ABSTRACT

AGE AND GROWTH OF BAIRDIELLA ICISTIUS IN THE SALTON SEA, USING SCALES AND OTOLITHS

By

Gwendolyn L. Lattin

May 1986

Age and growth of *Bairdiella icistius* from the Salton Sea was determined using otoliths and scales from 1500 fish. The fish were collected from 1979 to 1983 from sampling stations located around the Sea.

Otoliths were sectioned to facilitate reading. Otoliths and scales were read as projected images on a microfiche reader. Radii from the nucleus to growth patterns recognized as annuli were measured and body lengths at attained ages were calculated, assuming a linear relationship.

The information was separated by sex because different growth rates were determined for males and females. Based on fish aged to 8 years, L_∞ was nearly attained by the oldest of these fish.

Otoliths are deemed more reliable for aging bairdiella than scales.

WE, THE UNDERSIGNED MEMBERS OF THE COMMITTEE,

HAVE APPROVED THIS THESIS

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AGE AND GROWTH OF *BAIRDIELLA ICISTIUS* IN THE SALTON SEA, USING SCALES AND OTOLITHS

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By Gwendolyn L. Lattin

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INTRODUCTION

Bairdiella icistius (Jordan and Gilbert) is one of two fish from the family Sciaenidae (the other being the orangemouth corvina, *Cynoscion xanthulus*) that have become successfully established in the Salton Sea since their intial introduction in 1950 and 1951 (Walker, *et al*. 1961). Although sometimes refered to as gulf croaker, the common name of *B. icistius* listed in A List of Common and Scientific Names of Fishes from the United States and Canada (Bailey, 1970) is bairdiella.

Through the efforts of California Department of Fish and Game a total of 67 bairdiella, which are native only to the Gulf of California, were taken from the waters off San Felipe, Baja California and transplanted with other species to the Salton Sea (Walker, *et al*. 1961).

The Salton Sea is a large body of shallow water surrounded by desert located in both Riverside and Imperial Counties in Southern California. The elevation is below sea level. The major sources of water for the Sea are the Whitewater River at the north end of the Sea, the New River and the Alamo River at the south end of the Sea, runoff from irrigation surrounding the Sea, and local rainfall. There is no outlet and little leaching because of the impervious bottom. Approximately 33 miles long and

16 miles wide, at its deepest point the depth is less than 60 feet. This is ideal for bairdiella which is found primarily in shallow waters.

The present Salton Sea was formed when the Colorado River flooded its banks and was carried into the Salton Sink in 1905 and 1906. As time went on, the water became more saline because there was no outflow, creating a marine-like environment. Salinity at the Salton Sea in 1956 was 33 parts per thousand total salt content, only slightly less than the total salt content of the oceans. Today the salinty is at 38 parts per thousand. This is due to the high rate of evaporation and limited inflow of fresh water, in addition to salts being continually being leached into the Sea from the surrounding soils.

Thought of as only forage for corvinas, bairdiella was considered of little value as game or food fish when first introduced. The catch data showed that bairdiella was utilized as bait fish for corvina or listed as incidental catch when corvina was not available, corvina being the primary target of most anglers (Black, 1974). A more recent report by Black (1985) has documented a high contribution to the sportfishery by bairdiella at the Salton Sea during 1982-83 stating the annual angler success rate for bairdiella was 0.41 fish per angler hour.

Almost nothing is known about the life history of bairdiella in its native habitat, although Whitney (1961) used one sample of 43 specimens from San Felipe, Mexico to estimate growth by reading the annuli of the scales. No other biological information is available on bairdiella in the Gulf of California, where it is of only minor importance as a food fish (Skogsberg, 1939; Berdegue, 1956).

Previous information on the age and growth of bairdiella at the Salton Sea is limited to an analysis of length-frequencies for fish of age five or less (Whitney, 1961) a couple of years after the first introduction of these fish into the Sea.

Bairdiella have now resided at the Salton Sea for over 30 years and still little is known of their life history. This study describes, for _B. icistius_, age determination using otoliths and scales, growth, and weight-total length relationships.

MATERIALS AND METHODS

The majority of bairdiella samples (99%) were collected monthly from sampling stations established around the Salton Sea (Fig. 1) using gill nets during the period of March 1979 through February 1983. Variable mesh (2.5-17.8 cm) standard sampling gill nets made of monofilament nylon were utilized in collecting the fish for analysis. The remaining samples were obtained through the use of seines, hook-and-line methods, and dip net. The sampling plan was designed with the intention to collect 10 fish per cm size class each month for two years. The sampling stations were established around the Salton Sea in order to insure the widest possible size distribution of fish was collected each survey, despite the seasonal or random movement. Due to difficulties encountered with meeting these criteria, the sampling was extended for a longer period of time (until 1983).

The following information was taken at capture for each fish sampled and recorded on a 45 x 65 mm manila envelope: 1) date of capture; 2) length measurement-total length (TL) to nearest mm; 3) weight (to nearest g); 4) sex; 5) stage of maturity based upon macroscopic examination of reproductive organs; 6) the weight of the paired reproductive organs (to nearest g); and 7) method

