11-11-83

MARICULTURE PROGRAM

1982-1983

11-11-83

The past year 82-83 has been a good one for the mariculture research group. We have had some real breakthroughs in the areas of spawning, larval fish work and habitat studies. The completion of the egg to egg cycle for redfish in captivity, the determination that larval redfish can eat 100% of their body weight per day, and the elucidation of the time and place for redfish and speckled trout spawning are among the most notable.

As always, the mariculture group is very appreciative of the support of the following granting agencies.

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RESEARCH STAFF

C. R. Arnold	Associate Director, Marine Science Institute, Mariculture Program
G. J. Holt	Research Scientist
P. Thomas	Research Scientist
Wen Y. Lee	Research Scientist
W. Wofford	Postdoctoral Fellow
S. A. Holt	Research Associate
N. Brown	Research Associate
N. Wohlschlag	Research Assistant
J. Lewis	Laboratory Assistant
J. Munoz	Laboratory Assistant
J. Trant	Graduate Student
L. Nelson	Graduate Student
M. Judes	Graduate Student
D. Pena	Clerk Typist

MATURATION AND SPAWNING

Redfish which began spawning in August 1980 have continued for the past 38 consecutive months. These fish spawn an average 4 times per month, and the 201st spawn occurred on September 28, 1983. The size of the spawns have ranged from 100,000 to 2.5 million eggs. The percent fertilization and hatch has not changed during this period (about 95%). Contrary to what we expected the number of eggs per spawn has not decreased with time, but has in fact increased over the past year. This ability to have fertilized eggs on a year round basis, has been invaluable for our research work and will be a very important consideration in any future mariculture venture.

The egg to egg cycle for redfish was completed in our laboratory in April 1983. Eggs spawned and hatched in the lab in July 1980 were reared to maturity. Spawning by these lab-reared fish at the age of 44 months was the breakthrough which will enable us to begin selective breeding studies.

We have 52 one year old red snapper which will be sexually mature within the next year. We will conduct several spawning experiments which should give valuable information on the problems of spawning this species in captivity.

VISITING SCIENTIST (Parasites and Diseases)

The following is a summary of the research accomplished during my eight weeks at the Mariculture Lab, University of Texas Marine Science Institute, by Dr. Beverly Goven of Texas Wesleyan College in Fort Worth, Texas.

At the beginning of June, two objectives were established:

1) Set up a laboratory with routine diagnostic procedures to identify fish pathogens incurred in the mariculture lab.
2) Examine the redfish (Sciaenops ocellatus) presently in culture, for disease organisms and to establish treatment for any disease outbreaks.

The first objective was completed and 13 bacterial isolates were collected from internal and external lesions of fish. A diagnostic procedure was established and the isolates were identified by biochemical means. Three of these isolates were identified as Vibrio, the major bacterial pathogen in marine fish. As part of the diagnostic procedure, water quality was monitored to correlate any change in conditions with the onset of disease. Measurements of ammonia, nitrite, pH, temperature, salinity and dissolved oxygen were made at least three times a week.

One aspect of research was concerned with the immune status of the juvenile redfish. An experiment was designed in which a test group of juveniles was vaccinated against Vibrio anguillarum using a bacterin supplied by Pitman Moore Inc. The immunization method consisted of a 20 second immersion in the vaccine. A nonimmunized group, maintained under the same conditions served as a control. Samples from both groups were to be challenged with the Vibrio isolates obtained from previous outbreaks in the mariculture lab. This experiment was designed to determine serological cross reactivity among the isolated strains and those in the bacterin. Unfortunately this experiment was not completed because of a suspected red tide dinoflagellate tentatively identified as Gymnodinium breve was found in the raceways. Approximately all of the fish in the experiment died as a

result of the toxin produced by these organisms. The exact reasons for the bloom remains undetermined. However, the proper combination of environmental factors are thought to have contributed to the growth of the organisms.

REPRODUCTIVE PHYSIOLOGY

The research emphasis during the past year has been the collection of blood smaples from wild populations of spotted seatrout. Fish were captured weekly from October throgh December using a 900 foot gill net. Specimens were captured at dusk and dawn each week from January through August. Seventeen months of continuous data will allow analysis of long-term seasonal fluctuations in gonadal conditions and plasma hormone levels.

The Gonadosomatic Index (GSI) of male and female spotted seatrout from March 1982 through Aguust 1983 shows 2 peaks in female spawning activity in 1982 and 1 peak in 1983. These increases in female spawning activity appear to be associated with an increase in water temperature suggesting temperature is an important cue for the initiation of spawning in this species. Male GSI values show little change throughout the spawning season (1 April - 30 September). A sharp drop in GSI values is evident in both sexes in October, and probably correlates with the rapid drop in water temperatures. There appears to be a diurnal variation in GSI of spotted seatrout as well as a seasonal variation. Figure 1 shows a significant decrease in GSI values of both male and female fish at midnight, and a rise to near spawning levels by the middle of the following day. High GSI values at dusk indicate spawning during this time only, and

