sciaenid fishes produce sounds which are known to be associated with spawning. Thus, hydrophones have been used to record sounds of the black drum allowing the isolation of estuarine spawning sites in the Indian River Lagoon. This latter method allows precise measurement of environmental parameters at the time of spawning. Furthermore, one objective of the present study is to track black drum eggs from these isolated spawning sites for early life history studies. Black drum eggs, collected from the most productive spawning sites in the Indian River Lagoon - based on the hydroacoustic results -, were used to rear larvae in the lab under controlled conditions of temperature, salinity and photoperiod.

Most previous studies of black drum larvae have been concerned with morphological structures or natural distributions (e.g. JOSEPH et al.1964, ROSS et al.1983, HOLT et al.1988, PETERS and McMICHAEL 1990). Unfortunately, an adequate key for egg and larval identification does not exist and many egg and larval stages of similar families and species (e.g. other sciaenids and gerreids) are undescribed. JOSEPH et al.(1964), HOLT et al.(1988) and DITTY (1989) described the eggs and larvae, but in the present study, an advanced description of early larval development should give some more information useful for identification. Moreover, it is necessary to become familiar with egg and larval stages of other abundant species (Gerreidae), which spawn in the Indian River Lagoon, and differentiate them from *Pogonias cromis*. The purpose of the present study is to describe in detail the morphological characteristics of black drum eggs and larvae and to determine larval growth rates under various environmental conditions to obtain information on the early life history of this species that will be useful for both mariculture and management protection of wild populations.

MATERIAL AND METHODS

Hydrophones were used to record vocalization of adult males and to isolate estuarine spawning sites. Adult males produce distinctive vocalization, starting at sunset and lasting two to three hours, which are known to be associated with spawning. Fortnightly hydroacoustic studies correlated to the new and full moon cycle were carried out in the Indian River Lagoon (Fig.1) on a transect with acoustic monitoring at 24 stations over a 14 km route from Vero Beach to Fort Pierce Inlet.

Physical oceanographic parameters at the principal spawning site were monitored continuously with a submerged hydrolab unit and current meters. These parameters were water temperature, conductivity and dissolved oxygen, recorded in the water column 1 meter below the water surface and current patterns at depths of 2 and 4 meters. Furthermore, oceanographic parameters such as surface temperature, salinity and dissolved oxygen were studied at each hydroacoustic and planktonic station with portable field gear.

Black drum eggs and larvae were collected with a 1 meter diameter ring plankton net (335 μm) from surface waters in the Indian River Lagoon (mean Lagoon depth is

1.5 m, maximum 4 m) within the transect area. The plankton samples were preserved in a 5% formalin-seawater-solution, buffered with borax. During 1991 egg and larval collections were made in surface trawls at sites of maximum sound production. During the winter/spring spawning season 1992, quantitative surface ichthyoplankton tows were taken on a number of stations at different spawning sites to determine whether a relationship existed between sound production of the black drum, spawning activity and abundance of newly spawned eggs.

Planktonic black drum eggs collected at the most productive spawning sites, were used to rear larvae in the lab with the purpose to determine morphological characteristics of different egg and larval stages, reared under controlled conditions of temperature, salinity and photoperiod as well as to determine larval growth rates under the previously mentioned environmental conditions.

On arrival in the lab, the living ichthyoplankton samples were immediately sorted and eggs transferred by pipette to the experimental tanks. Black drum eggs were incubated at 20°C, in 10 liter tanks each containing 50 eggs, filled with filtered seawater (S=27‰). First feeding larvae were fed with cultured algae and cultured rotifers (*Brachionus plicatilis*), after nine days larvae were fed with brine shrimp *Artemia* nauplii. The photoperiod regime of 12 hours light and 12 hours darkness (12L:12D) was used. Indirect aeration was provided, because larvae were raised in a seperate screen inside the tanks. Thus, aeration could not cause mortality of the young, sensitive larvae. During the first week, the water was not changed, except for the addition of small amounts of water together with the food organisms. During the subsequent weeks, the water was partly changed once a week.

Morphological characteristics of eggs and larvae, reared under controlled conditions, were described, drawn and photographed. Larvae were sampled every day for growth measurements during the first week, later at irregular intervals. On each sampling day about ten larvae were measured from the tip of the snout to the end of the tail (total length).

RESULTS

HYDROACOUSTIC STUDIES: In the Indian River Lagoon, black drum adult males produce distinctive vocalizations of very low frequency, seen in the sonograph (Fig.2). Known as "loud drum" sounds (MOK and GILMORE 1983), these 0.2 kHz sounds dominating all other sounds recorded within the Intracoastal Waterway in the Lagoon, both in number and intensity. Black drum sounds can be heard through the hull of the boat at night, without using a hydrophone. Black drum acoustic activity was most pronounced one to two hours after sunset, but first sound production would occasionally precede sunset and could be heard to 2400 hr at temperatures of 16.5 to 29.0°C and salinities of 18 to 34‰. The largest number of stations with calling male black drum were consistently observed on new and full moons. Recording of sounds on the transect area has shown, that individual sounds were recorded in the southern part of the transect area, whereas large group sounds were recorded in the northern part of the area (Fig.3). North of Harbor Branch, individual as well as large group sounds of adult black drum were present.