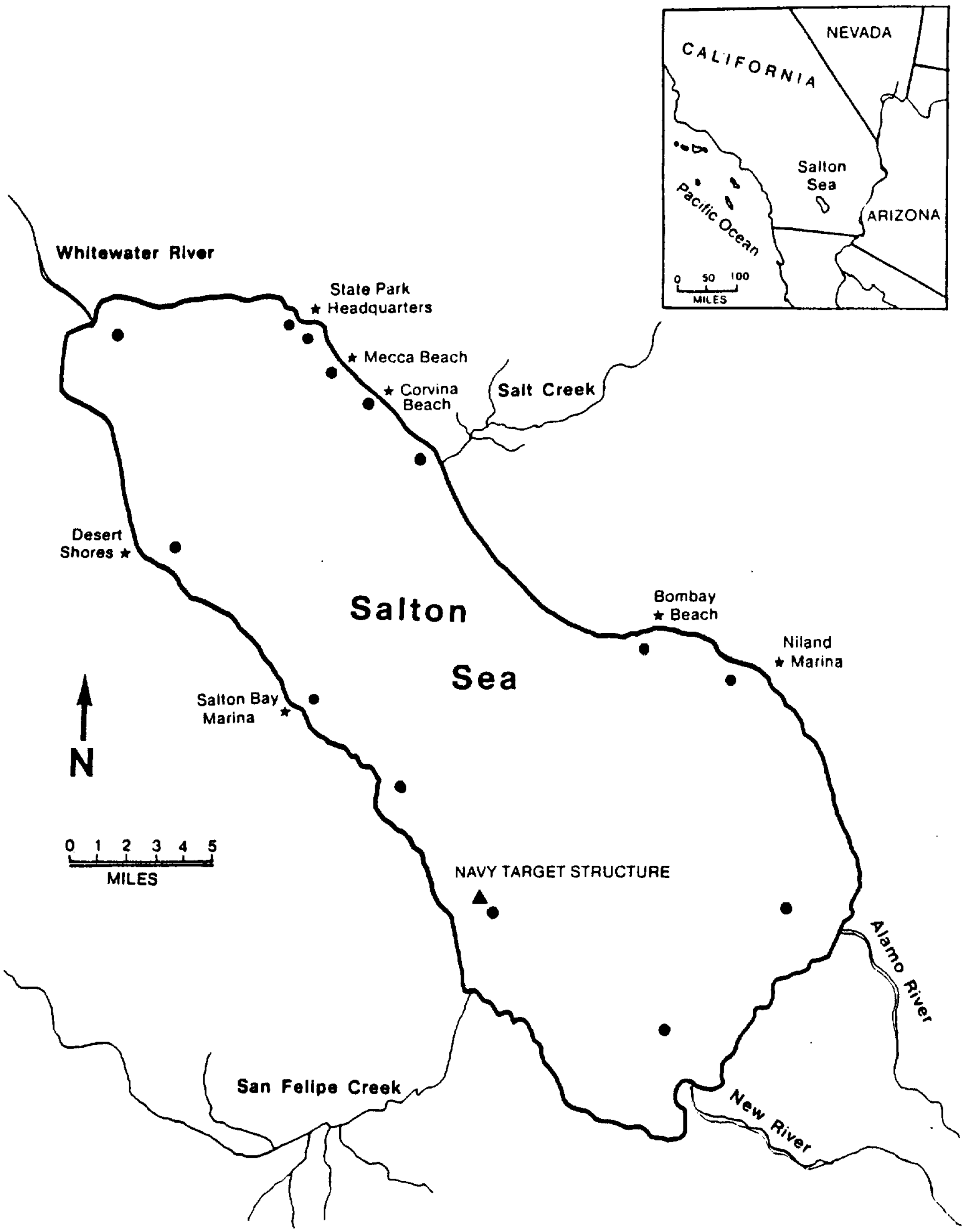


Figure 1. Locations of sampling stations at the Salton Sea.

of capture. Sagitta were removed from each side of the head, the otoliths were cleaned and placed in the envelope along with scales. To decrease the probability of collecting regenerated scales, the scales were removed from the protected area behind the pectoral fin below the lateral line.

Techniques For Aging Bairdiella

Because whole bairdiella otoliths are difficult to age, they were sectioned on a Buehler Isomet low speed diamond saw. One otolith of the pair was selected from each sample and embedded in a stick of clear casting resin which contained an average of 6 otoliths. Each stick was placed on the saw and a dorsal-ventral 0.33 mm wafer was cut through each otolith, using two diamond-edge blades separated by copper shims. For small otoliths (young-of-the-year fish) the wafer section was reduced to 0.25 mm thickness. The labelling of the wafer was acheived by writing with a diamond pencil on the resin surrounding the otolith section. The labelled wafer was stored in a seperate envelope identified with only the species and the sample number. Sectioned wafers when read were dipped in water and placed between the glass plates of a microfiche reader with a magnification of 22X. All otoliths were read twice, at least 6 months apart. When the readings did not agree, the otoliths were read a third time. The value of the two agreeing readings was accepted as the best estimate of age. For the purpose of this study, an otolith exhibited a single year of growth when an inner opaque zone and an outer hyaline zone were complete, with an opaque margin formed on at least 50% of the outer edge of the otolith section.

The number of annuli, the distance from the nucleus (in mm measured on the projected image) to each annulus, the distance from the nucleus to the margin, the plane in which the aging was done, the margin condition, and the legibility of each otolith was noted each time the sample was read.

Air dried scales were placed between the glass plates of the microfiche reader at a magnification of 17X. Measurements (in mm measured on the projected image) were made from the nucleus through the center dorsal portion of the scale.

Calculations

In order to estimate the true mean growth rate of bairdiella, lengths at annulus formation were determined by reading otoliths and scales with measurements made at each successive annuli. A relationship for each, scale size and otolith size, to fish size was established where b is the slope and c is the intercept on the length axis. The relationship described by the regression line was used to estimate back calculations of length at the last complete year represented on the otolith or scale using the equation:

$$l_n - c = \frac{s_n}{s} (l-c)$$

where, l_n = length in mm of fish when annulus 'n' was formed, l = length of fish in mm at time scale or otolith sample was obtained, s_n = radius of annulus 'n' (at length 'l_n') in mm, and s = total scale or otolith radius in mm.

Ages were assigned to all fish examined. The lengths and ages from these fish were used to generate the constants for a von Bertalanffy growth equation:

$$l_t = L_\infty \; [1 - \exp - k(t-t_o)]$$

where, L_t = length at time t, L_∞ = theoretical maximum length, k = constant expressing the rate of approach to L_∞, and t_o = theoretical age at which L_t = 0 (Ricker, 1975).

The relationship between total length and weight was tested in the relationship $W = aL^b$, where W = weight in grams, L = total length in centimeters, and a and b are constants, with values determined using $\log_{10}$ transformation and fitting the values to a straight line by least squares (Tesch, 1971).

Analysis of variance was used to determine if there was a significant difference between the sexes in weight, Log weight, and length.