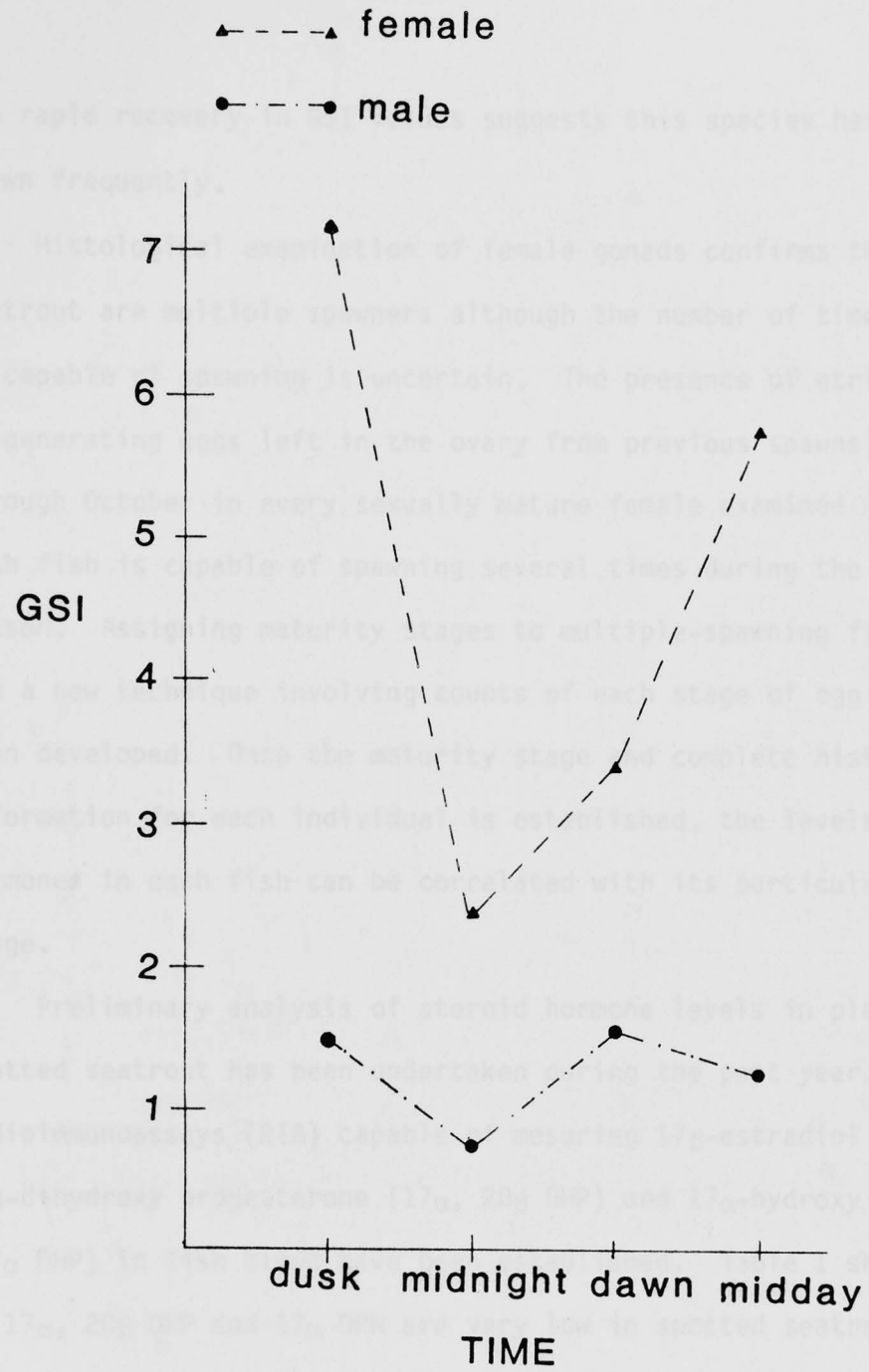


Figure 1 GSI values for male and female spotted seatrout during a 24 hour period in July, 1983.

$$GSI = \frac{\text{Gonad weight}}{\text{Body weight}} \times 100$$

the rapid recovery in GSI values suggests this species has the ability to spawn frequently.

Histological examination of female gonads confirms that spotted seatrout are multiple spawners although the number of times an individual is capable of spawning is uncertain. The presence of atritic bodies (degenerating eggs left in the ovary from previous spawns) from April through October in every sexually mature female examined indicates that each fish is capable of spawning several times during the reproductive season. Assigning maturity stages to multiple-spawning fish is difficult, and a new technique involving counts of each stage of egg in the ovary has been developed. Once the maturity stage and complete histological information for each individual is established, the levels of steroid hormones in each fish can be correlated with its particular reproductive stage.

Preliminary analysis of steroid hormone levels in plasma from female spotted seatrout has been undertaken during the past year. Sensitive radioimmunoassays (RIA) capable of mesuring 17β-estradiol (E_2), 17α, 20β-dihydroxy progesterone (17α, 20β OHP) and 17α-hydroxy progesterone (17α OHP) in fish blood have been established. Table 1 shows that levels of 17α, 20β OHP and 17α OPH are very low in spotted seatrout. While these are known to be important maturation hormones in many freshwater fishes, they do not appear to fulfill this function in spotted seatrout. Highest levels of 17α, 20β OHP reached are 0.369 ng/ml in ripe fish in late summer, compared with 100 ng/ml in rainbow trout at a similar reproductive stage. 17α OHP levels are highest in regressed fish in early fall (mean 1.12 ng/ml). Estradiol (E_2) levels are also very low, although they appear

Table 1.

Seasonal Cycle of Steroid Hormone Levels in Female Spotted Seatrout (ng/ml).

		17α, 20β OHP	17α OHP	Estradiol
Late Spring				
	maturing	.052	.131	--
	ripe	.044	.027	.258
Late Summer				
	maturing	.04	.363	.66
	ripe	.199	--	.386
Early Fall				
	ripe	.175	--	0
	regresed	0	1.12	.027

higher in ripe fish than those in other maturity stages. Preliminary data indicates there maybe a diurnal rhythm in steroid hormone levels in spotted seatrout. Testosterone levels in male fish are higher at midnight and dawn than during the early evening.

The production of hormones by fish ovaries is also being investigated. Previous studies with freshwater fish have shown that ovarian hormones are synthesized from progesterone. However, our experiments with the estuarine Atlantic croaker indicate a different enzymatic pathway (ieΔ 5 pathway, through pregnenolone and dehydroepiandrosterone). This finding may explain why the maturational hormones which are in high concentrations in freshwater fish are present in low concentrations in Atlantic croaker and spotted seatrout.

FUTURE RESEARCH

Analysis of long term seasonal and short term diurnal hormone levels in male and female spotted seatrout blood will be completed. A major emphasis will be to identify the maturation hormone in female spotted seatrout. Fecundity of ovaries collected throughout the spawning season will be analyzed to determine yearly spawning ability of females in different size categories. The activity of ovarian enzymes in Atlantic croaker which control the production of hormones will be monitored throughout the reproductive season. Changes in enzyme activities will be correlated with changes in the steroidogenic pathway and degree of ovarian maturation. A thorough understanding of the reproductive physiology of spotted seatrout and Atlantic croaker will enable interpretation of the results obtained from laboratory studies with redfish, a closely related species. Once the hormonal control of reproduction in redfish has been

determined, it should be possible to control accurately laboratory spawning of this species and ensure a constant supply of eggs by altering the photoperiod and water temperature and by hormonal treatments.

STRESS PHYSIOLOGY

A series of experiments were performed to determine the degree of stress associated with various procedures commonly used in the culture of finfish. Analysis of samples is incomplete but preliminary data suggest the redfish recover rapidly from the stress of capture, transport and transfer to a new holding tank. One hour after transfer plasma glucose titers were 251 mg/dl, five to six times control levels, but by 24 hours had returned to basal levels (Table 2).

Table 2. Plasma Glucose Levels in Redfish After the Combined Stress of Capture, Transport[1] and Transfer to Another Tank.

	Hours After Transfer						
	0	1	3	6	24	72	144
Plasma Glucose (mg/dl)	46[2]	251	201	188	39	44	42

[1] 30 min of confinement in 50 gallon transport tank.

[2] Mean of six individuals.