ICHTHYOPLANKTON STUDIES: Based on the results of the hydroacoustic studies, isolated spawning sites of the black drum can be determined. These informations can be used for tracking black drum eggs and larvae in the Indian River Lagoon. Qualitative ichthyoplankton collections demonstrated that the sound production of the black drum is correlated with the abundance of black drum eggs in the plankton. Spawning on new and full moon phases will place eggs and larvae in the water column on a flooding tide during the period following sunset.

Detailed quantitative evaluation of the abundance of black drum eggs relative to maximum sound production is still under analysis.

MORPHOLOGY: Black drum eggs and larvae raised under controlled conditions (T=20°C, S=27‰) were used for a comprehensive advanced description of each developmental stage.

Black drum eggs are pelagic, ranging from 0.93 to 1.08 mm in diameter, with most eggs having a diameter of 0.98-0.99 mm (Fig.4). In general one oil globule is visible, in early egg stages up to four oil globules with a diameter of 0.21-0.27 mm can be observed (Fig.5a). In later developmental stages, by the time the embryo is visible, occasionally two globules are present, but not more. At stages with a well developed and pigmented embryo, only one pigmented oil globule occurs (Fig.5b).

Yolksac-larvae hatch at a mean length of 2.66 mm TL (Fig.6a). The oil globule is positioned near the posterior margin of the unpigmented yolksac, close to the anus. The pigmentation is formed by bright golden-yellow chromatophores, but viewed with transmitted light these pigments appear dark brown to black. In later developmental stages of yolksac-larvae the pigmentation pattern does not change till the onset of feeding (Fig.6b+c) at a mean length of 3.2 mm TL.

The pigmentation pattern in black drum yolksac-larvae varies, as seen in Figs. 7 a-c. The most abundant pigmentation type is characterized by three chromatophore bands or partial bands from the anus back and the head pigment above the eyes (Fig.7a). Small pigment spots outline the posterior end of the notochord. The pigment may be also expanded across the body to form a web-like pattern (Fig.7b) or may be contracted into little spots (Fig.7c).

Transition from the yolksac-stage to active feeding occured at day 5-6, when larvae were about 3.2 mm long. At 3.3 mm TL - in the postlarval stage - nearly the whole body is covered by a dark web-like pigmentation (Fig.6d). Pigmentation is reduced in later postlarval stages (Figs.6 e+f).

Postlarval metamorphosis to the juvenile stage occured at day 30, when larvae were about 16.2 mm in size. At this stage, all fin rays have been developed, the vertical black bars - which remain to adult size - appeared (Fig.6g). The dorso-lateral part of the chromatophore-bars contains black as well as red pigmentation. At 18.0 mm TL the mandibular barbels are present.

GROWTH STUDIES: Hatching occured 12 - 16 hours after collection in a water temperature of 20°C (S=25-31‰) at a mean total length of 2.66 mm. The eyes of black drum larvae showed first pigmentation at an age of two days and the mouth was breaking through at an age of three days. Larvae started feeding on the fifth day at a mean length of 3.17 mm TL. At this stage, almost all yolk had been absorbed. Older larvae, over 3.65 mm TL, started feeding on brine shrimp *Artemia* nauplii on the ninth day. On day 14 and at 6.5 mm TL black drum larvae ate adult *Artemia*.

Length-measurements for investigation of growth (Fig.8) during the first 35 days after hatching have shown that lengths of black drum larvae are very short at hatching (2.66 mm TL) compared to one-day-old larvae. First days growth is relatively large, to 3.04 mm mean TL at a mean growth rate of 0.389 mm day^{-1}. However, growth decreases from day-two to day-seven-old larvae from 0.233 to 0.088 mm day^{-1} and is very slow until one or two days after larvae feed, as seen in Table 1. The first increase in daily growth rate was observed on day eight with a mean growth rate of 0.135 mm day^{-1} (Tab. 1). Then growth increases rapidly with growth rates from 0.386 to 0.546 mm day^{-1}, reaching an exponential growth, as seen in Figure 8.

The length-frequency-distribution of 111-day-old black drum juveniles, hatched on March 19, 1992, showed, that lengths varied from a minimum-size of 4.3 cm TL to a maximum-size of 9.0 cm TL (Fig.9), with a distinct peak at the 5.0-5.5 cm size-class. Most abundant size-classes have been found in the 5.0 to 7.0 cm range. The length-frequency-distribution demonstrated that no juveniles of the 7.5-8.5 cm size-class existed, whereas only one specimen with the highest length of 9.0 cm TL was measured.

DISCUSSION

The investigation of the abundance of black drum eggs in qualitative ichthyoplankton samples, collected in the Indian River Lagoon, demonstrated that early developmental eggs were concentrated in the Intracoastal Waterway at night. Analysis of sound production of the black drum in the Indian River Lagoon indicated that black drum produce low frequency sounds (MOK and GILMORE 1983), which are correlated to the abundance of newly spawned eggs in qualitative plankton samples which can then be tracked from the spawning site. Based on hydroacoustic studies, spawning of the black drum took place during the winter months, from early fall to late spring (MOK and GILMORE 1983).