To determine if there was a difference between scale age and otolith age a t-test was performed.

RESULTS

Ages were assigned to 2267 bairdiella examined. These fish ranged from less than 1 to over 8 years in age, and in size from 81 to 373 mm TL.

Data for otoliths and scales was seperated by sex (Table 1) when growth equations for male and female were transformed to linear form and then compared by analysis of variance. Females (Table 2) were found to grow significantly faster than males ($F = 61.82$, $p<0.001$). The relationship between total length and weight fit the relationship $W = aL^b$ (Figs. 2,3), showing a high correlation for females where $r = .966$ and $r = .932$ for males.

At the Salton Sea females tend to slightly heavier at a given length than males (analysis of variance, $F = 118.57$, $P < 0.001$). There is also a significant difference for length when the data is divided by sex, with females being longer than the males (analysis of variance, $F = 86.49$, $P < 0.001$).

Otoliths

Measurements made from direct observation of the otoliths from male and female bairdiella were used to back-calculate lengths and their means for each age group

Table 1. Paramerters of the von Bertalanffy equation for bairdiella at the Salton Sea using otoliths and scales.

Otoliths

Sex	L,	SE	k	SE	T_0	SE
Female	339.70	3.43	0.423329	0.017165	-0.6308	0.053606
Male	315.51	7.24	0.365166	0.031663	-1.0449	0.129728

Scales

Sex	L,	SE	k	SE	T_0	SE
Female	371.30	7.59	0.291939	0.017926	-1.5172	0.079830
Male	353.62	15.61	0.248894	0.030266	-1.9458	0.176399

Table 2. Parameters for the length-weight equation $W = b\ aL^b$ for bairdiella at the Salton Sea.

Sex	Y - Axis intercept (a)	Regression coefficient (b)	Correlation coefficient (r)	Number (n)
Male	0.000020	2.89898	.93178	337
Female	0.000013	2.97148	.96644	736

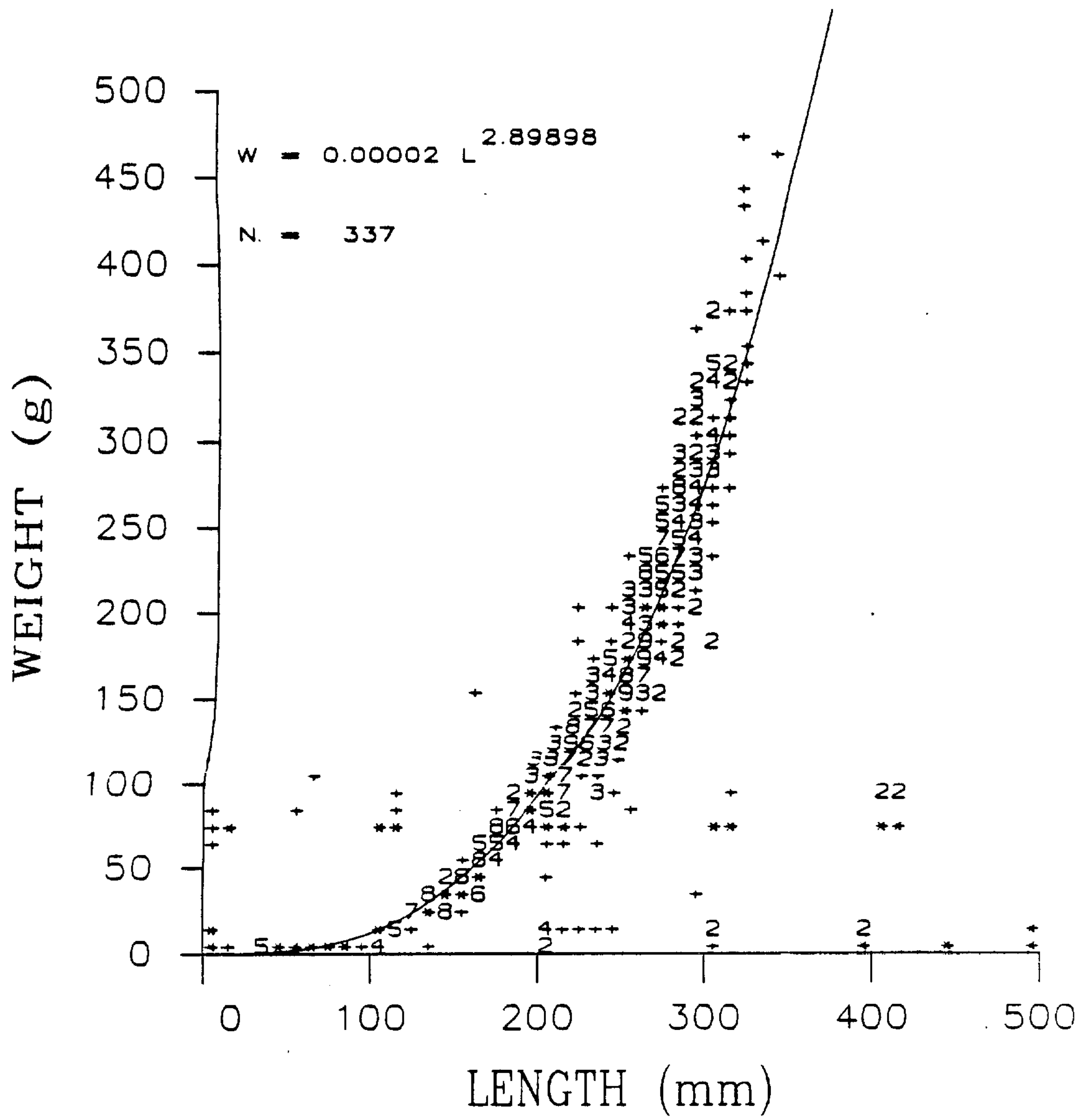


Figure 2. Length-weight relationship based on 337 male bairdiella sampled at the Salton Sea during the period of March 1979 through February 1983.