Anesthetics may be useful to limit the effects of stress caused by handling and other procedures. Pretreatment with quinaldine sulphate, a fish anesthetic, prevented the minor hyperglycemic response of redfish to rapid transfer from one aquarium to another (untreated mean - 70 mg/dl, quinaldine sulphate treated mean - 54 mg/dl).

Another experiment demonstrated that 1 lb redfish could be kept at densities of up to 35 per 200 1 tank without causing undue stress (as shown by plasma glucose levels).

The interactions of ascorbic acid (ASA) and glutathione with environmental contaminants is being investigated in teleosts. Most teleosts have a dietary requirement for ascorbic acid which increases during exposure to adverse environmental stimuli so that symptoms of ASA deficiency may occur during chronic exposure.

The effects of capture and changes in salinity and temperature on the ASA content of mullet tissues was examined. None of the treatments significantly altered ASA levels in mullet livers. Both capture and exposure to a hypoosmotic environment (5 o/oo SW) caused a marked depletion of kidney ASA stores which may represent a non-specific stress response. The ASA content of gill tissues appears to be mainly dependent on the external salt concentration. The seasonal fluctuations in ASA reserves was also determined in natural populations of mullet. The ASA conent of mullet livers was highest during the warmest months and declined to minimum levels towards the end of winter. The results of these studies were compared to those obtained after exposure to cadmium and 20% water-soluble fractions of a No. 2 fuel oil. The ASA content of kidney and gill tissues fell rapidly after exposure to oil. Hepatic ASA reserves decreased 25% during chronic oil exposure. Cadmium caused an even greater decline in liver ASA levels. Depletion of liver ASA reserves may be a characteristic response of fish to certain types of pollutants.

GROWTH CHARACTERISTICS OF REDFISH EGGS AND LARVAE REARED IN THE LABORATORY

This report summarizes the growth characteristics of the early life stages of redfish, beginning at fertilized eggs to 15 days larvae. Parameters observed for fish larvae included standard length, dry weight and length-weight relationship. Whenever possible, regression curves were fitted to these biological measurements over time. Significance of these regression lines was evaluated by analysis of variance, while difference between lines was tested by analysis of covariance. Eggs were monitored for changes in dry weight, size, total carbon and c/n ratios during the 24 h development period.

Larval growth in length and weight

Two growth periods were evident in the early life stage of *S. ocellatus* larvae; one extending from hatching through the depletion of yolk sac and the other beginning at the onset of active feeding. Growth rates during the first stage were small and averaged < 0.06 mm/day, while at the other stage the rates appeared exponential and average ≥ 0.20 mm/day.

Data suggested that larvae raised at 24 and 28°C were similar in their growth patterns in terms of length (Fig. 1). The final length at day 15 was 5.12 mm for fish grown at 28°C, 4.80 mm at 24I and 4.78 mm at 24H. Accordingly, fish raised in 1500 liter tank showed increases in length similar to those in smaller containers (1 liter beaker).

The relationship between age and length was best represented by two equations, asymtotic and quadratic (Table 3). The latter usually gives a

Table 3. Age-length relationship of Sciaenops ocellatus larvae. r^2 = (correlation coefficient)^2, S = Standard error from regression.

Experiment	Relationship	Regression parameters		
		r^2	S(L/t)	F
28I	$L = 2.205\ e^{0.054t}$	0.917	0.086	65.897
	$L = 2.610 - 0.052t + 0.016t^2$	0.961	-	60.723
24I	$L = 2.278\ e^{0.045t}$	0.909	0.076	59.947
	$L = 2.698 - 0.067t + 0.014t^2$	0.994	-	419.470
24H	$L = 2.356\ e^{0.041t}$	0.934	0.057	85.492
	$L = 2.695 - 0.042t + 0.011t^2$	0.977	-	107.527
24I+H	$L = 2.317\ e^{0.043t}$	0.918	0.063	155.909
	$L = 2.696 - 0.055t + 0.013t^2$	0.982	-	360.238
All combined	$L = 2.279\ e^{0.047t}$	0.901	0.074	200.262
	$L = 2.668 - 0.054t + 0.014t^2$	0.947	-	187.628

better fit than the former. The regression equation based on all individuals reared either at 24 or 28°C is represented by $L(mm) = 2.668 - 0.054t + 0.014t^2$, where t is the age in days and F equals 187.63 ($p < 0.01$, d.f. = 2, 21).

The growth pattern in terms of weight differed in several aspects from that recorded for standard length. Within the first 5 days after hatching, larval fish decreased in weight at an average rate of > 1.0 ug/day. Fish grew abruptly thereafter, with a slope much steeper than that observed for the length data for the corresponding period. The average rate of weight increase was temperature dependent. It was 17.74 μg/day at 24°C and 30.25 μg/day at 28°C. Hence, fish grown at higher temperature were always heavier than the ones of the same age grown at 24°C.

Table 4 shows the relationship between age and weight. Since temperature has a pronounced effect on the increase in fish weight, the growth curves at 24°C and 28°C are treated separately. At 28°C, it is $W(\mu g) = 60.521 - 28.850t + 2.852t^2$, with a correlation coefficient of 0.988. At 24°C, the two sets of data points from incubator and hatchery tank are combined together and represented by $W(\mu g) = 47.213 - 15.476t + 1.642t^2$. The correlation coefficient is 0.978. In both cases, the F-statistics are significant at $p = 0.01$.

The dry weight-length relationship generally follows a simple power law. Data obtained from the S. ocellatus were no exception (Fig. 2). Under all the experimental conditions, the log-transformed lengths and weights gave rise to linear regression lines and the slopes varied only within a small range (< 0.2 μg/mm). The analysis of covariance showed no significant difference in either their elevations or slopes ($p > 0.05$,

Table 4. Length-weight relationship of Sciaenops ocellatus larvae. r^2 = (correlation coefficients)^2, S = Standard error from regression.

Experiment	Relationship	Regression parameters		
		r^2	S(W/L)	F
28I	$W = 229.836 - 175.992L + 36.571L^2$	0.974		91.884
	$W = 0.363L^{4.090}$	0.971	0.211	199.960
24I	$W = 181.934 - 138.998L + 29.342L^2$	0.988	-	205.980
	$W = 0.445L^{3.854}$	0.973	0.162	213.976
24H	$W = 217.097 - 163.580L + 33.795L^2$	0.992	-	301.848
	$W = 0.468L^{3.859}$	0.956	0.185	129.596
24I+H	$W = 196.044 - 148.940L + 31.180L^2$	0.986	-	440.567
	$W = 0.457L^{3.855}$	0.964	0.164	374.212
All combined	$W = 272.716 - 196.994L + 38.551L^2$	0.973	-	373.165
	$W = 0.407L^{3.967}$	0.966	0.175	624.796

d.f. = 1,12). All data points are therefore combined to show a regression line of Log(W) = 3.967 Log(L) - 0.390.