A procedure for identifying eggs of the most common sciaenids has been developed by HOLT et al.(1988). It was found that one-day-old yolksac-larvae can be identified. However, sciaenid eggs could be easily confused with eggs of some Haemulidae, Scombridae, Sparidae and Stromateidae, which have similar characteristics (JOSEPH et al.1964). Recognition of preserved eggs and larvae is difficult, however, the progress in describing sciaenid eggs and larvae to the species level through laboratory rearing of specimens captured within the study site is progressing to the point that these samples will soon be confidently sorted to species, therefore, their spatial/temporal distribution determined.

As it was shown in the present study, the pigmentation pattern in black drum yolksac-larvae varies. The pigmentation is characterized by three chromatophore bands from the anus back and the head pigment above the eyes, but may be also expanded across the body to form a web-like pattern or may be contracted into little spots. Eggs and yolksac-larvae in general have been described by JOSEPH et al.(1964) and HOLT et al.(1988), but this advanced description of eggs and early larval development should give more useful identification information.

Growth studies at a rearing temperature of 20°C demonstrated that two growth periods were evident in the early life stage of black drum, observed 35 days after hatching. One extending growth from hatching through the absorption of the yolk sac, with the highest growth rate of 0.389 mm day^{-1} from the first to the second day after hatching. Then growth decreases and is very slow until one or two days after larvae feed. Growth rates in terms of total length during the first stage were low (0.233 to 0.088 mm day^{-1}), whereas during the second stage, the rates appeared exponential with growth rates up to 0.546 mm day^{-1}. LEE et al.(1984) indicated that two growth periods were also evident in the early life stages of the sciaenid *Sciaenops ocellatus*; one during the depletion of the yolksac, the other at the onset of active feeding. Larval growth rates of wild black drum from Tampa Bay, estimated from otolith analyses, showed lower growth rates (0.2-0.3 mm day^{-1}, PETERS and McMICHAEL 1990) than our observations. However, these lower rates agreed with rates of laboratory-reared larvae (about 0.2 mm day^{-1}), raised by JOSEPH et al.(1964), which grew to 5 mm SL and 7.5 mm SL after one month at 21°C.

Even under controlled environmental conditions in rearing tanks, different growth rates in one cohort occur. PAULY (1983) reported, that growth differences create an increasing range in variability of length-at-age for each year class, as fish become older. The length-frequency-distribution of 111-day-old black drum juveniles - the survivors of the larval period - showed that lengths varied from 4.3 to 9.0 cm TL, with a distinct peak at the 5.0-5.5 cm size-class. Fish of the same age but of different sizes will be in different stages of development because developmental characters are more closely correlated with size than age. These differences were first observed during the larval stage. Standard deviations of mean total length data increased with age. This same trend was observed in growth studies of the sciaenid *Sciaenops ocellatus* (HOLT 1990). Several hypotheses exist to explain the different growth rates among black drum cohorts: (1) variation in growth can have a genetic component that is expressed through ability to compete (KINGHORN 1983), (2) different success at first feeding could result in higher larval growth rates of some individuals which is relative to environmental conditions and food availability, and (3) social interactions and territorial behavior among individuals in the rearing tank, when food is scarce.

Further studies will be carried out in the next spawning season of the black drum to determine larval growth rates under different environmental conditions (e.g. change in temperature, salinity), both in the field and laboratory.