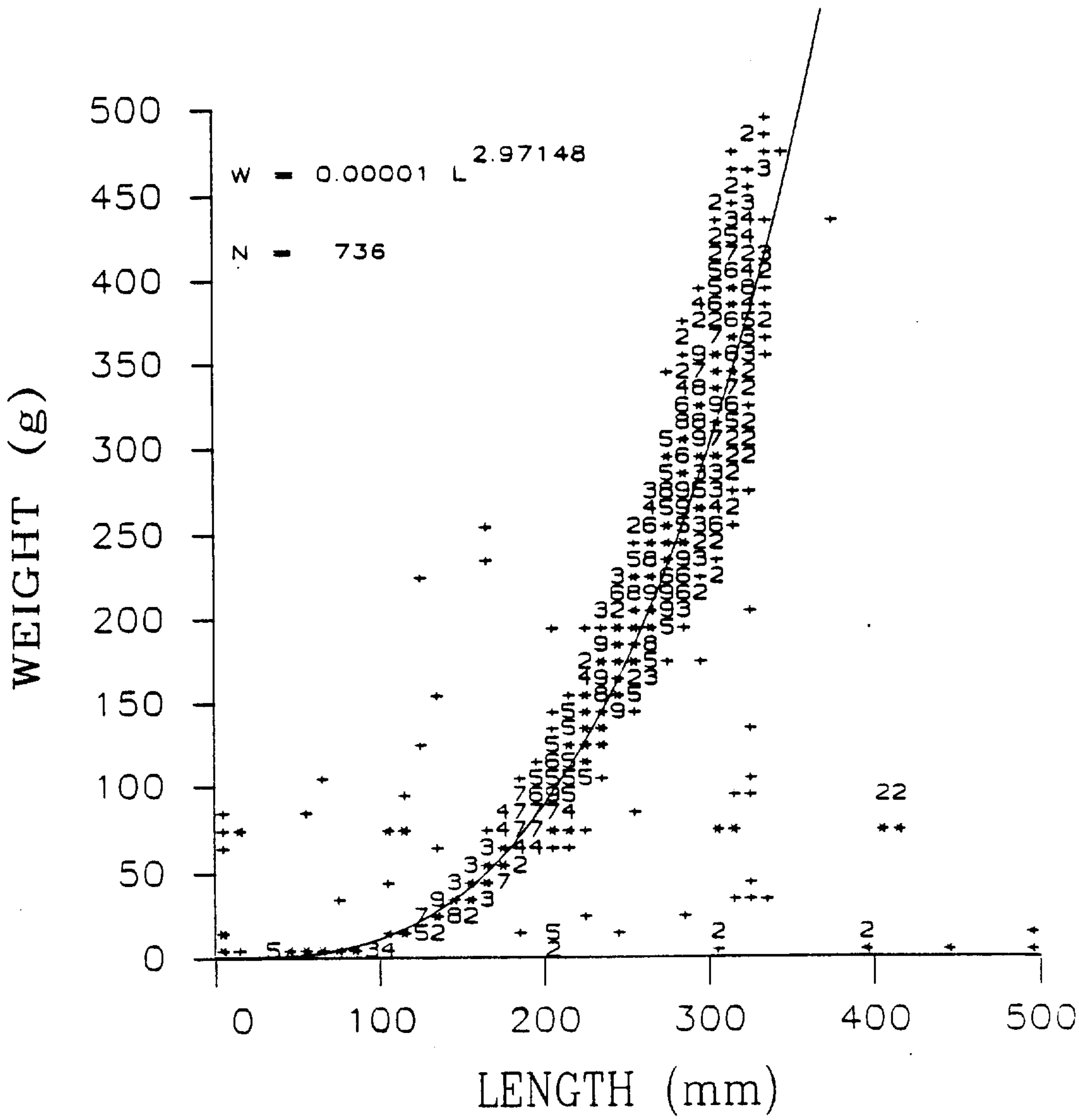


Figure 3. Length-weight relationship based on 736 female bairdiella sampled at the Salton Sea during the period of March 1979 through February 1983.

(Tables 3,4). These calculated mean lengths (mm) were as follows; I--153.61, II--193.50, III--239.50, IV--242.23, V--256.74, VI--270.05, and VII--278.22 for the males. For the females the calculated mean lengths (mm) were greater; I--161.64, II--207.87, III--239.44, IV--261.94, V--278.25, VI--292.37, and VII--303,33.

These calculated means fit within the predicted growth curves by the von Bertalanffy equation (Fig. 4,5) as generated by the data on Tables 5 and 6. The von Bertlanffy growth curves show females from age one grew faster than the males and reached a greater size. In each sex the rate of growth is rapid the first 4 years, tapering off to a relatively low rate during the remaining 4 years until an asymptote is reached exhibiting maximum length the fish is estimated to obtain. The oldest male and female examined were 8 years old.

Scales

The calculated mean lengths (mm) for scales (Tables 7,8) were; I--152.91, II--211.00, III--241.42, IV--263.37, V--281.36, VI--289.93, and VII--296.41 for the males. For the females the calculated mean lengths (mm) were also greater as shown in otolith back-calculations; I--152.68, II--218.03, III--258.51, IV--283.91, V--299.48, VI--307.25, and VII--313.87.

These calculated means fit within the predicted growth

Table 3. Back calculations using otoliths from male bairdiella.

Age Group	l_1	l_2	l_3	l_4	l_5	l_6	l_7	Number of Samples
I --------	148.82							99
II --------	152.80	190.69						114
III --------	159.90	201.76	231.75					56
IV --------	159.88	200.56	230.17	254.46				59
V --------	157.50	194.76	223.29	245.24	261.14			31
VI --------	152.10	193.80	221.85	243.06	264.21	276.43		11
VII --------	144.29	179.45	206.28	226.17	244.86	263.66	278.22	16
Average ----	153.61	193.50	239.50	242.23	256.74	270.05	278.22	Total 386

Table 4. Back calculations using otoliths from female bairdiella.

