

Growth, Mortality, and Condition of Cottonwick in the Gulf of Mexico

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Abstract: Scales and otoliths of cottonwick, *Haemulon melanurum*, collected on 2 reef sites in the northwestern Gulf of Mexico were examined for usefulness in determining age. Scales were used to estimate age. Back-calculated lengths at annulus formation ranged from 158 mm fork length (FL) (age 1) to 352 mm FL (age 11). No difference in growth was observed between areas, but there was significant year-to-year variation in mean FL for age-classes 2–5. There was no difference in parameters of the von Bertalanffy model due to area of collection. The equation was $FL_t = 350(1 - e^{-0.32(t + 0.1)})$. Annual instantaneous mortality (Z) differed significantly between reefs (0.77 vs 0.95), with a weighted mean of 0.90. The length: weight relationship was $W = 0.00013 FL^{2.6614}$. Variation in condition between seasons and areas was attributed to normal variation in gonadal weight due to reproductive cycles.

Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 39:34–44

The cottonwick, *Haemulon melanurum* (Haemulidae), is reported from reef habitats off Bermuda and the southeastern Atlantic Coast of the United States through the Gulf of Mexico and Caribbean Sea to Brazil. It is taken in recreational, commercial, and artisanal fisheries, particularly in the West Indies (Fischer 1978), but is of particular interest because it is virtually unexploited in the northwestern Gulf of Mexico. The cottonwick is a nocturnal, benthic predator on small fish, echinoderms, crabs, nudibranchs, and other invertebrates (Randall 1967, R. S. Nelson, unpubl. data). There is no previously published information regarding the population dynamics of the species. In this study age, growth, and annual mortality of cottonwick are estimated at 2 reef sites in the northwestern Gulf of Mexico.

This work was funded by the U.S. Environmental Protection Agency (EPA–79–D–X0514) and the Southeast Fisheries Center of the National Marine Fisheries Service. Acknowledgements are extended to D. Mason and C. S. Manooch of the Beaufort Laboratory; G. Gitschlag, M. Renaud, and E. Klima of the Galveston Laboratory, National Marine Fisheries Service, Southeast Fisheries Center; and to L. Martin, G. Boland, and B. Gallaway of LGL Ecological Consultants, Inc. for assistance during the course of this work.

Methods

Cottonwick were sampled seasonally from the East (EFG) and West (WFG) Flower Garden Banks during 8 cruises:

Fall 1980 (10/30–11/6, 11/19–11/23);
Winter 1981 (1/22–1/28);
Spring 1981 (4/13–4/24);
Summer 1981 (7/7–7/18);
Fall 1981 (10/15–10/22, 10/29–11/01);
Spring 1982 (4/27–5/07);
Summer 1982 (7/31–8/11);
Fall 1982 (10/19–10/30).

Located approximately 120 nautical miles southeast of Galveston, Texas, the Flower Garden Banks rise from the 130 m contour to within 16 m of the surface at their shallowest expression. Both banks have been fished historically by the Gulf of Mexico snapper fishery, and have been studied extensively over the last 10 years (Bright and Pequenat 1974, Brooks et al. 1979, Bright et al. 1980, Boland et al. 1983).

Fish were collected using hook-and-line, rectangular 0.65 m³ traps of 50 × 100 mm and 22 × 48 mm polyvinyl mesh baited with squid, submerged gill nets with 75 cm² mesh, and SCUBA divers using pole spears. Hook-and-line fishing was concentrated between 1900 and 0200 hours, traps and gill nets were set in the early evening and retrieved the next day; diver collections were during the day.

All fish were weighed (g) and fork length (FL) was measured to the nearest mm within 1 hour of capture. Scales and otoliths (sagittae) were removed and prepared for examination following procedures described by Nelson and Manooch (1982). Gastrointestinal tracts and gonads were removed and preserved for subsequent analyses. Observations on salinity, temperature, sigma-t, transmissivity, and dissolved oxygen were gathered at both banks during all cruises.

Mounted scales were examined on a Eberbach projector (27X). Measurements were taken on each legible scale from the focus to each observed ring and the scale edge. Otoliths and otolith sections (Nelson and Manooch 1982) were submerged in clove oil in a blackened watch glass and examined under reflected light with a microscope at 12X. In whole otoliths, counts were made from the focus to each ring and the dorsal edge; sectioned otoliths were counted along the medioventral ridge.