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APPENDIX

FIGURES 1 - 9

TABLE 1

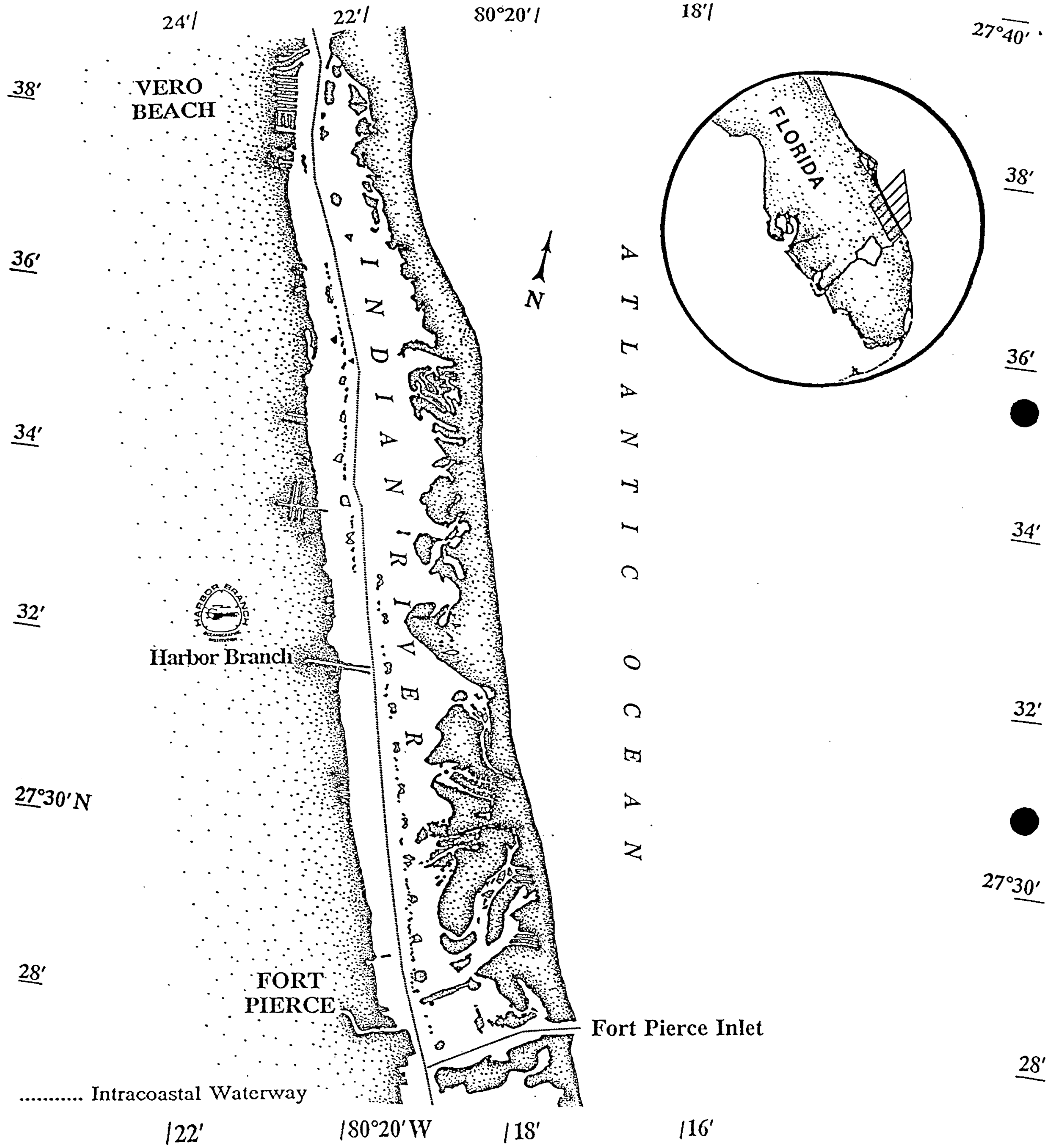

Fig.1: Study area in the Indian River Lagoon, East Florida (U.S.A.), for hydroacoustic and ichthyoplankton studies.

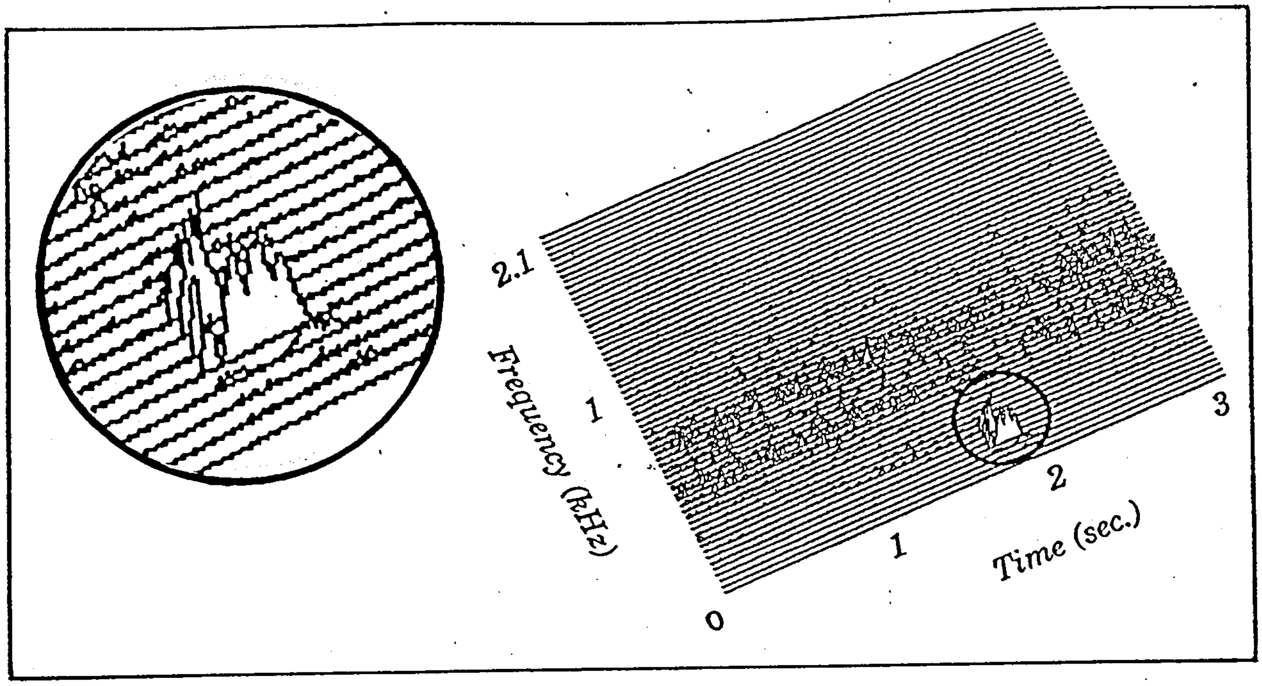

Fig.2: Sonograph of Pogonias cromis sounds.