Age Group	l_1	l_2	l_3	l_4	l_5	l_6	l_7	Number of Samples
I --------	148.12							170
II --------	163.26	206.35						267
III --------	170.97	215.10	246.74					116
IV --------	168.40	222.23	250.69	275.00				149
V --------	165.53	209.75	243.88	269.18	287.83			94
VI --------	159.63	201.79	233.66	257.23	279.14	296.81		37
VII --------	155.59	191.99	222.23	246.36	267.77	287.92	303.33	33
Average ----	161.64	207.87	239.44	261.94	278.25	292.37	303.33	Total 866

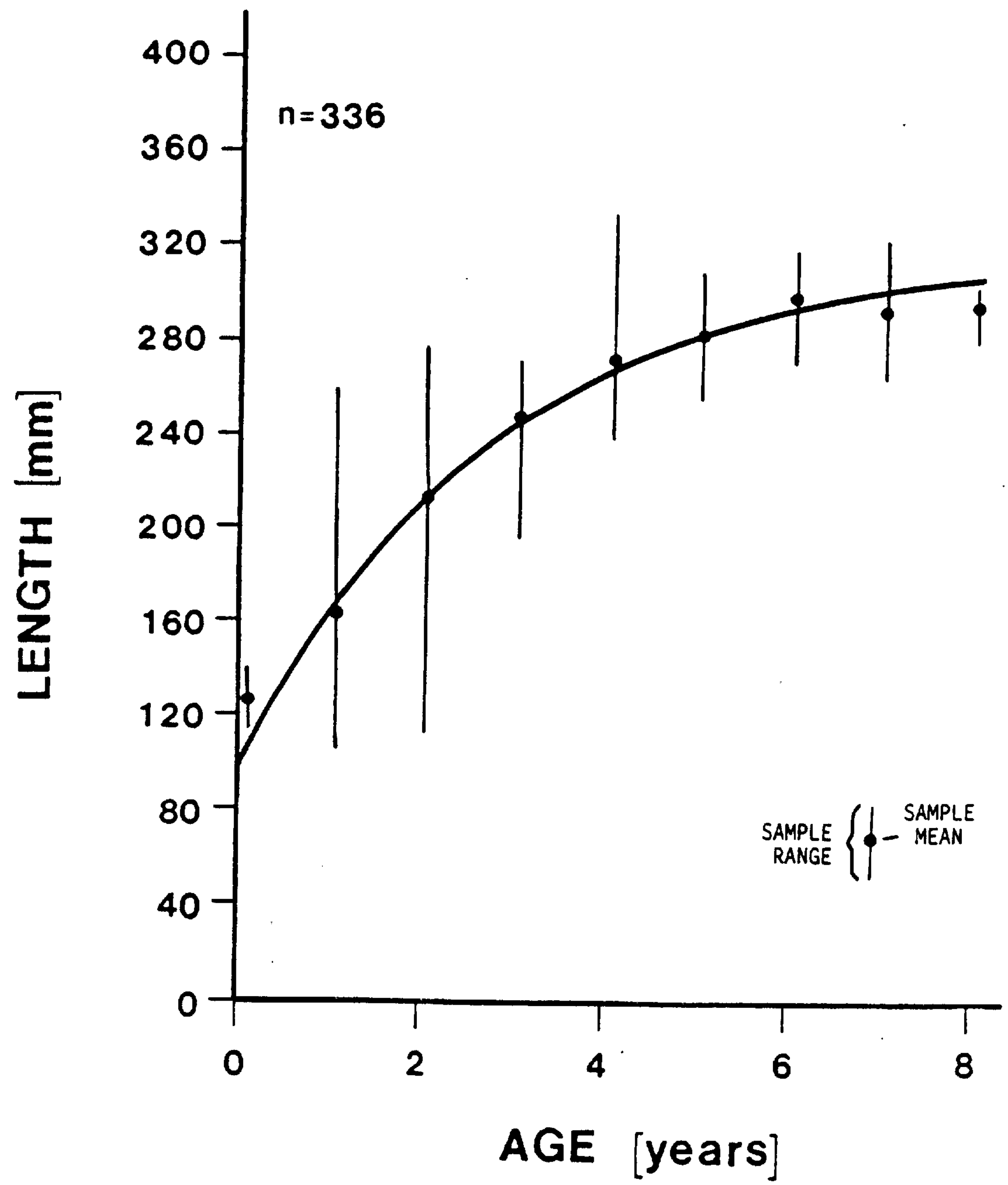


Figure 4. Von Bertalanffy growth curve of male bairdiella using otoliths. For comparison the range and mean lengths of each age group in the sample are plotted on the curve.

