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AGE, GROWTH, AND MORTALITY OF BLUE RUNNER, *Caranx crysos* FROM THE NORTHERN GULF OF MEXICO

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ABSTRACT: Estimates of age, growth, and mortality for blue runner obtained from commercial fisheries in northwest Florida and the Mississippi delta were developed using otolith sections. The oldest fish was 11 years old, the largest was 460 mm fork length. Mean back-calculated fork lengths varied from 212 mm at age 1 to 422 mm at age 11. The von Bertalanffy equation for combined sexes was $FL_t = (1\text{-}e^{-0.35(t + 1.07)})$ where FL = fork length (mm) and t = age (years). Regression equations for the interconversion of fork length (FL), standard length (SL), and total length (TL) were:

$TL = -7.4792 + FL\,(1.1938)$, ($r = 1.00$, $\alpha = 0.01$),
$FL = 1.9453 + SL\,(1.0596)$, ($r = 1.00$, $\alpha = 0.01$), and
$TL = -5.1694 + SL\,(1.2651)$, ($r = 0.99$, $\alpha = 0.01$).

The weight-length relationship for combined sexes was $W = 0.0000251355\ FL^{2.94593}$ ($N = 193$, $r = 0.98$, $\alpha = 0.01$) where W = whole body weight in grams and FL = fork length in millimeters. Estimates of annual mortality, determined by four methods, ranged from 0.41 to 0.53.

The blue runner (*Caranx crysos* Mitchill 1815) is a coastal pelagic species found in the western North Atlantic, from Nova Scotia to Brazil (McKenney, Alexander, and Voss 1958). It is abundant along the southeast coast of the United States, throughout the West Indies and, seasonally, in the northeast Gulf of Mexico (Berry, 1959; Ginsburg, 1952). A commercial beach seine fishery for this species exists in the northeastern Gulf of Mexico with annual landings of approximately 600 metric tons (Anonymous 1980). Recently, there has been increasing interest in this relatively unexploited species and landings may increase substantially in the near future.

Very little work has been done on age and growth of blue runner. Munro (1974) provided a weight-length equation of $W = 0.0056\ TL^{3.302}$ where W = weight (g) and TL = total length (mm), and estimates of 620 mm TL for maximum length and 5,400 g for maximum weight for blue runner from the Caribbean Sea. Berry (1965) provided a maximum recorded length of 711 mm and estimated maximum weight of 2,724 g. Reintjes (1979) stated that no data were available on age-size relationships, growth rates, age-at-first-spawning, life expectancy, mortality rates and sex ratios. In this paper we provide estimates of maximum age, size at age, and mortality rates as well as von Bertalanffy growth curves and regression equations for length-weight and length-length conversions.

METHODS

Fresh blue runner were purchased

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from commercial fisheries (1980 through 1982) for this study. They were weighed for total body weight to the nearest gram and measured for fork length (FL) to the nearest millimeter. Stratified sub-sampling techniques of Ketchen (1950) were used to select blue runner from northwest Florida and Mississippi delta catches for age, growth, and mortality studies. Otoliths (sagittae), scales, dorsal spines and scutes were collected from 10 blue runner in a preliminary evaluation of their utility in determining age. Scales and scutes were found to have indistinct and inconsistent marks and were rejected. Whole otoliths, sections from otoliths and dorsal spines were found to have marks that were suitable for age determination, but the marks on otolith sections were superior in clarity and consistency.

Both otoliths were removed from each fish and stored dry in vials. Two or three cross-sections, 0.15 mm thick, were cut from the core of each otolith on a low-speed saw following the methods of Berry, Lee, and Bertolino (1977) and were mounted on glass slides using Protexx[3] mounting medium. A closed-circuit television system was used for examining cross-sections at 140X magnification with both transmitted and reflected light.

Annuli were counted and their distances from the core were measured along the axis indicated in Fig. 1. The margin of each otolith section was examined to determine if an annulus was being formed at the time of capture. Age was determined a second time for a sub-sample of 100 otolith sections and compared with the first age determination for these otoliths in order to evaluate the accuracy of annuli counts.

[3]Reference to trade names does not constitute endorsement by the National Marine Fisheries Service, NOAA.

