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TITLE THE BIOLOGY OF THE ATHERINID FISH ODONTESTHES BONARIENSIS (VALENCIENNES) IN NORTHEASTERN RIO GRANDE DO SUL, BRAZIL

AUTHOR HERMAN KLEEREKOPER

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THE BIOLOGY OF THE ATHERINID FISH *ODONTESTHES BONARIENSIS* (VALENCIENNES) IN NORTHEASTERN RIO GRANDE DO SUL, BRAZIL

by
Herman Kleerekoper

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Committee in charge:

Assistant Professor Karl F. Lagler, Chairman
Dr. Ralph Hile, Research Associate in Zoology
Dr. Frank F. Hooper, Instructor in Zoology
Professor William R. Taylor
Assistant Professor Alvalyn E. Woodward

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1. INTRODUCTION

This paper deals with the biology of the atherinid fish Odontesthes bonariensis (Valenciennes) in northeastern Rio Grande do Sul, Brazil. The data presented in this paper were collected by me in my capacity as Limnologist of the Division of Game and Fish of the Federal Ministry of Agriculture of Brazil, from 1941 to 1947, or by members of parties under my direction. During this seven-year period an extensive limnological survey was made of a series of lakes and their affluents situated along the northeastern coast of the state of Rio Grande do Sul, Brazil's most southerly state (Figure 1). This survey furnished, for the first time, a relatively complete picture of the general ecological conditions of the region, which will be presented in a separate paper. Although this survey had been organized originally for the collection of general ecological, limnological, and biological data, its character was changed during the course of the investigations when the large fresh-water silverside Odontesthes bonariensis (Valenciennes) - see Figure 2 - was found in some of the lakes. This member of the Family Atherinidae is known in the Portugese language as "peixe-rei", meaning king-fish. It also occurs in the La Plata Basin where it is the most important commercial fresh-water fish. In the La Plata region it has been reared artificially for several years and cultivated in farm ponds and impoundments. The popularity of this fish in Argentina is due to its fine flavor, large size, and the facility with which it becomes