Legible scales and otoliths were read 3 times over intervals of at least 1 month. When disparities between readings exceeded 3 years the sample was rejected, otherwise the modal or mean age was selected as the estimated age.

Mean marginal growth (i.e. the amount of growth between the last presumed annulus and the edge of the scale or otolith) was calculated for all age classes by season of collection in order to evaluate the assumption of annual ring formation. A distinct seasonal minimum for marginal growth values would support the hypothesis

of annual formation. Additional evidence of the validity of age estimates was taken from the correspondence between 1) increases in estimated age and fish length, 2) the relationship between growth in body length and growth along a dimension of the aging structure, 3) correspondence between age estimates from separate structures (i.e. scales and otoliths) from the same fish, and 4) for direct evidence of growth over time, an analysis of data collected in a mark-recapture study conducted concurrently with this work (Boland et al, 1983).

The relationship between fish length and scale radius was described by regressing the natural logarithm of (\ln) of FL on \ln scale radius. ANCOVA was used to test the effect of fish sex, area, and cruise of collection on this relationship. The resulting equation was used to back-calculate FL at the time of annulus formation.

An ANOVA using least square means in orthogonal contrasts was used to test differences in mean observed FL due to cruise and area of collection. The youngest 5 age classes sampled for the 3 fall cruises (1980–1982) were used in the analysis. Least square means were used because of the unbalanced nature of the model, while the youngest age classes were selected for this analysis because rate of growth during the earliest years of life is greatest, growth differences should be most discernible, and age determinations are generally most reliable for the youngest age classes.

A test of differences in condition was conducted by regressing \ln body weight on \ln FL and using ANCOVA to test the area, cruise, and interaction effect on the slopes of the regressions. This test is tantamount to calculating an allometric condition factor (Ricker 1975) for each cruise and area combination and testing for differences.

Back-calculated length at age data were fit to the von Bertalanffy growth model using the Marquardt method and nonlinear regression techniques (Ray 1982). Growth models were fit to data from the EFG, WFG, and to all data pooled. Differences in the models were tested using a maximum likelihood ratio test (Nelson and Manooch 1982).

Instantaneous mortality rates (Z) for fish sampled by hook-and-line were calculated using the regression method (Ricker 1975). Age-length keys were derived separately for each sampling period and catch curves were constructed using all fish collected during each period. Differences in Z were tested using ANCOVA. An inverse-variance weighted mean Z (Snedecor and Cochran 1967) was calculated from the results of all regressions.

Results and Discussion

Both scales and sectioned otoliths exhibited patterns of an apparent cyclical nature. Whole otoliths were not generally legible. Markings on otoliths became increasingly difficult to interpret in fish > 270 mm FL. Growth bands in larger fish began to overlap along the otolith margin in apparent response to a reduction in otolith growth along the dorsal-ventral axis and an increase in growth along the proximal-distal axis. Scales were legible from most fish < 310 mm FL and from

some fish as large as 360 mm, thus scales were used for most age estimates. Illegible scales were either regenerated, exhibited no discernible changes in density patterns of circuli, or had patterns which could not be reliably counted. Otoliths from fish < 260 mm FL were randomly subsampled, sectioned, and used in a pairwise comparison with scales (Table 1).

Eighty-one percent (549 of 677) of all scale samples examined exhibited interpretable growth rings composed of patterns of compressed circuli. Observed rings were defined by clear cutting-over of circuli in the postero-lateral fields in conjunction with increased intra-circular distances in the anterior field. Rings which were distinct around the non-ctenoid portion of the scale were counted as annuli (Grimes 1978, Nelson and Manooch 1982).

Validation of age estimates

Marginal increment analyses of cottonwick with estimated ages 3–7 years indicate singular minima (Fig. 1). For fish age 3–5, the minimum mean increment occurred during Spring. Fish age 6–7 exhibit apparent Summer minima. Other ages were not represented in the sample from all seasons. A Wilcoxon Signed Rank test (Steel and Torrie 1980) revealed no significant ($P > 0.25$) difference in age estimates derived from scale: otolith pairs removed from the same fish (Table 1). Five of 20 cases were discordant, involving discrepancies of one year.