Inorganic carbon (carbonates) of fish larvae was obtained through acidification; dry samples were treated with 2 N HCl for 6 h and then dried again. The weight difference between the treatments was referred as inorganic carbon of fish larvae. The results show that the carbonate content of fish larvae increased with age, but significant increase (> 11 μg) was not recorded until day 13, suggesting that greater accretion of carbonates in the otoliths probably occurred at this time.

Size and weight of eggs during development

Fertilized eggs averaged about 0.95 mm in diameter, and showed no progressive changes during development. Temperature affects only the time when eggs hatched but not the size. Table 5 shows the average egg size at various points of time during development. The eggs were originally from the same batch of fertilized eggs, but incubated at different temperature.

Fertilized eggs varied in their initial dry weight. Generally, individual egg averaged 37.56 to 43.97 μg. Weight loss was small (< 5%) in the first 12 h of development, but greatly increased thereafter. At hatching the average weight loss was about 15.5%.

Newly hatched larvae weighed 50% of the fertilized eggs and the yolk sac carried was 1.13 mm long and 0.65 mm wide. At day 3, the oil globule of unfed larvae diminished to about 63 μm in diameter. Individual egg case estimated to be 10.17 μg, which was obtained by subtracting the weight of newly hatched larvae from that of the eggs ready to hatch (at 21.5 h and 28°C).

Table 5. Egg sizes at three incubation temperatures.

	22.2°C		24.5°C		28.2°C	
	$\bar{X}$ (mm)	SD	$\bar{X}$ (mm)	SD	$\bar{X}$ (mm)	SD
0.5 h	-*	-*	0.946	0.018	-*	-*
19.5 h	0.951	0.019	0.952	0.016	0.953	0.017
24.5 h	0.949	0.022	0.944	0.016	hatched	

* Data are not available.

FIGURE LEGENDS

Fig. 1. Growth curves of Sciaenops ocellatus larvae.
* - in incubator at 28°C; + - in incubator at 24°C; O - in hatchery room at 24°C.

Fig. 2. Length-weight relationship of Sciaenops ocellatus larvae. Data points are represented as in Fig. 1.

Fig. 1

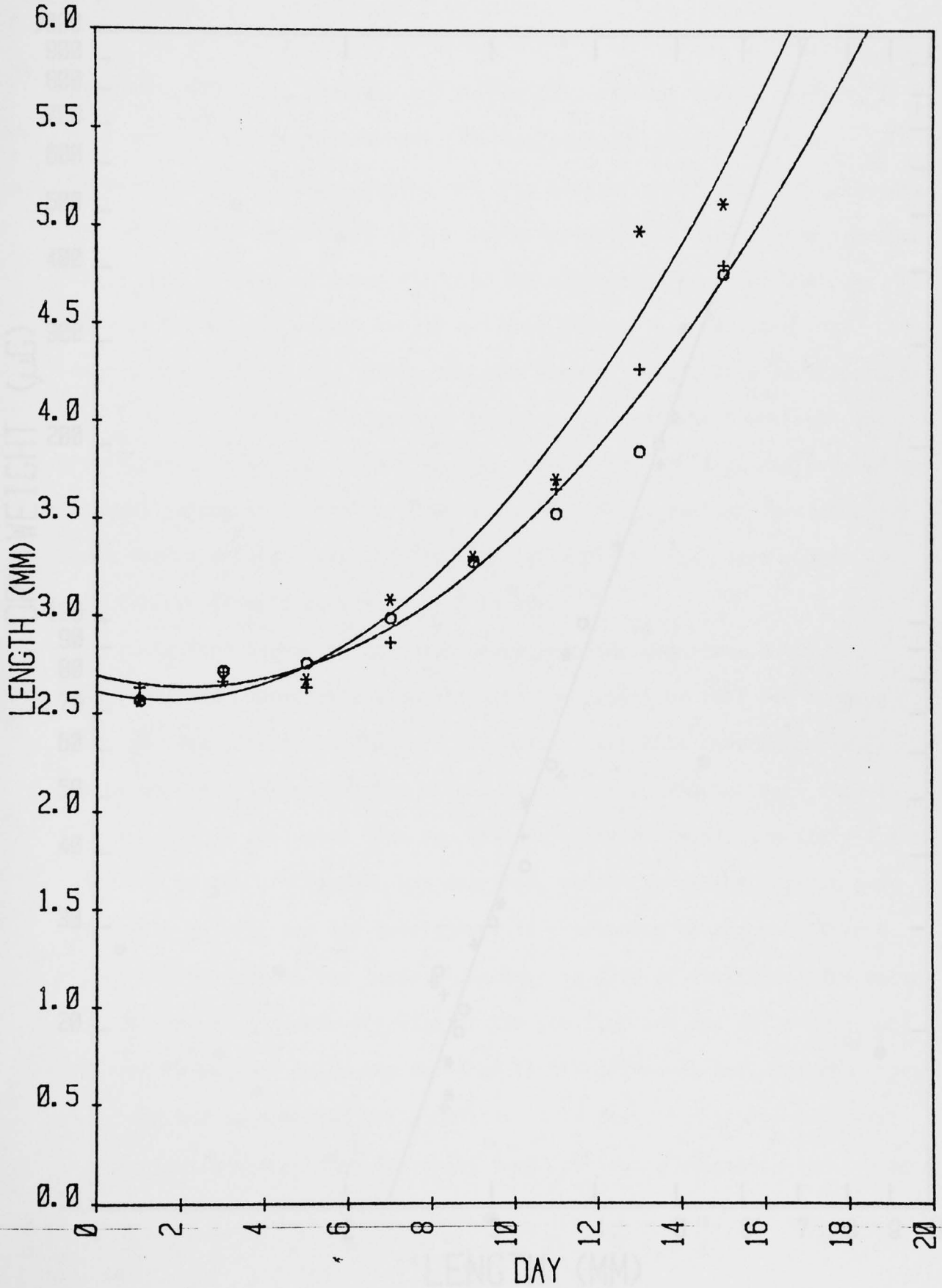
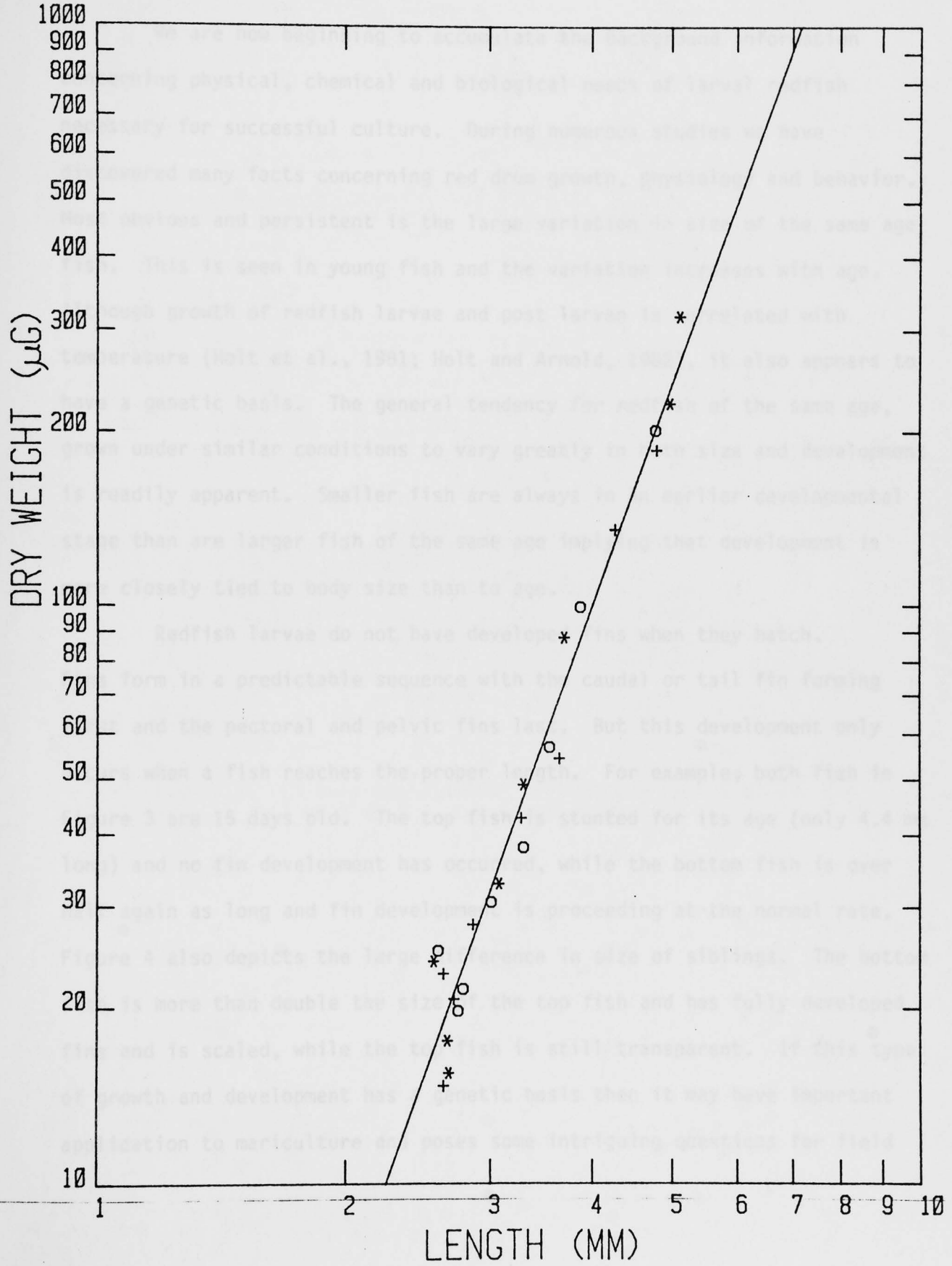