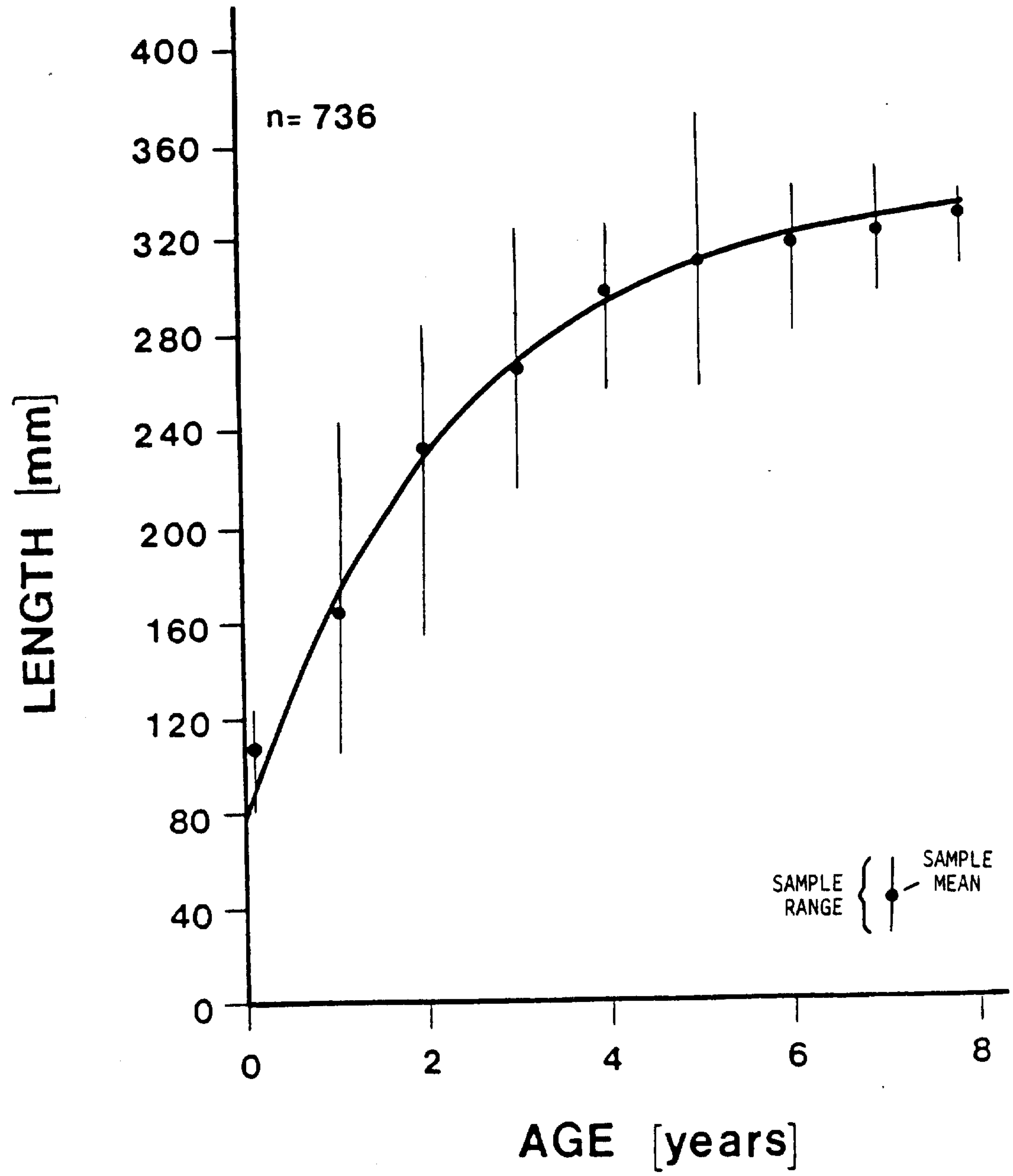


Figure 5. Von Bertalanffy growth curve of female bairdiella using otoliths. For comparison the range and mean lengths of each age group in the sample are plotted on the curve.

Table 5. Fitted lengths and sample lengths using male bairdiella otoliths.

AGE	FITTED LENGTH	SAMPLE MEAN LENGTH	S.E. OF SAMPLE MEAN	SAMPLE SIZE
0.0	100.08	128.00	3.521	5
1.0	165.98	162.19	2.767	85
2.0	211.73	212.36	2.330	92
3.0	243.73	244.82	1.491	61
4.0	265.51	269.60	2.201	48
5.0	280.81	277.84	2.541	25
6.0	291.42	294.13	5.826	8
7.0	298.79	291.00	4.743	9
8.0	303.91	293.67	4.631	3
			Total Sample Size	336

Table 6. Fitted lengths and sample lengths using female bairdiella otoliths.

AGE	FITTED LENGTH	SAMPLE MEAN LENGTH	S.E. OF SAMPLE MEAN	SAMPLE SIZE
0.0	79.61	106.08	3.813	12
1.0	169.37	163.71	2.032	154
2.0	228.16	231.08	1.810	181
3.0	266.66	265.04	1.514	113
4.0	291.87	295.33	1.133	128
5.0	308.38	310.33	1.624	79
6.0	319.19	315.74	3.202	23
7.0	326.27	319.34	1.688	41
8.0	330.90	325.80	4.872	5
			Total Sample Size	736

Table 7. Back calculation using scales from male bairdiella.

Age Group	l_1	l_2	l_3	l_4	l_5	l_6	l_7	Number of Samples
I -------	139.89							120
II --------	148.13	197.06						175
III --------	154.97	210.26	235.53					185
IV --------	156.57	213.31	238.40	257.22				79
V --------	161.49	219.73	251.74	270.12	283.02			29
VI --------	159.64	218.97	251.10	270.11	282.86	290.19		10
VII --------	149.69	206.65	230.35	256.04	278.19	289.66	296.41	2
Average -----	152.91	211.00	241.42	263.37	281.36	289.93	296.41	Total 600