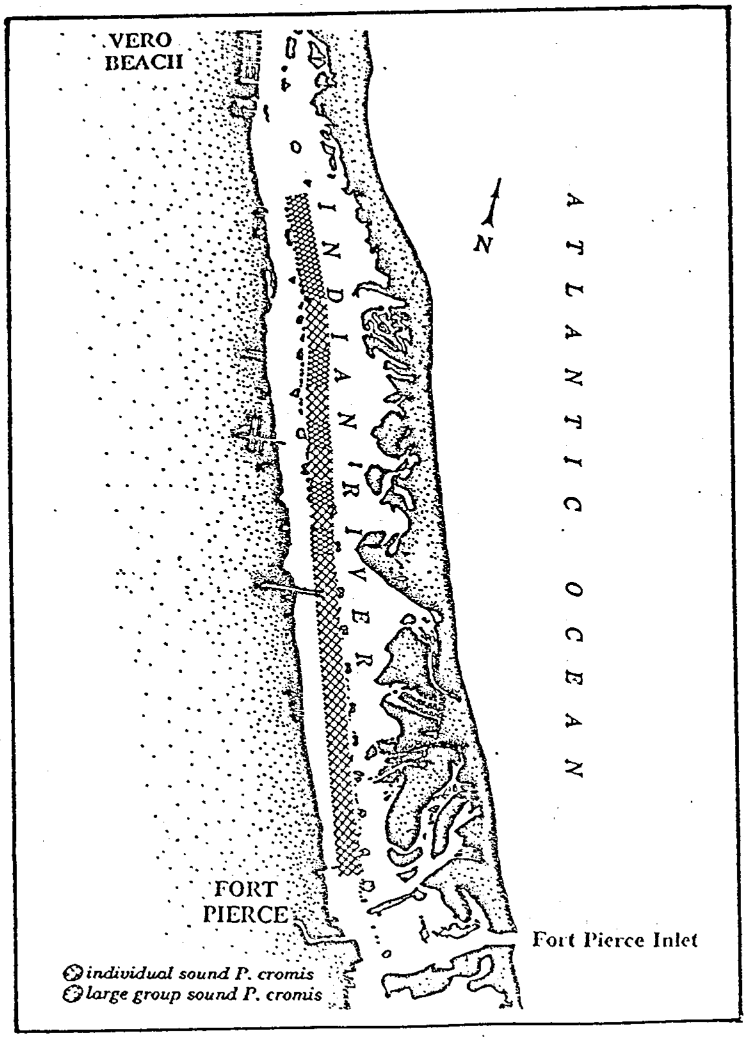

Fig.3: Isolated spawning sites of Pogonias cromis at the short transect area in the Intracoastal Waterway (Indian River Lagoon).

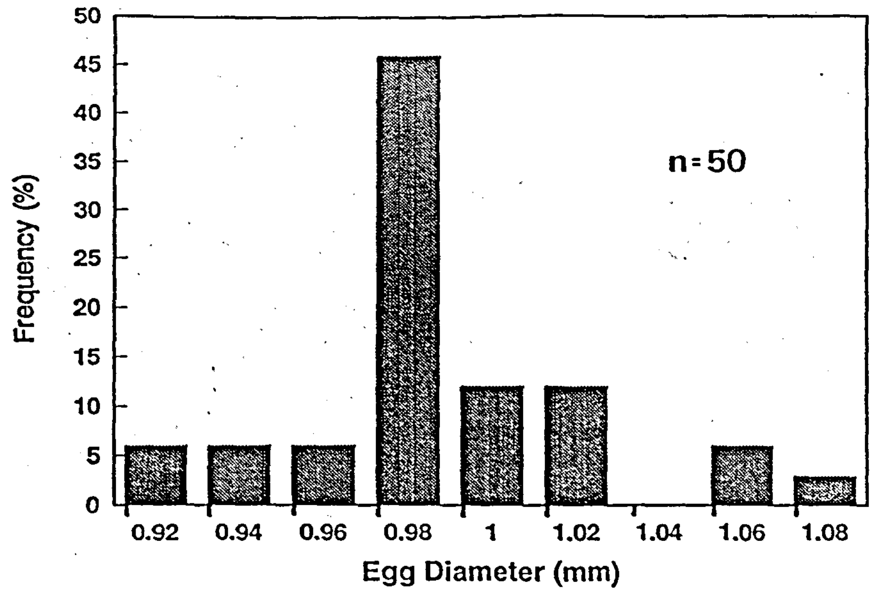

Fig.4: Frequency distribution of the egg diameter of Pogonias cromis eggs.