Observed FL increased regularly in relation to estimated age (Fig. 2, Table 2). The relation between FL and scale diameter was

Table 1. Age estimates derived from cottonwick scales and otoliths during Fall 1980 and Winter 1981 cruises on the East and West Flower Garden Banks.

Cruise	FL	Scale estimate	Otolith estimate
Fall 1980	189	2	2
"	201	2	2
"	204	2	2
"	212	2	2
"	224	2	3
"	227	2	2
"	228	2	3
"	242	3	4
"	243	3	3
"	254	6	5
"	254	3	3
"	255	5	5
"	257	5	5
"	259	4	4
"	259	5	5
Winter 1981	211	2	2
"	225	2	2
"	226	2	2
"	241	3	3
"	252	3	4

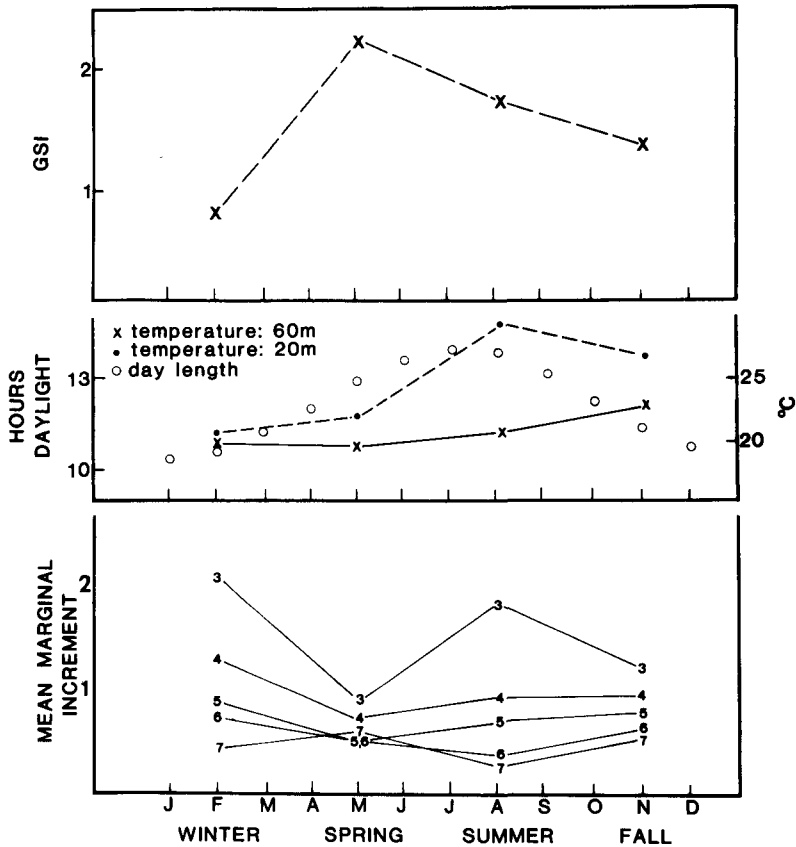


Figure 1. Seasonal mean marginal scale increment for all cottonwick age 2–7 sampled on the East and West Flower Garden Banks, 1980–1982. Day length in hours and mean water temperature (C) at 20 m and 60 m depths on the Flower Gardens, and mean gonosomatic index (GSI = ovary wet weight/body wet weight) for all female cottonwick sampled during the same period.

$$FL = 79.77e^{(0.00525 A)}, r = 0.99, N = 549,$$

where A is the scale diameter (mm/27), indicating a direct relationship between scale growth and growth in fish length. The equation was used to back-calculate FL at age for all samples.

Twenty of 1,868 tagged cottonwick were subsequently recaptured. Fish at large longer than 1 day showed growth rates of 0.4 mm/day to -0.01 mm/day, with a mean of 0.04 mm/day or 14.6 mm/year. Recaptured fish averaged 279 mm FL at the time of tagging. Age 6 cottonwick examined in this study averaged 274 mm FL and mean annual increment for the age class was 14 mm/year (Table 2). Observed growth in recaptured cottonwick corresponds closely to the empirical back-calculated growth rate.