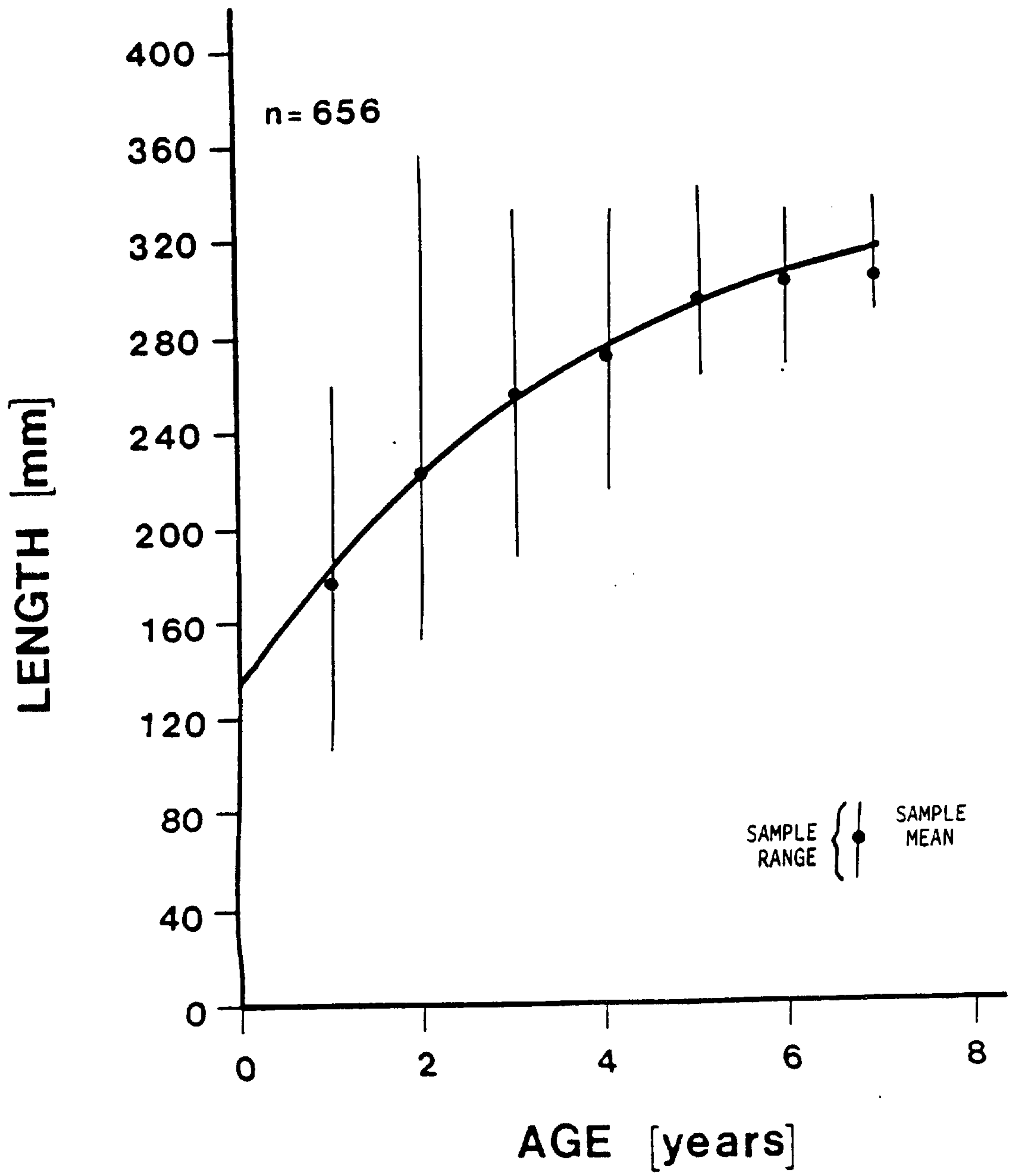
Table 8. Back calculation using scales from female bairdiella.

Age Group	l_1	l_2	l_3	l_4	l_5	l_6	l_7	Number of Samples
I --------	138.43							195
II --------	145.42	205.26						381
III --------	152.96	218.67	253.09					392
IV --------	159.02	232.81	269.52	288.35				215
V --------	166.37	227.61	266.85	289.86	305.02			88
VI --------	155.10	213.50	255.35	282.18	299.21	308.64		30
VII --------	151.45	210.32	247.74	275.16	294.22	305.86	313.87	5
Average -----	152.68	218.03	258.51	283.91	299.48	307.25	313.87	Total 1306

curves of the von Bertalanffy equation (Fig. 6,7) as generated by data from Table 9 and 10 for scales. These von Bertlanffy growth curves also show females from age one grew faster than the males and reached a greater size. In each sex the rate of growth is rapid the first 4 years, tapering off to a relatively low rate during the remaining 4 years until an asymptote is reached exhibiting maximum length the fish is estimated to obtain. The oldest male and female included were 8 years old.

There were only a few fish aged older than 8 years old; these were aged as 9 and 10 years old. These fish were eliminated from the statistical analysis of this study to prevent distortion by so few data points at the extreme end of the distribution.

A paired t-test was performed on ages assigned to 1145 fish by otolith and scale methods. It was found that the mean difference in assigned ages was significantly different from 0 ($t = 16.56$, $P < 0.001$).



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SAMPLE RANGE
SAMPLE MEAN
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6
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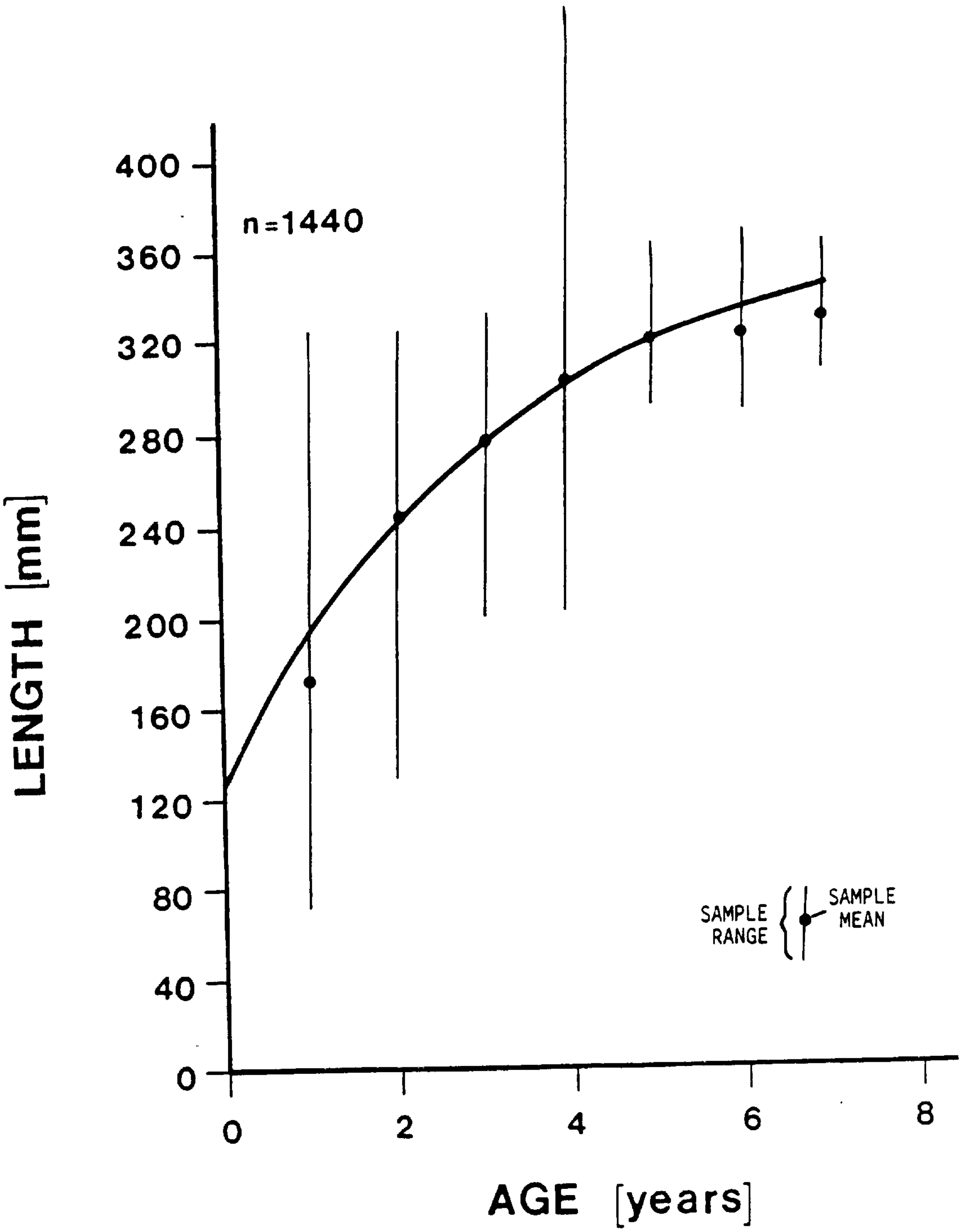
AGE [years]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LENGTH [mm]
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2
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AGE [years]
SAMPLE RANGE
SAMPLE MEAN