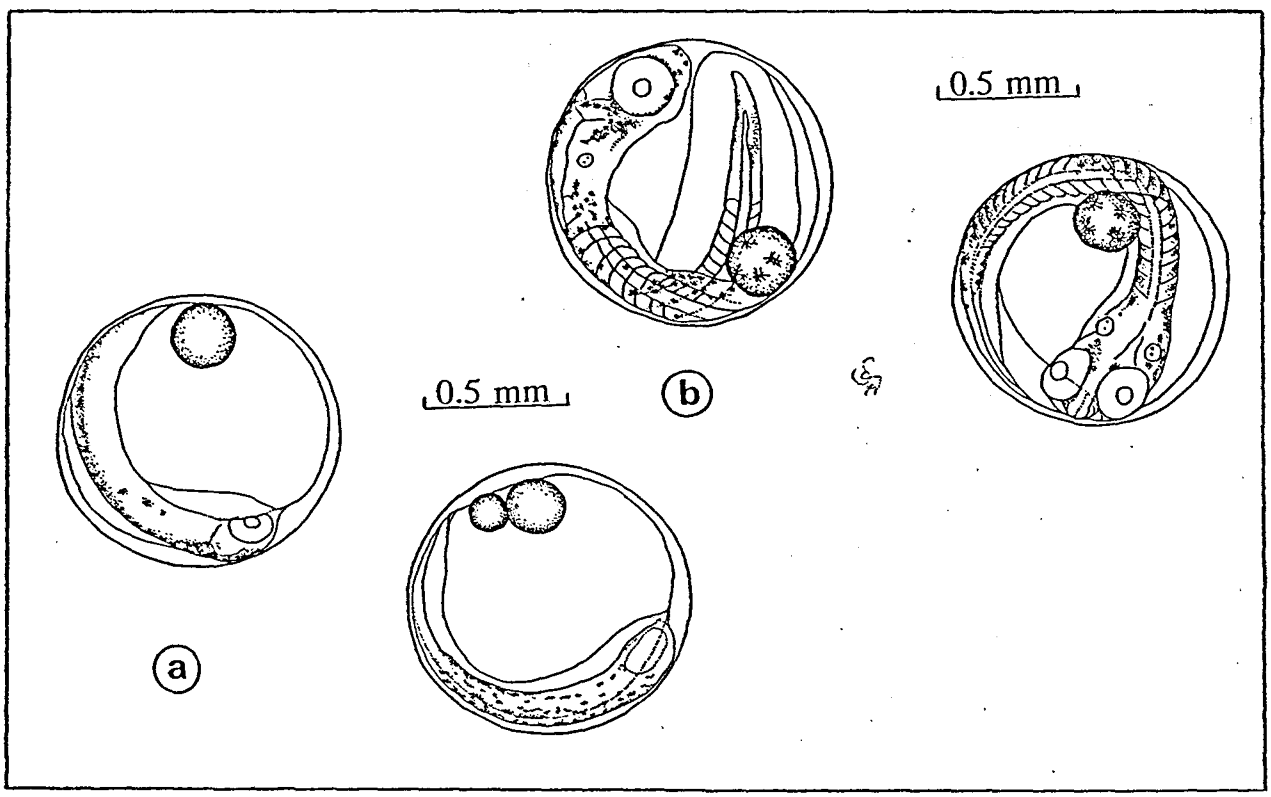

Fig.5: Pogonias cromis eggs: (a) early stage with primitive embryo - oil globule and embryo not pigmented, 1-4 oil globules observed; (b) late developmental stage with pigmented embryo and oil globule - only one oil globule at this stage.