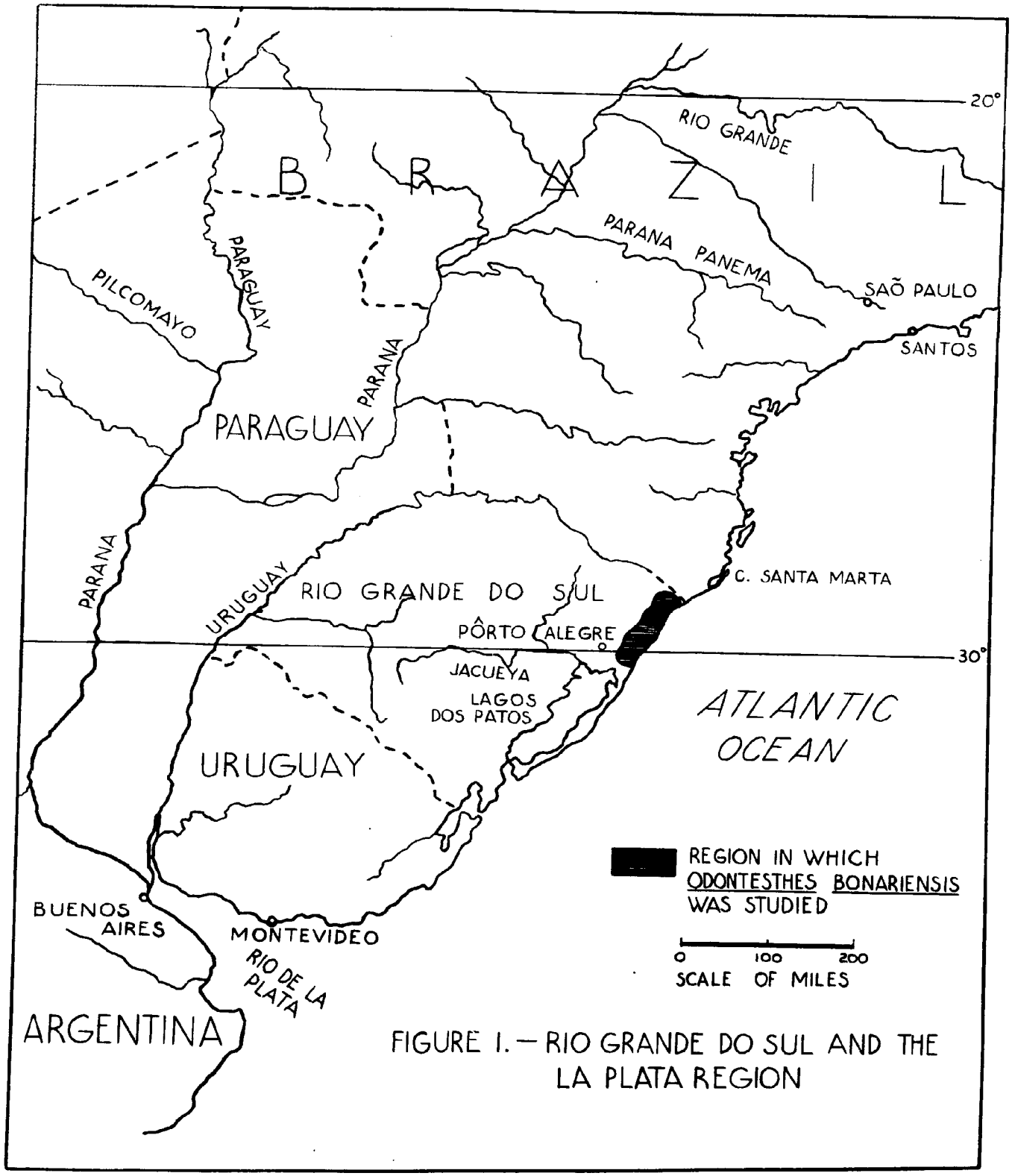


FIGURE 1. — RIO GRANDE DO SUL AND THE LA PLATA REGION

adapted to the waters of man-made impoundments.

On many occasions various private and official institutions in Brazil introduced this species from Argentina by importing either eyed-eggs or fingerlings. These attempts were unsuccessful; the species at least did not become firmly established, although survivors of some of the introduced specimens may still exist.

In view of the widespread interest in Odontesthes bonariensis as an "exotic" fish in Brazil and of its importance as food in the La Plata countries, the discovery of the species as indigenous in certain Brazilian lakes led me to change the program of the survey in order to be able to collect as much information as possible of direct bearing on its life history and ecology. It was believed that before the management or introduction of this species into other bodies of water could be considered, much fundamental knowledge of the species and its natural environment should be obtained. Too often considerable public funds have been applied in Brazil in the construction and organization of hatcheries and fish-cultural stations without the foundation of previous scientific research that might indicate the possibilities of success or the desirability of the operations.

In the course of these investigations information was gathered which pointed towards the probability that this fish would be adaptable to many southern Brazilian conditions as well as to temperatures prevailing in the more northerly regions of the country. Experiments were then started on artificial