6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
LENGTH (MM)
0
2
4
6
8
10
12
14
16
18
20
DAY

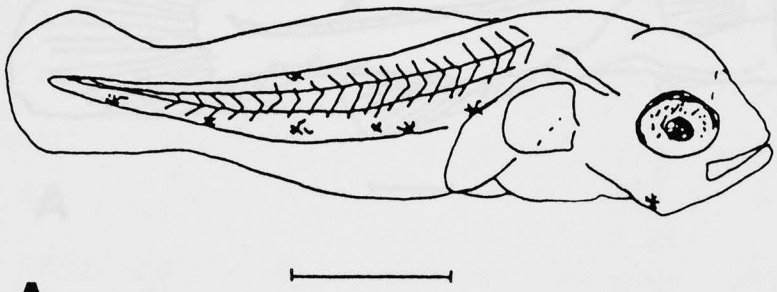
Fig. 2


DRY WEIGHT (µG)
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
LENGTH (MM)

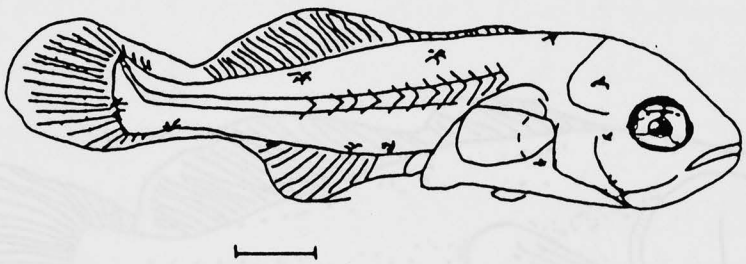
EGGS AND LARVAL FISH STUDIES: FEEDING, GROWTH AND DEVELOPMENT

We are now beginning to accumulate the background information concerning physical, chemical and biological needs of larval redfish necessary for successful culture. During numerous studies we have discovered many facts concerning red drum growth, physiology and behavior. Most obvious and persistent is the large variation in size of the same age fish. This is seen in young fish and the variation increases with age. Although growth of redfish larvae and post larvae is correlated with temperature (Holt et al., 1981; Holt and Arnold, 1982), it also appears to have a genetic basis. The general tendency for redfish of the same age, grown under similar conditions to vary greatly in both size and development is readily apparent. Smaller fish are always in an earlier developmental stage than are larger fish of the same age implying that development is more closely tied to body size than to age.