Table 9. Fitted lengths and sample lengths using male bairdiella scales.

AGE	FITTED LENGTH	SAMPLE MEAN LENGTH	S.E. OF SAMPLE MEAN	SAMPLE SIZE
0.0	135.74	142.81	2.222	54
1.0	183.75	176.18	2.604	120
2.0	221.18	221.97	1.991	175
3.0	250.36	254.82	1.885	186
4.0	273.11	268.38	3.062	80
5.0	290.85	291.62	2.624	29
6.0	304.68	298.70	3.910	10
7.0	315.46	302.50	7.500	2
			Total Sample Size	656

Table 10. Fitted lengths and sample lengths using female bairdiella scales.

AGE	FITTED LENGTH	SAMPLE MEAN LENGTH	S.E. OF SAMPLE MEAN	SAMPLE SIZE
0.0	134.79	142.04	1.855	126
1.0	195.57	184.19	2.512	195
2.0	240.75	242.35	1.546	382
3.0	274.31	276.86	1.360	394
4.0	299.25	300.53	1.520	219
5.0	317.77	316.49	1.245	89
6.0	331.53	318.03	3.110	30
7.0	341.76	326.60	5.192	5
			Total Sample Size	1440

DISCUSSION

A limited amount of previous age and growth information for bairdiella was obtained by the use of scales. Since I have shown there are different growth rates for males and females, the data collected previously from bairdiella taken at San Felipe, Mexico or those collected at the Salton Sea a few years after introduction cannot directly be compared to this study because they were not separated by sex. Not only were the fish from the study at San Felipe not separated by sex, but it was such a small sample (43 specimens). These fish from the Gulf of California reached an average length of 131 mm at the time of the first annulus, 154 mm at the second, and 172 at the third.

A few years after the bairdiella had been introduced to the Salton Sea, Whitney (1961) found that the growth of the 1952 year-class was comparable to the bairdiella from the Gulf of California during their first two years. However, the fish from the Sea showed no growth after that. He concluded that competition resulted in a cessation of growth among the 1952 fish. Also competition among members of the large 1953 year-class resulted in a slow rate of growth for them. Competition between year-classes led to a virtual elimination of the 1954, 1955, and 1956 year-classes. It took three seasons for the fish from the 1953 year-class to reach the same length the 1952 fish had attained their first year.

This study uses both scales and otoliths, and resulted in a difference between ages assigned to fish using scales and otoliths. This difference is probably due to a conservative reading of the scales, by counting annuli as false annuli, or vice versa, reading false annuli as annuli. When trying to follow a ring completely around to determine if it was an annulus, the edges of the ring often became discontinuous or gave the appearance of a false annulus with broken or discontinuous circuli. On other scales of the same fish these rings may be much clearer and easily determined to be annuli. It has been known that there is a fair amount of variability in scales even when taken from the same area. Environmental factors may affect the physiology of the fish, its diet, or the amount of food it eats. Any extreme that may change the rate of growth, even spawning, may be shown as accessory marks or false annuli. For bairdiella growth decreases with age. On the scale this is seen as it harder to tell the annulus near the edge of the scales because of less growth on the scale between annuli and the numerous tightly packed circuli, making it difficult to follow the annulus around to the area of cutting over.

It is much easier to distinguish annuli when reading otoliths where only hyaline and opaque areas are being dealt with. Annuli on otoliths are read as whole rings with no cutting over. False annuli on the otoliths are spotted quickly as a slight break that does not continue around the otolith. Crystalization has occured in some otoliths, which may also show that some bairdiella have undergone some extreme physiological changes.

To further validate the nature of the annuli back calculations were made to determine the theoretical length of the fish at each age before it was caught. These were compared to the von Bertalanffy equation from the sampled fish. This method is based on the assumption of linear relationship between otolith and/or scale size to fish length. This relationship was tested with both scale diameter and otolith diameter graphed against total length showing there was a linear relationship observed, with a higher correlation for otoliths ($r = 0.89$ for males and $r = 0.90$ for females) than for scales ($r = 0.87$ for males).

SUMMARY

An age and growth study of *Bairdiella icistius* was undertaken at the Salton Sea to provide information to aid in understanding this fishery.

Otoliths and scales obtained from fish collected during 1979 to 1983 were used to establish ages for more than 1500 bairdiella. These otoliths and scales were read and used to construct an age-length frequency and to obtain constants for a von Bertalanffy growth curve.

As determined by statistical analysis, data was separated by sex. The age determination method for otoliths and scales was validated by back-calculating fish lengths. A weight-length equation was derived from a data base of 1073 fish. Growth and length were significantly different between males and females.

Otoliths are deemed more reliable for aging bairdiella than scales.

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