The data presented support the hypothesis of annual ring formation. Marginal scale growth minima coincide with periods of increasing photoperiod, temperature, and gonadal development (Fig. 1), and it seems likely that ring formation is coincident with gonadal maturation, possibly associated with the resorption of calcium salts during oogenesis. Differences in the time of annulus formation among age groups may be an indication that spawning periods differ among age classes, but it is equally likely that the actual period of formation occurs between spring and summer sampling seasons used in this study, and apparent differences are merely an artifact of the sampling periodicity.

Growth rate

Estimates of mean observed and back-calculated length at age for cottonwick from the EFG and WFG were not significantly different ($P > 0.13$), and back-calculated lengths were consistent across all age classes (Table 2). There was no difference in growth between the sexes ($P > 0.10$) (Fig. 2).

Year of collection had a significant effect on observed FL for ages 2–5 collected during the 3 fall cruises (Table 3). Age 2 fish were smaller in 1980 than in 1981, the only other year they entered the sample. Age 3 fish were largest in 1981 and differed significantly among all years. Four and 5-year-old fish collected during fall 1981 were slightly, but significantly, smaller than those collected during fall 1982.

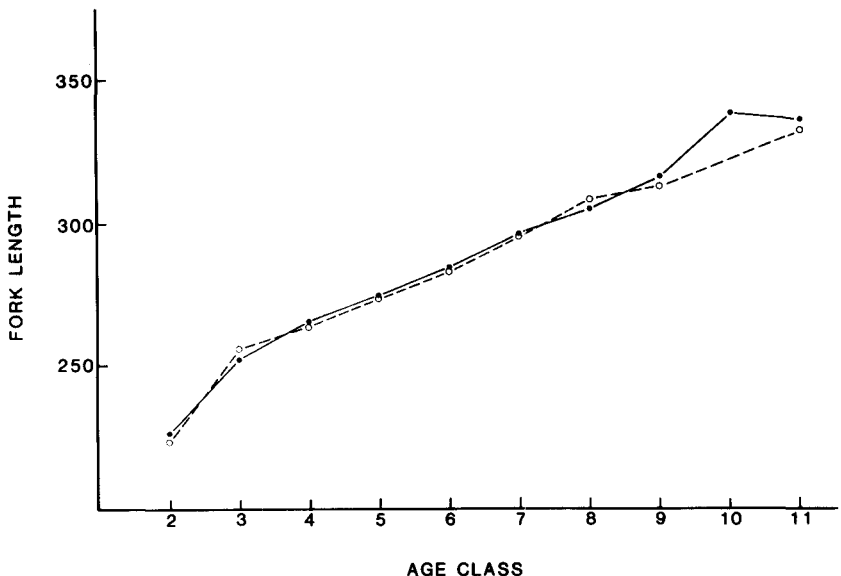


Figure 2. Mean observed fork length (mm) at age for male and female cottonwick collected on the East and West Flower Garden Banks, 1980–1982. Open points represent females, closed points males.

Table 2. Mean observed and back-calculated FL (mm) with standard error (SE) and sample size (N) by age for cottonwick sampled at the East (EFG) and West Flower Garden (WFG), and back-calculated FL at time of annulus formation by age for all samples pooled, 1980–1982.

Age	WFG						EFG					
	Observed			Back-calculated			Observed			Back-calculated		
	N	FL	SE	N	FL	SE	N	FL	SE	N	FL	SE
1				187	158	0.7				336	158	0.6
2	11	222	3.6	187	197	1.0	11	223	3.5	336	200	0.8
3	18	253	2.1	176	225	1.1	29	255	3.2	325	229	0.8
4	18	262	1.2	158	244	1.2	69	265	0.9	296	248	0.8
5	18	272	1.9	140	259	1.4	99	275	1.4	227	263	1.1
6	35	286	1.9	105	272	1.7	68	284	1.8	128	276	1.7
7	32	299	2.1	66	285	2.5	37	297	2.2	60	291	2.8
8	20	306	3.5	34	297	4.3	18	306	3.2	23	308	3.7
9	8	317	3.8	14	310	9.5	1	310	~	5	325	12.0
10	2	331	11.1	5	329	5.1	3	342	8.9	4	347	14.6
11	3	343	6.7	3	341	7.3	1	333	~	1	383	~