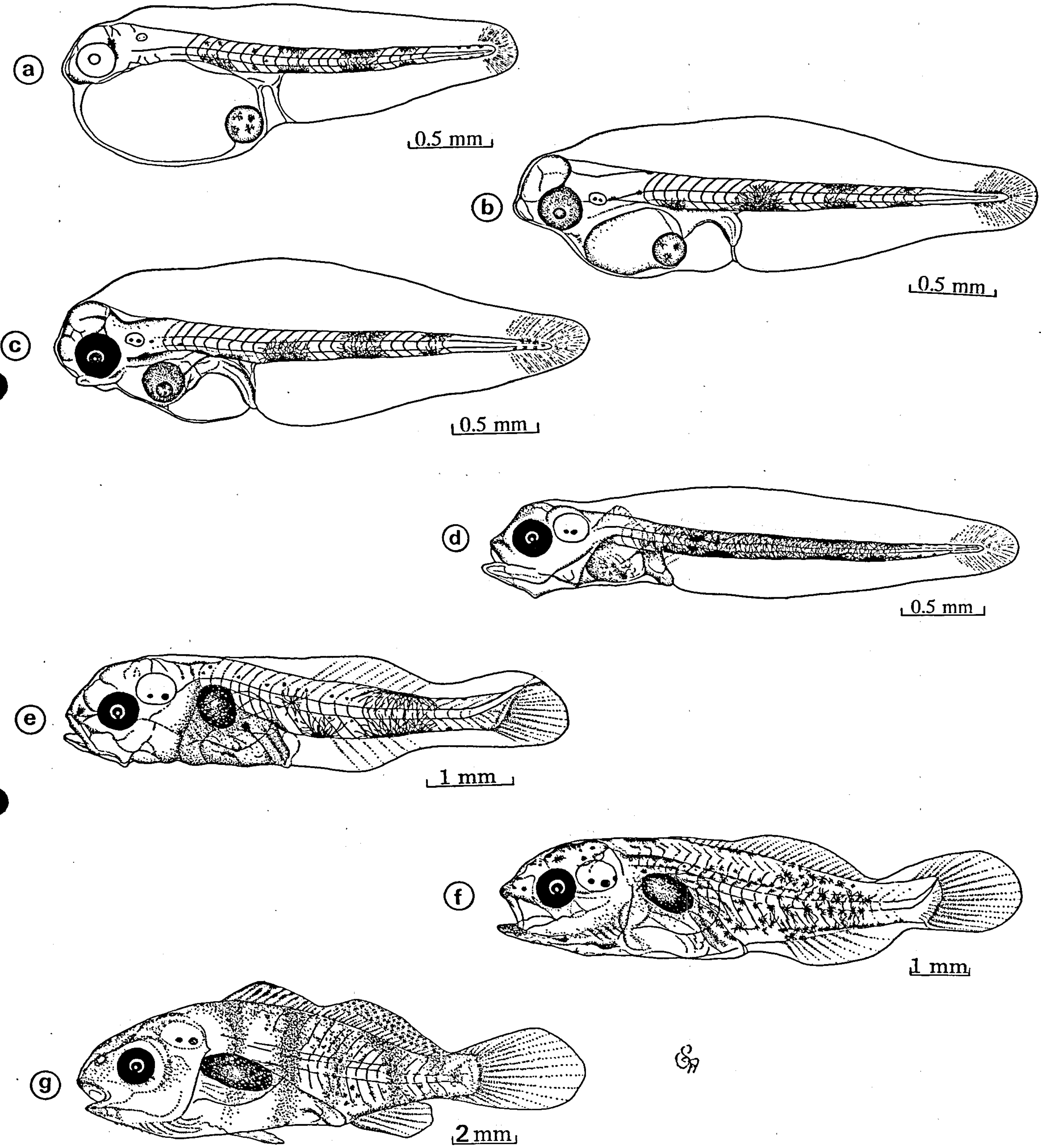

Fig.6: *Larvae of Pogonias cromis, hatched and raised at 20°C and 27‰:* ***(a)*** *newly hatched yolksac-larva (2.66 mm TL),* ***(b)*** *2-day-old larva (3.04 mm TL),* ***(c)*** *3-day-old larva (3.13 mm TL),* ***(d)*** *7-day-old larva (3.19 mm TL),* ***(e)*** *15-day-old larva (5.9 mm TL),* ***(f)*** *19-day-old larva (9.6 mm),* ***(g)*** *30-day-old juvenile (16.8 mm TL).*

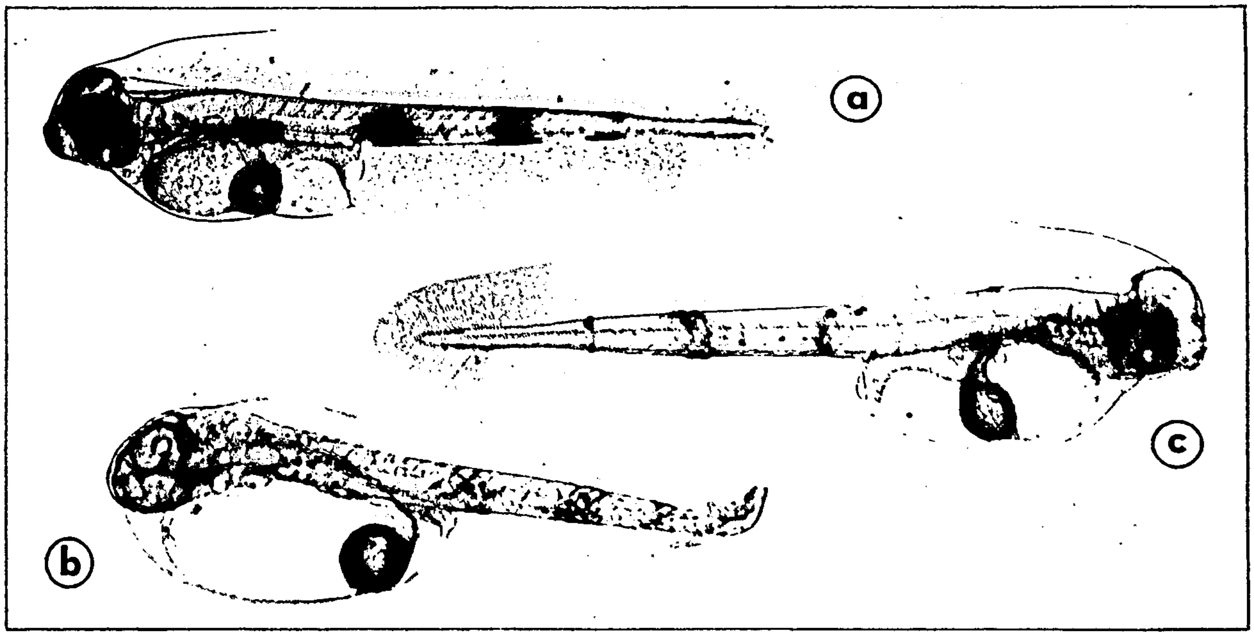

Fig.7 (a)-(c): Variations in pigmentation pattern of Pogonias cromis yolksac-larvae.