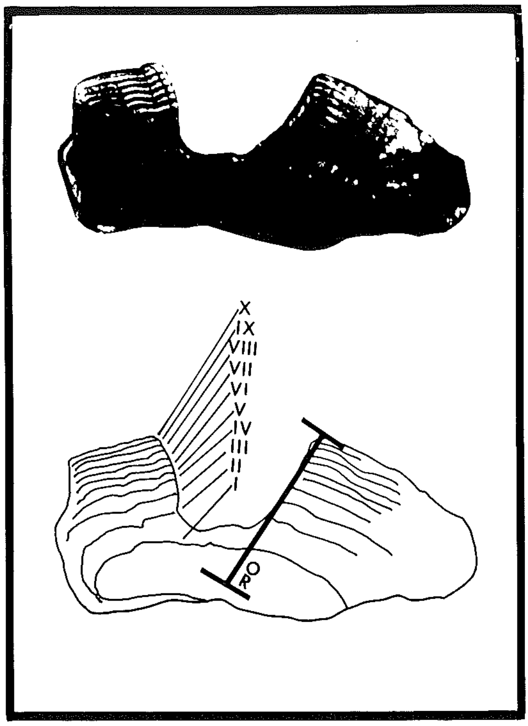

Figure 1. Cross section of a blue runner otolith from a 10-year-old male (420 mm FL) collected August, 1981 off the Mississippi Delta.

The relationship between otolith radius and fork length was determined by least squares regression and was used to back-calculate fork lengths at the time of annulus formation. The resulting length-at-age data were used to determine mean length-at-age which was plotted against age to produce a back-calculated growth curve. Growth curves derived from empirically observed length at age of capture and from the theoretical growth equations of von Bertalanffy (Ricker 1975) were plotted for comparison (computer program by Abramsom 1971).

Back-calculated length-at-age data were used to construct an age-length key which was used to convert fork length data to estimates of age. Age structures were derived for two Mississippi delta length-frequency samples, one sample of 990 fork length measurements taken from a single day's catch in August 1981, and one sample of 1,088 fork length measurements taken from a single day's catch in September 1981. The resulting age structures were used for estimation of annual mortality (a), annual survival (s), instantaneous mortality (z) by the methods of Jackson (1939), Heincke (1913), Robson and Chapman (1961), and finding the slope (m) of a regression line fitted to ln (N_y) and Y, where N_y is number of fish caught in age group Y, then substituting in the equation $a = 1\text{-}e^m$. Length-weight and length-length (fork length-total length-standard length) relationships were determined by least squares regression using measurements in millimeters and grams from 177 to 193 fish, depending on the kind of length (following methods of Ricker 1975).

RESULTS AND DISCUSSION

Examination of otolith-section margins showed that marks were being formed during all months for which blue runner from northwest Florida and the Mississippi delta were taken. A majority of the fish collected from June to October in northwest Florida and from July to September in the Mississippi delta were forming annuli at the margins, indicating that summer was a season of peak annulus formation (Fig. 2). The lack of otolith samples from winter months, however, precludes a definitive statement on the annual nature of these presumed annuli.

Growth of the otolith was found to be proportional to the growth of the fish: $FL = 22.9 + OR^{0.679815}$ ($r = 0.86$, $\alpha = 0.01$) where FL = fork length in mm and OR = otolith radius in units of 0.0071 mm. This equation was used for back-calculation of fork length at time of annulus formation for 726 otolith sections which were assigned to age groups. Duplicate age determinations for 100 otolith sections produced exact agreement for 94% of the readings and + or − one year agreement for 100% of the readings. The six readings differing by + or − one year were all for older fish whose annuli where crowded at the margin.

The appearance and spacing of annuli in blue runner otoliths are similar to that seen in king mackerel (*Scomberomorus cavalla*) by Beaumariage (1973) and by Johnson *et al.* (1983) and in Spanish mackerel (*Scomberomorus maculatus*) by Powell (1975). Because of this and the findings on marginal increment analysis, proportionality of otolith growth, and repeatability of annuli counts, the marks on otolith sections were presumed to have been deposited once each year (Fig. 2).