Redfish larvae do not have developed fins when they hatch. Fins form in a predictable sequence with the caudal or tail fin forming first and the pectoral and pelvic fins last. But this development only occurs when a fish reaches the proper length. For example, both fish in Figure 3 are 15 days old. The top fish is stunted for its age (only 4.4 mm long) and no fin development has occurred, while the bottom fish is over half again as long and fin development is proceeding at the normal rate. Figure 4 also depicts the large difference in size of siblings. The bottom fish is more than double the size of the top fish and has fully developed fins and is scaled, while the top fish is still transparent. If this type of growth and development has a genetic basis then it may have important application to mariculture and poses some intriguing questions for field

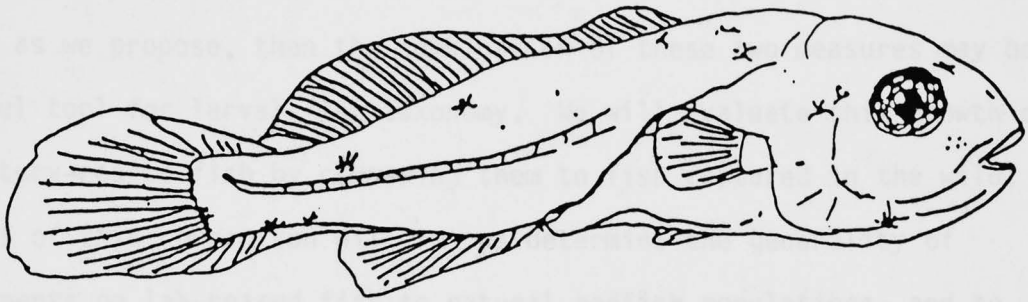


A

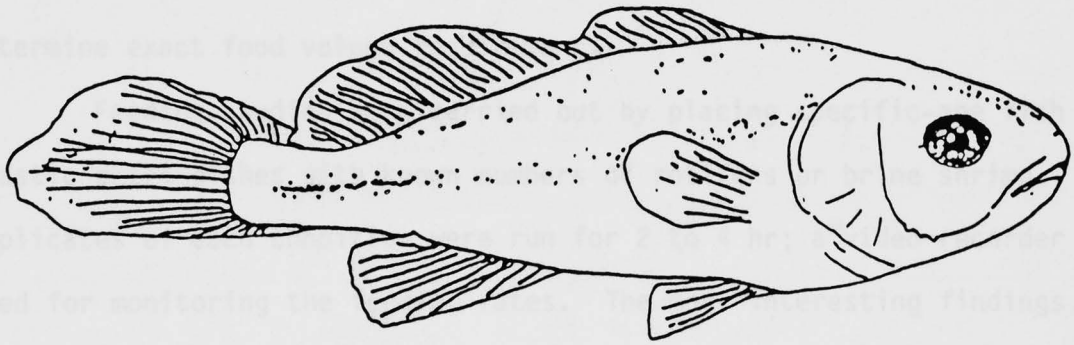


B

Figure 3. Fifteen day old redfish larvae. A) 4.4 mm SL, and B) 7.8 mm SL. Bar equals 1 mm.



A



B

Figure 4. Eighteen day old redfish. A) 9.9 mm SL, and B) 20.9 mm SL. Bar equals 1 mm.

ecologists.

If size, and stage of fin and scale development are as closely linked as we propose, then the combination of these two measures may be a powerful tool for larval fish taxonomy. We will evaluate this growth of laboratory-reared fish by comparing them to fish captured in the wild. Results of this comparison will let us determine the generality of experiments on lab-reared fish to natural redfish populations, and to assess our culture techniques.

Other work during the year has been aimed toward determining optimum growth, and elucidating factors that play an important role in growth. Temperature has previously been shown to be of over-riding importance in determing growth but we felt that photoperiod, crowding and food density could also enhance or detract from the optimum growth. We conducted experiments to analyze the effects of these factors and to determine exact food volume requirements.

Feeding studies were carried out by placing specific-age fish in plastic petri dishes with known numbers of rotifers or brine shrimp. Ten replicates of each condition were run for 2 to 4 hr; a video recorder was used for monitoring the feeding rates. The most interesting findings were: (1) not all day 4 first feeding larvae ate rotifers; the average was about 1/2 rotifer per hour, and (2) day 10 larvae could eat 100% of their weight per day in brine shrimp nauplii (Table 6).

Table 6. Feeding rates of several ages of redfish larvae fed rotifers (RO) and brine shrimp nauplii (BS).

Age	Starved	Duration of Test	Food	Number Eaten/hr	Body wt[1] of Fish	Wt of Food Eaten/hr
D-4	*	4-hr	Small RO	0.44	16.4	0.44
D-7	4-hr	4-hr	RO	2.44	21.9	1.22
D-10	12-hr	2-hr	RO	3.45	99.2	1.72
D-10	12-hr	2-hr	BS	4.30	128.6	10.10
D-10	12-hr	2-hr	BS	2.70	74.1	7.29
D-11	NO	15-hr	RO BS	1.90 2.20	110.0	5.17

* These larvae have never fed before the experiment.

[1] Weights of food and fish are dry weights in mg.

Table 7. The effect of light and photoperiod (light (L) - dark (D) cycles) on the 1st two week survival and growth of redfish.

	12L - 12D		18L - 9D		24L	
	* % S	Lgt	% S	Lgt	% S	Lgt
High Light	62.0	(4.8)	49.1	(4.9)	40.0	(5.0)
Low Light	49.3	(4.85)	10.7	(5.5)	29.0	(5.0)

* % S is percent survival to two weeks, each number is the average for three replicates. Lgt is standard length in mm. High light was 450 and 230 lux on the front and top respectively and 130 lux on the back of the experimental chambers. Low light was 450 and 150 lux on the front and top and only 10 lux on the back. In both conditions there was no light under the chamber.

Another experiment analyzed the role of day length or photoperiod and light intensity during the first two weeks on survival and growth. The rationale was that these factors would be important to feeding success and would therefore influence survival and growth. Incubators with built-in light control systems were used and the back lighting intensity was varied by using black cloth on the interior walls. We found that of the three photoperiods used, the 12 hour light - 12 hour dark cycle was significantly better for larval survival, but there was no difference in growth in length among the conditions (Table 7).

The growth rates may have been controlled more by density or the number of fish in each container than by light. The largest fish were in the chambers with poorest survival and therefore fewest fish. This density-dependent growth rate is currently under investigation. The best photoperiod for survival in this experiment is the same as the natural day length which red drum encounter in September and October when they are normally spawned and hatched.

Work this year also includes a completed study on ammonia and nitrite tolerance of redfish. Ammonia is the principal end product of nitrogen metabolism in fish and nitrite is an intermediate in the bacterial nitrification of ammonia which can build up in recirculating water systems. In static on recirculating systems ammonia and nitrite concentrations are potentially lethal and it is important to identify the effects of these products.

Fertilized redfish eggs were exposed to controlled concentrations of ammonium sulfate or sodium nitrite in static bioassays that were maintained for two weeks. Eggs were obtained from laboratory spawns induced by manipulations of the photoperiod and temperature cycle. Culture methods follow those described by Holt, Godbout and Arnold, 1981. In one series of ammonia tests, three week old larvae reared in the lab were used. Percentage hatch, percentage survival and final standard length were variables used in evaluating the effects of toxicants.