	TOTAL LENGTH (MM)													
AGE (DAYS)	3.04	3.13	3.16	3.17	3.19	3.49	5.72	6.25	8.79	9.79	11.8	12.6	16.73	19.28
2	0.389 (±0.056)													
3		0.233 (±0.010)												
4			0.173 (±0.008)											
5				0.152 (±0.108)										
7					0.088 (±0.007)									
8						0.135 (±0.061)								
12							0.508 (±0.003)							
15								0.386 (±0.044)						
19									0.408 (±0.028)					
22										0.516 (±0.026)				
27											0.433 (±0.025)			
29												0.434 (±0.017)		
33													0.521 (±0.027)	
35														0.546 (±0.042)

***Tab.1:** Daily growth rates of black drum larvae, raised at T=20°C, S=27‰, observed at an age up to 35 days.*

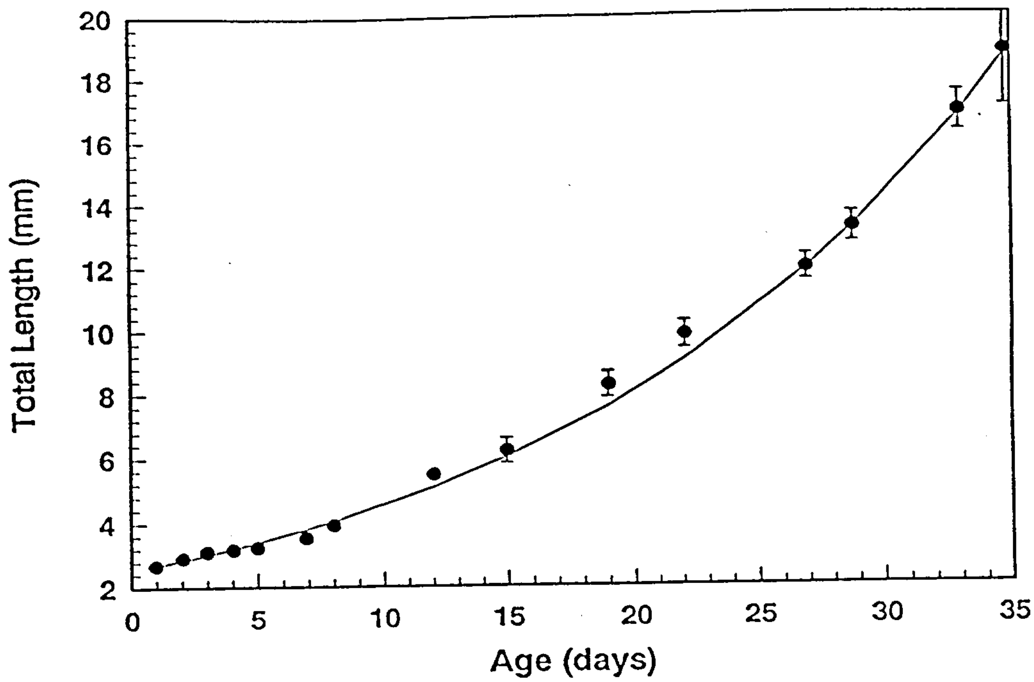

Fig.8: Relationship between mean total length of black drum larvae and age in days (day 1: hatching) at a rearing temperature of 20°C and 27‰ salinity.

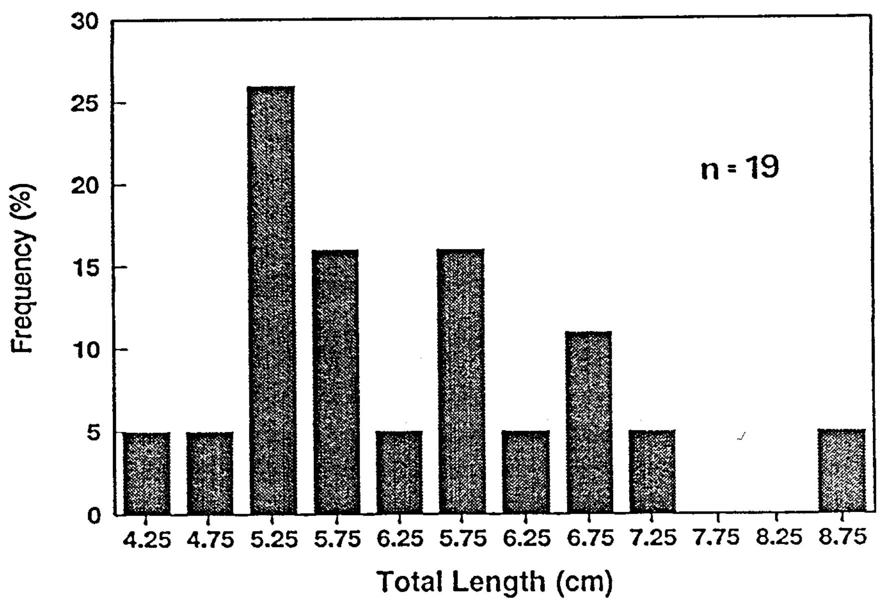

Fig.9: Length-frequency-distribution of 111-day-old Pogonias cromis juveniles, hatched at the end of the spawning season on March 19, 1992.