Blue runner is a fast growing, moderately long-lived species which typically attains 75% of its maximum

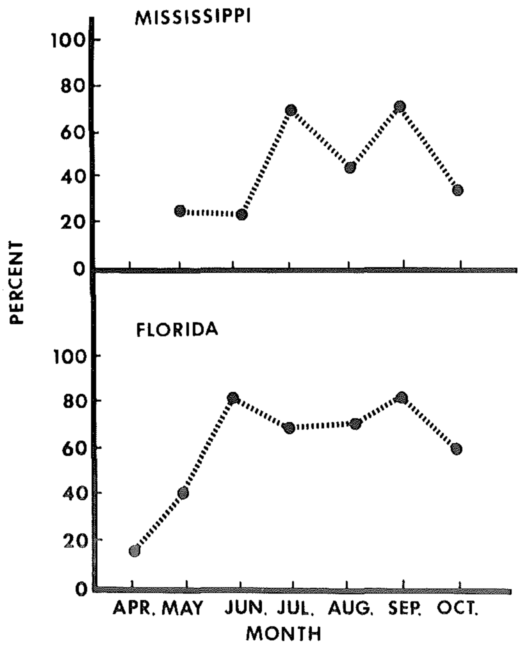

Figure 2. Percentage of blue runner forming opaque zone at margins of otoliths by month, sexes combined, from the northeastern Gulf of Mexico, 1980-82.

Table 1. Back-calculated fork lengths-at-age (mm) for female blue runner collected from the Mississippi delta and northwest Florida during 1980-82.

Age class	N	Mean empirical length ± ISD	Presumed Annulus 1	2	3	4	5	6	7	8	9	10	11
I	83	238 ± 33.3	219										
II	183	275 ± 34.6	212	269									
III	43	342 ± 34.2	224	228	335								
IV	31	364 ± 28.1	216	281	326	359							
V	7	397 ± 16.5	215	282	328	364	391						
VI	8	401 ± 8.8	205	269	210	344	374	397					
VII	5	371 ± 45.7	166	233	277	306	329	348	365				
VIII	11	410 ± 9.5	189	248	286	319	343	366	386	404			
IX	3	419 ± 2.6	197	253	284	314	337	359	379	399	418		
X	0	— —	—	—	—	—	—	—	—	—	—	—	
XI	2	414 ± 2.1	184	231	267	296	320	399	357	374	389	402	414
Weighted mean back-calculated length			214	271	320	343	356	369	377	400	406	402	414
± ISD			± 27.1	± 31.1	± 32.6	± 31.7	± 29.4	± 27.3	± 25.0	± 12.2	± 15.8	± 0.0	± 2.1
Number of back-calculations contributing to means			376	293	110	67	36	29	21	16	5	2	2
Annual growth increment			214	57	49	23	13	13	8	23	6	-4	12

Table 2. Back-calculated fork lengths-at-age (mm) for male blue runner collected from the Mississippi delta and northwest Florida during 1980-82.

Age class	N	Mean empirical length ± ISD	Presumed Annulus 1	2	3	4	5	6	7	8	9	10	11
I	59	234 ± 27.7	219										
II	174	270 ± 31.7	209	265									
III	46	328 ± 39.1	220	281	322								
IV	15	363 ± 33.6	220	285	326	357							
V	9	398 ± 15.0	215	478	323	359	387						
VI	8	395 ± 15.6	196	258	304	339	368	391					
VII	10	404 ± 22.7	192	257	298	332	358	381	399				
VIII	8	412 ± 21.7	194	356	297	327	352	374	394	410			
IX	4	417 ± 1.7	183	249	293	320	344	363	381	396	413		
X	4	415 ± 9.7	175	229	267	299	323	344	362	379	397	413	
XI	1	451 ± —	165	254	294	326	352	372	384	400	412	427	439
Weighted mean back-calculated length			211	267	314	340	360	375	389	399	406	416	439
± ISD			± 26.8	± 30.8	± 32.3	± 26.8	± 23.6	± 20.6	± 20.4	± 20.2	± 11.7	± 12.2	± —
Number of back-calculations contributing to means			338	279	105	59	44	35	27	17	9	5	1
Annual growth increment			211	56	47	26	20	15	14	10	7	10	23

size in its first 3-4 years of life. The oldest fish in this study was estimated to be 11 years and the largest fish was 460 mm FL.