Ammonia (unionized) concentrations from 0.11 to 8.5 mg 1^{-1} were tested on 12-h old fertilized eggs. The highest concentrations caused high mortality within 24 to 48-h post hatch and as the concentrations decreased the time of survival increased. Eggs were relatively insensitive to ammonia. The highest concentration (8.5 mg 1^{-1}) did not reduce hatching success which ranged from 82 to 99% in all tests. The 96-h LC_{50} and 95% confidence limits were 0.39 (0.29 - 0.53) mg 1^{-1} NH_3-N.

Acute toxicity of ammonia to young redfish varied with age of first exposure. Newly hatched larvae were very insensitive to ammonia while three week old larvae tolerated much higher levels. A concentration of 0.7 mg 1^{-1} resulted in 100% mortality in larvae exposed for one week beginning with the egg stage; the same dose was tolerated by three week old larvae. Standard lengths of three week old larvae exposed to 0.4 mg 1^{-1} (9.0 mm $\pm$ 0.41) and 0.8 mg 1^{-1} (8.0 $\pm$ 0.89 mm) did not differ from controls (8.4 $\pm$ 0.58 mm) after one week of exposure, but the experimental fish were more darkly pigmented which may be an indication of stress.

Nitrite concentrations up to 100 mg 1^{-1} did not significantly increase mortality of newly hatched larvae. After two weeks of exposure,

survival of 10 and 100 mg l^{-1} NO_2-N dosed larvae did not differ from controls, but their growth rate was slightly reduced. Nitrite levels in our systems are generally below 1 mg l^{-1}.

In conclusion our data indicate that unionized ammonia may be a potential hazard in redfish culture systems, but under normal circumstances nitrite should cause no problem.

NATURAL HABITAT STUDIES

There were three basic objectives of this work; 1) determine spawning time and spawning area for redfish through the collections of eggs and larvae; 2) determine the age and growth rate of both planktonic and demersal larvae; and 3) continue seagrass meadow sampling to establish a long term data base to study annual variation in recruitment rates.

Redfish eggs were sampled at three sties in the immediate vicinity of the Aransas Pass since historical data had suggested that redfish spawn near the tidal pass. Eggs were collected in surface samples with a 1 m net of 505 um mesh. Samples were taken weekly beginning 15 August, but no eggs were found until 15 September (Figure 5). The maximum abundance of eggs was encountered on 1 October (when almost 5,000 eggs per m^3 were taken on the north side of the pass) and on 5 October. This indicates that redfish spawning occurs in September and early October.

Laboratory and field data indicate that spawning takes place near dusk and, in 27-30°C water the eggs hatch in about 18 hours. All samples were taken between 0900 and 1030 hrs or about 12 hours after spawning. Given an average long shore current speed of 1/4 to 1/2 knot it is probable that the eggs were spawned within 3 to 5 miles of the pass.

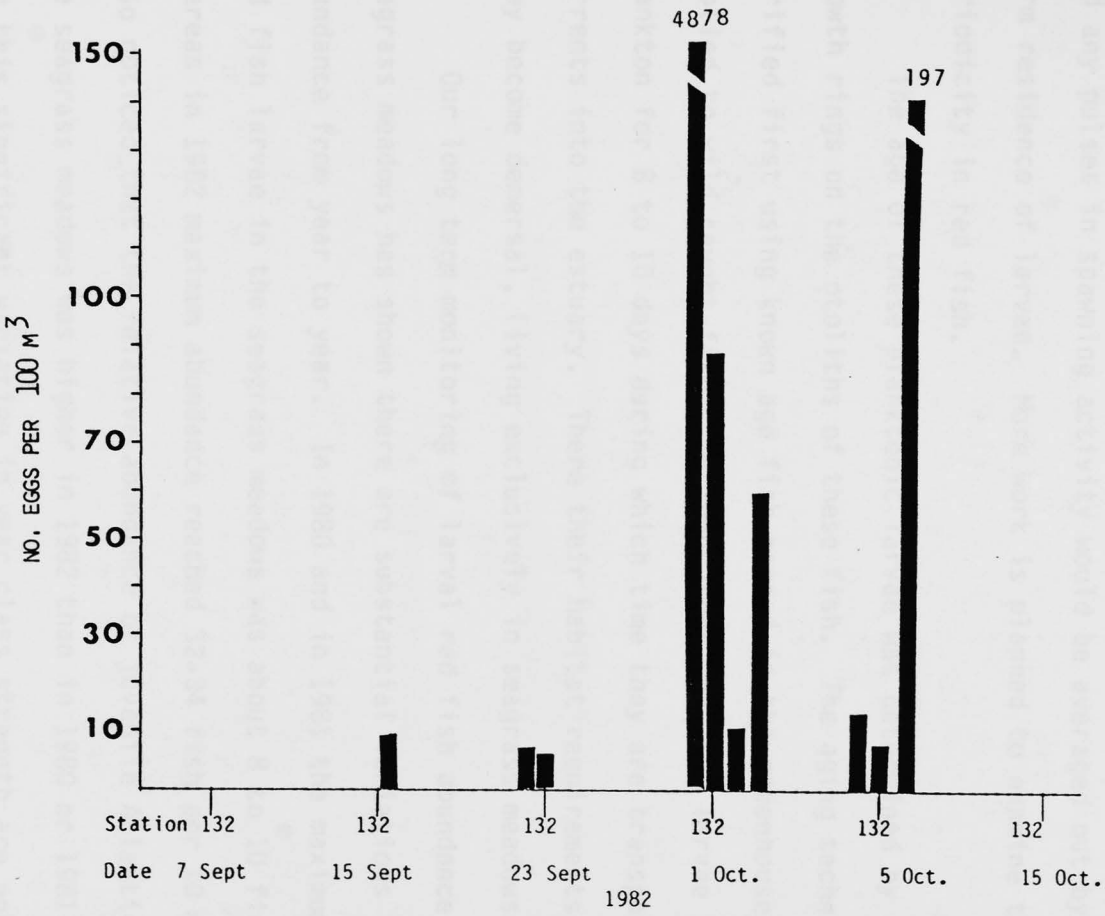


Figure 5. Number of redfish eggs taken in surface plankton tows within 1 mile of the Aransas Pass during the fall 1982.

Red fish larvae were also captured in the icthyoplankton samples and were present in the plankton over a longer priod of time than the eggs (Figure 6). This is to be expected since early larvae remain in the plankton for several days (see below) compared with only 18 hours for eggs and any pulses in spawning activity would be averaged out by the longer term residence of larvae. More work is planned to examine this spawning periodicity in red fish.