Back-calculated age at annulus formation												
Age at capture	N	1	2	3	4	5	6	7	8	9	10	11
1	0											
2	22	158	201									
3	48	159	202	233								
4	86	158	200	230	250							
5	134	159	199	229	248	264						
6	105	156	197	224	244	259	273					
7	71	160	200	228	246	262	275	288				
8	38	157	195	222	243	260	275	288	301			
9	10	154	194	219	236	251	266	279	293	304		
10	5	152	192	229	253	269	283	299	310	324	337	
11	4	152	185	216	239	259	280	299	314	326	338	351
Mean length	523	158	199	228	247	261	274	288	301	314	337	351
Mean increment		158	41	29	19	14	13	14	13	13	23	14

Mean back-calculated growth of 158 mm during the first year decreased to 41 mm during the second year, 29 mm during the third, and varied between 13 and 23 mm/year thereafter.

There was no significant difference ($P > 0.87$) in the parameters of the von Bertalanffy growth model between EFG and WFG fish. The best estimate for both areas pooled was

$$FL_t = 350(1 - e^{-0.32(t + 0.1)});$$

where L_t is FL at time t in years, 350 is the calculated value for the mean asymptotic FL, 0.32 is the calculated value for the growth coefficient k , and -0.1 is t_0 , the theoretical age of zero length.

Results of this study are consistent with previous studies of growth in the congenics *Haemulon plumerei*, *H. aurolineatum*, and *H. flavolineatum*; the white

grunt, tomtate, and French grunt, respectively. Scales and otoliths have been used to estimate ages for the white grunt and tomtate (Manooch 1978, Manooch and Barans 1982). White grunt collected off North Carolina and South Carolina had a mean back-calculated FL of 97 mm at age 1 and annual increments of 88 mm to 23 mm from ages 2–12, reaching a maximum age of 13 and a maximum FL of 550 mm (Manooch 1978). Tomtate from the South Atlantic Bight had a mean back-calculated FL of 103 mm at age 1 and annual mean increments of 66 mm to 8 mm FL between ages 2 and 9, attaining a maximum FL of 281 mm (Manooch and Barans 1982). Brothers and McFarland (1980) used daily rings on otoliths to determine growth over the first 100 days of life for the French grunt. Their estimate of mean standard length (SL) of 40 mm at 100 days (0.40 mm/day) is comparable with estimates of first year growth in cottonwick (136 mm in SL; 0.37 mm/day). French grunt and cottonwick reach similar maximum sizes (Randall 1983) and have similar feeding habits (Randall 1983, R. S. Nelson, unpubl. data).

Condition

For all cottonwick collected the relationship between weight (W in g) and FL (mm) was

$$W = 0.0001312 FL^{2.6614}$$

There was no significant difference between areas, but cruise and the cruise by area interaction yielded significant ($P < 0.0001$) differences. The expected weight for a 300 mm FL cottonwick is 514 g when calculated from all data. The source of variation in the regressions is explained by a reduction in the exponent for fish collected on the WFG during fall 1980 (452 g at 300 mm FL, exponent = 2.6392) and spring 1981 (459 g, 2.6419) and from both banks in winter 1981 (468 g, 2.6454), fall 1981 (481 g, 2.6501), and spring 1982 (481 g, 2.500). These periods are all coincident

Table 3. Mean observed FL (mm) at age for cottonwick age 2–5 during Fall 1980–1982. Significance levels for ANOVA of between year effects and null hypotheses of equal mean FL are given for all contrasts.

Age class	(P) years	FL		Contrasts		
				1980	1981	1982
2	<0.0500	215	1980			
		234	1981	<0.05		
3	<0.0001	246	1980			
		264	1981	<0.01		
		253	1982	<0.07	<0.01	
4	<0.0500	263	1980			
		269	1981	>0.15		
		262	1982	>0.85	<0.02	
5	<0.0001	266	1980			
		279	1981	<0.01		
		272	1982	<0.02	<0.01	

with seasons of little or no observed gonadal activity (Fig. 1). Differences in condition resulted from normal variation on gonadal weight associated with reproductive cycles.