Back-calculated and empirical fork lengths-at-age are presented in Tables 1, 2, and 3. The empirically observed fork lengths show a wide range of ages at any given size and, conversely, a wide range of size for any given age. This is not unusual for warm-water fishes and may be seen in species as diverse as red grouper (*Epinephelus morio*) (Moe 1969) and king mackerel (Beaumariage 1973;

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Table 3. Back-calculated fork lengths-at-age (mm) for male and female blue runner combined, collected from the Mississippi delta and northwest Florida during 1980-82.

Age class	N	Mean empirical length ± ISD	Presumed Annulus 1	2	3	4	5	6	7	8	9	10	11
I	151	233 ± 37.0	215										
II	359	273 ± 33.4	211	267									
III	90	335 ± 37.2	222	284	328								
IV	46	364 ± 29.6	217	282	326	358							
V	16	397 ± 15.1	215	280	325	361	389						
VI	16	398 ± 12.6	201	264	307	341	371	394					
VII	15	393 ± 34.3	184	249	291	232	349	370	388				
VIII	19	411 ± 15.3	191	242	290	322	347	370	389	407			
IX	7	418 ± 2.2	189	251	289	317	341	361	381	397	415		
X	4	415 ± 9.7	175	229	267	299	323	344	362	379	397	413	
XI	3	426 ± 21.7	178	238	276	306	331	350	366	383	397	411	422
Weighted mean back-calculated length			212	270	317	342	358	372	384	399	406	412	422
± ISD			± 28.4	± 31.1	± 32.5	± 29.5	± 26.3	± 23.9	± 23.1	± 16.6	± 12.7	± 12.0	± 14.9
Number of back-calculations contributing to means			726	575	216	126	80	64	48	33	14	7	3
Annual growth increment			212	58	47	25	16	14	12	15	7	6	10

Johnson *et al.* 1983).

The back-calculated fork lengths-at-age data for both males and females show a positive "Rosa Lee's phenomenon" (back-calculated lengths from older fish smaller than lengths calculated from younger fish for the same presumed annulus). The possible causes of this phenomenon have been reviewed by Ricker (1975). In the case of blue runner the most likely causes are natural selection and/or gear selection. Natural selection may be indicated if there is higher mortality in smaller fish of the same age than larger fish because of predation or the larger faster growing fish may enter the commercial school that are exploited earlier in life than the smaller slower gorwing fish. Gear selection may be a cause of the phenomenon in that the fish used in this study were obtained from purse and beach seines both of which depend on commercial school fish as their target, thus the smaller growing fish not in the schools would not be caught.

The parameters of von Bertalanffy's theoretical growth (Ricker 1975) showed some variation among males, females and combined sexes. These parameters and the resultant equations are as follows:

for males: $K = 0.32$, $L_\infty = 420$, $t_0 = -1.17$ and $L_t = 420\,(1\text{-}e^{-0.32(t+1.17)})$,

for females: $K = 0.38$, $L_\infty = 404$, $t_0 = -1.00$ and $L_t = 404\,(1\text{-}e^{-0.38(t+1.00)})$, and

for combined sexes: $K = 0.35$ $L_\infty = 412$, $t_0 = -1.17$ and $L_t = 412\,(1\text{-}e^{-0.35(t+-1.17)})$

where L_t = length at age t, K = growth coefficient, $L\infty$ = asymptotic length, and t_0 = time when length would theoretically be zero.

The K value for blue runner indicate that females grow at a slightly faster rate while L_∞ values indicate a slightly higher asymptotic length for males. Manooch (1979) provided an interesting graph relating K values and maximum age for a number of species that neatly resolve themselves into a snapper/grouper cohort and a coastal pelagic cohort. A K value of 0.35 and a maximum age of 11 years places the blue runner in the middle of the coastal pelagic (0.22 to 0.47).