The age of these planktonic larvae was determined by counting daily growth rings on the otoliths of these fish. The aging techniques were verified first using known age fish reared in the greenhouse and then applied to wild caught fish. We found that red fish larvae remain in the plankton for 8 to 10 days during which time they are transported by tidal currents into the estuary. There their habitat requirements change and they become demersal, living exclusively in seagrass meadows.

Our long term monitoring of larval red fish abundance in the seagrass meadows has shown there are substantial variations in relative abundance from year to year. In 1980 and in 1981 the maximum abundance of red fish larvae in the seagrass meadows was about 8 to 10 fish per 10 m^2 whereas in 1982 maximum abundance reached 32-34 fish per 10 m^2. It was also noticed that the relative abundance of juvenile Atlantic croaker in the seagrass meadows was higher in 1982 than in 1980 or 1981. The causes for this significant variation in year class strength are unknown, but long term monitoring of the annual recruitment rates of red fish and other sciaenids which have similar life histories, while making concurrent measurements of abiotic factors (such as temperature and salinity) which might influence egg and larval survival, should help us elucidate those factors which regulate year-class strength.

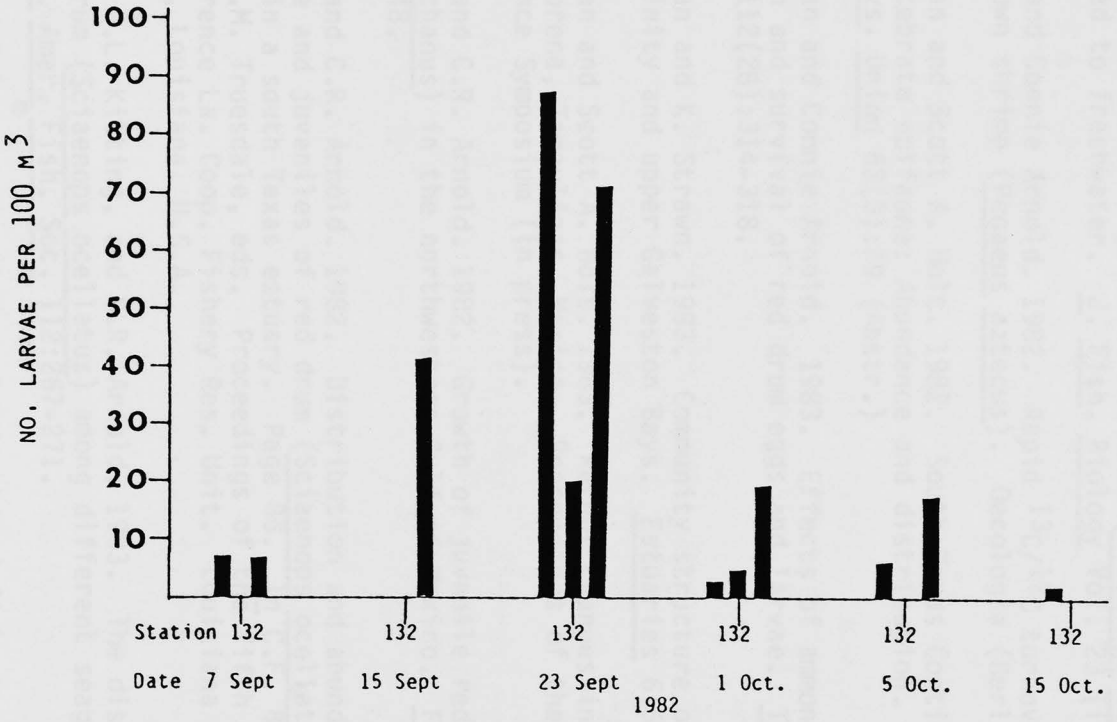


Figure 6. Number of redfish larvae taken in surface plankton tows within 1 mile of the Aransas Pass during the fall 1982.

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"Seasonal occurrence of some marine teleost eggs near Port Aransas, Texas". By: Scott A. Holt and G. Joan Holt at the Annual Gulf Estuarine Research meetings, Marineland, Florida in November, 1982.

"Sea Grant Aquaculture Plan 1983-1987", G.J. Holt was member of the Aquaculture Systems working group and C.R. Arnold was group leader of the Marine Fishes Section, TAMU, 1982.

"Recent changes in the avifauna of the Rio Corona Tamaulipas, Mexico". By: G. Joan Holt and Scott A. Holt at the Tamaulipan Biotic Province Symposium, Corpus Christi, Texas in October, 1982.

"Age and growth of young red drum using otolith counts". By: Scott A. Holt, J. Gourley and C. Arnold at the 7th Annual LFC, Fort Collins, Colorado, January, 1983.

"Informal workshop on Current Research in Otolith Work". Chaired by Scott A. Holt, at the 7th Annual LFC, Fort Collins, Colorado, January, 1983.

"Ontogenetic changes in habitat preferences by red drum in South Texas estuaries" in a Symposium on "Early Life History Strategies of Fishes" by Scott A. Holt at 113 Annual A.F.S., Milwaukee, August, 1983.

"Growth characteristics of red drum (Sciaenops ocellatus) larvae raised in the laboratory". By W.Y. Lee, G.J. Holt and C.R. Arnold at the 7th Annual L.F.C. Fort Collins, Colorado, January, 1983.

"Growth and development of larval and post larvae red drum with a comparison of lab reared and wild caught fish". By: G. Joan Holt and C.R. Arnold at the 7th Annual L.F.C. in Fort Collins, Colorado, January, 1983.

"Possible Application of HPLC to in vitro Incubation of Teleost Steroidogenic Tissue". By: J.M. Trant and P. Thomas at American Society of Zoologists Annual General Meeting, Louisville, KY, December 1982.

"Interactions of Glutathione and other Acid Soluble Thiols with Cadmium in Striped Mullet (Mugil cephalus)". By: H.W. Wofford & P. Thomas at American Society of Zoologist Annual General Meeting, Louisville, KY, December 1982.

"Effects of Pollutants and Other Environmental Variable on the Ascorbic Acid Content of Fishes Tissues". By: P. Thomas & J.M. Neff at Second International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole, MA. April 1983.

"Elevated Acid Soluble Thiol Content in Fish Hepatic Tissue: A Response to Pollutants". By: P. Thomas & H.W. Wofford at Second International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole, MA, April 1983.

"Tissue Thiols in Striped Mullet: Interations with Cadmium". By: H.W. Wofford & P. Thomas at Second International Symposium on Responses of Marine Organisms to Pollutants, Woods Hole, MA., April 1983.

"Concentation Dependent Attration/Avoidance to Skin Extracts of Black Bullhead Catfish". By: P.J. Rubec & P. Thomas at Fourth Biennial Conference on Ethology and Behavioral Ecology of Fishes, Normal May 1983.