Mortality

Mortality rates did not differ significantly among cruises, ($P > 0.35$), but a significant ($P < 0.001$) difference was detected between the 2 banks (Table 4). Adjusted instantaneous mortality rates were 0.95 for the WFG and 0.77 for the EFG, and are assumed to represent natural mortality. The pooled (EFG and WFG) weighted estimate of Z was 0.90.

The methods used to estimate mortality are subject to the major assumptions that: 1) natural and fishing mortality have remained constant over the time span represented by the oldest fish in the population with constant size-specific recruitment; 2) the sample used in estimating age is a random subsample of the population for which mortality estimates are calculated; 3) the age-length keys must be applied to fish subject to the same growth and survival rates as the fish used to derive it; and 4) for the population in question all size classes corresponding to the age series used in mortality estimation should be present in the area of collection (Robson and Chapman 1961, Ricker 1975, Kimura 1977, Westrheim and Ricker 1978).

Historical catch records indicate that cottonwick are not a target species of commercial fishing operations in the Gulf of Mexico (Gulf of Mex. Fish. Manage. Council 1980). Since there is little recreational fishing on the Flower Gardens, survival can be assumed constant to the extent that natural mortality has been constant. Mortality estimates derived from the regression technique are least sensitive to minor violations of this assumption (Ricker 1975, Robson and Spangler 1978).

Age estimates were obtained from a random subsample of the total catch. Ages (6–10 years) used in the estimation of mortality were selected in order to eliminate

Table 4. Modal and mean age of the sample in years, and instantaneous rates of total (Z) mortality for cottonwick sampled on the East (EFG) and West (WFG) Flower Gardens during fall (F), winter (W), spring (Sp), and summer (SO) (1980–1982). Indicated age series were used in mortality estimates

Area	Season	N	Mean age	Modal age	Age series	Z	SE	r
EFG	F80	109	5.3	6	6–8	1.39	0.61	–0.91
WFG	"	596	6.0	6–7	7–10	1.37	0.32	–0.95
WFG	W81	339	6.1	6	6–10	1.02	0.08	–0.99
EFG	Sp81	56	4.8	4–5	6–8	0.55	0.41	–0.80
WFG	"	185	5.9	7	7–10	0.74	0.14	–0.97
EFG	S81	86	4.8	4–5	6–7	1.10	~	~
WFG	"	84	6.1	5	5–10	0.48	0.07	–0.96
EFG	F81	89	5.0	4–5	6–9	0.94	0.22	–0.95
EFG	Sp82	211	5.3	5	6–9	0.92	0.29	–0.92
EFG	S82	516	5.9	6	6–10	0.89	0.39	–0.79
EFG	F82	89	5.3	5	6–8	0.35	0.20	–0.87

inclusion of small fish which were under-represented by the sampling gear used. Unique age-length keys were constructed on a cruise-by-cruise basis, and as there was no significant variation in age-length distributions between areas within each cruise, the technique should not appreciably bias estimates of mortality (Westrheim and Ricker 1978).

The final assumption was addressed by analyzing age-specific depth distributions over the range of depths sampled (16 m to 103 m). There was no indication of segregation by age, and it appears that all ages were equally likely to be encountered at all depths.

Mortality rates for cottonwick are similar to those calculated for tomtate, *H. aurolineatum*. Manooch and Barans (1982) estimated instantaneous annual mortality ranging from 0.67–1.04 over the years 1974–1978 from the hook-and-line catch of tomtate collected off the Carolinas. In a study of the white grunt, Manooch (1978) estimated annual instantaneous mortality at 0.46 to 0.55 (1972–1974). Higher mortality rates for tomtate and cottonwick are likely the result of differing rates of predation. While the white grunt attains lengths in excess of 550 FL mm, both the tomtate (290 mm) and cottonwick (350 mm) are smaller fish more likely to encounter potential predators than the larger white grunt. Differences in mortality detected between reefs indicate that yield models might be improved by incorporating variable natural mortality rates for different components of the stock being managed.

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