Regression equations for the interconversion of fork length, total length, and standard length were calculated using measurements from 193 blue runner selected from all size intervals. These equations with their correlation coefficients (r) were:

TL = -7.4792 + FL (1.1938);
r = 1.00; α = 0.01

FL = 1.9453 + SL (1.0596);
r = 1.00; α = 0.01

TL = -5.1694 + SL (1.2651);
r = 0.99; α = 0.01

Length-weight equations for males, females, and combined sexes were also calculated by least-squares regression using blue runner from all size intervals:

males: $W = 0.0000349967\ FL^{2.88318}$ n = 194, r = 0.99, α = 0.01,

females: $W = 0.0000168893\ FL^{3.01616}$ n = 177, r = 0.99, α = 0.01, and

combined sexes: $W = 0.0000251355\ FL^{2.94593}$ n = 193, r = 0.98, α = 0.01

where W = weight in grams and FL = fork length in millimeters. There is a slight difference between the equations for males and females, indicating some difference in body proportions. Actual conversions of length to weight by this equation agree well with those derived by the equation of Munro (1974) $W = 0.0065\ FL^{3.302}$ where fork length is expressed in centimeters and weight in grams.

Shown in Table 4 is the age-length key derived from length at age of capture data of Table 3 and the catch curves derived by using this key. Catch curve-number of fish in age group is the sum of the number of fish in the sample in each length interval times the percent composition value for that age group in each length interval. The two length-frequency data sets from which catch curves were derived were both taken for fish from Mississippi delta waters. For calculation purposes, full recruitment to

Table 4. Percent composition of length contrived by age group and catch curves derived therefrom for two length-frequency samples from the Mississippi delta.[1]

Fork Length Interval (mm)	Age Group 1	2	3	4	5	6	7	8	9	10	11	Number of Fish[2] Sample 1	Sample 2
250-274	7.1	78.6	14.3									12	63
275-299	11.0	57.0	22.0	7.1			3.0					66	131
300-324	7.5	57.5	30.0	5.0								232	196
325-349	3.6	32.1	48.2	16.1								304	225
350-374	2.0	14.0	40.0	28.0	2.0	2.0	2.0					168	244
375-399			17.8	31.1	17.8	13.3	13.3	6.7				137	144
400-424			2.0	9.8	11.8	17.7	9.8	25.5	13.	5.9	3.8	65	81
425-449					14.3		28.6	42.9		14.3		5	4
450-474											100.0	1	0
Catch Curve Sample 1	39	302	342	162	36	33	30	28	9	5	4	990	
Catch Curve Sample 2	46	345	353	184	31	38	33	12	5	3			1088

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Table 5. Estimates of annual mortality (a), annual survival (s), and instantaneous mortality (z) by four methods for two separate samples of blue runner from Mississippi delta.[1]

Method of Computation	Sample 1 a	Sample 1 s	Sample 1 z	Sample 2 a	Sample 2 s	Sample 2 z
Jackson (1939)	.53	.47	.75	.51	.49	.71
Heincke (1913)	.53	.47	.75	.51	.49	.71
Robson and Chapman (1961)	.49	.51	.67	.47	.53	.63
Regression analysis	.41	.59	.52	.41	.59	.53

[1]Sample 1 collected August 1981 and Sample 2 collected September 1981.

the fishery was considered to be age 3. Mortality rates (Table 5) showed little variation between the two samples and little variation among methods of calculation. The methods of Jackson (1939) and Heincke (1913) yielded identical results, while annual and instantaneous mortality rates from the Robson and Chapman (1961) and regression methods were slightly lower than the others.

Annual mortality (a) for blue runner is higher than that calculated for king mackerel by Johnson *et al.* (1983) and about the same as that calculated for king mackerel by Beaumariage (1973). Blue runner and king mackerel have similar life expectancies; however, king mackerel are heavily exploited (annual catch approximately 45,000 metric tons (Manooch 1979)) while blue runner are almost totally unexploited (annual catch approximately 635 metric tons (Anonymous 1980)). This lack of exploitation of blue runner can be seen in the catch curves of Table 4, where catch at age is remarkably consistent for ages 5 to 9 and has the further implication that estimates of annual mortality are virtually synonymous with natural mortality for the species.

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