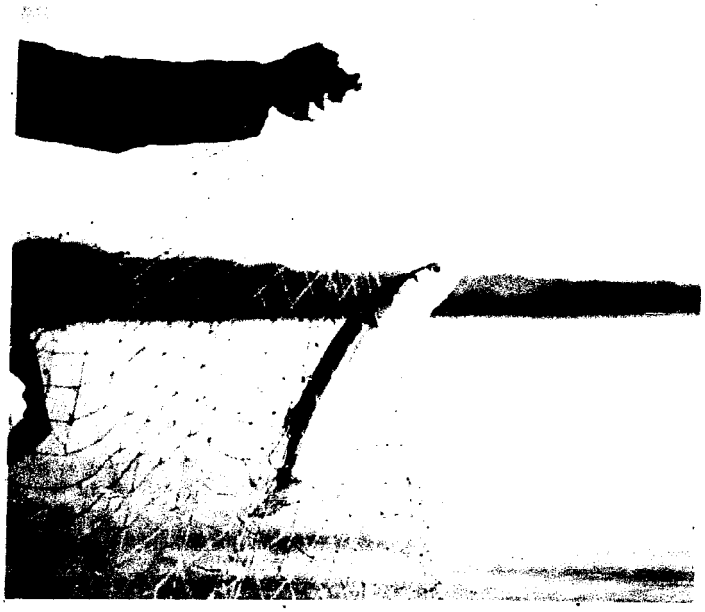


FIGURE 2.- ODONTESTHES BONARIENSIS IN GILL NET



FIGURE 3.- EXCURSIONS WERE MADE IN LARGE DUG-OUT CANOES

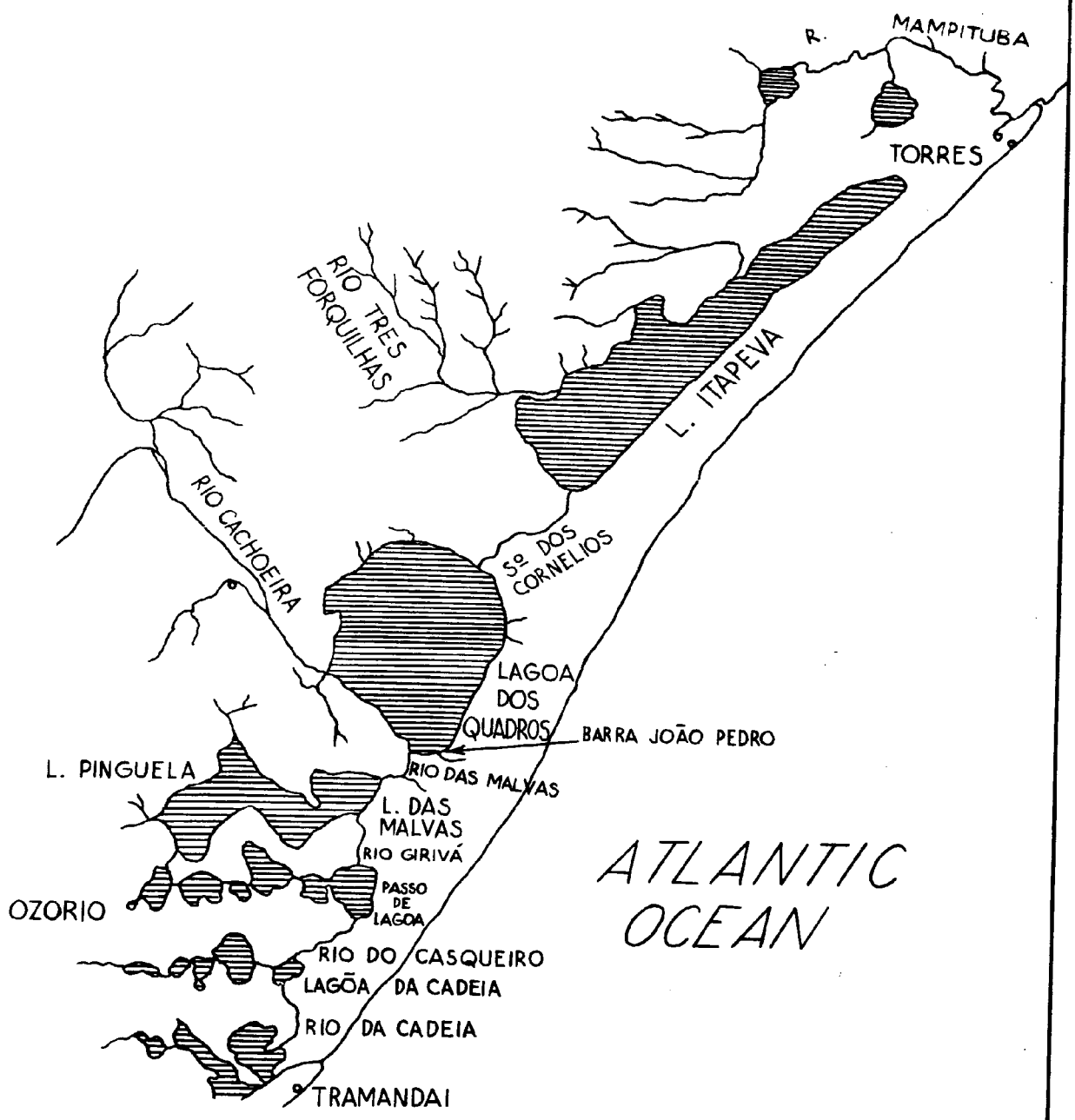


FIGURE 4.- THE NORTHERN PART OF THE TRAMANDAI BASIN

propagation, transportation, stocking, and tolerance of environmental factors. These studies, carried out in most primitive conditions, were successful eventually and led to the building and organization of a limnological station and fish hatchery at Lagoa dos Quadros, township of Osorio. The results of these studies will be presented in a separate paper.

The problems of a biological and limnological survey in a relatively unexplored country like Brazil are very different from those presented to biologists in parts of the world better known biologically. Great difficulty is presented by the absence of many details of taxonomic knowledge of the aquatic flora and fauna. Serious impediments are offered by the lack of detailed maps. The almost total absence of roads made conditions specially unfavorable.

Excursions into the lake region (Figure 4) were made usually by large, dug-out canoes (Figure 3). Later a sea-worthy motor boat became available.

During the seven years of investigation I received the cooperation and assistance of many official and private persons, too numerous to make personal acknowledgements possible. I extend my personal thanks to Dr. Ascanio Faria, formerly Director of the Division of Game and Fish, Federal Ministry of Agriculture, Rio de Janeiro, under whose competent administration this research project was started, and whose enthusiasm and unfailing support made the work possible. Important financial and other aid has been received from the State of Rio Grande do Sul, under the governments of Dr. Cilon Rosa and Dr.

Walter Jobim.

Many of the statistical analyses were performed during the author's sojourn in the United States, at the University of Michigan, while on a fellowship of the U.S. Department of State. The author is grateful to Dr. Ralph Hile of the U.S. Fish and Wildlife Service, and to Dr. Karl F. Lagler, University of Michigan, for discussion and criticism of the data and conclusions presented in this thesis.

For sharing the many hardships inherent in field work in primitive areas, and for assisting his work in many ways the author is indebted to his wife, Mrs. J. van Neck Kleerekoper.

II. BIONOMICS, DISTRIBUTION AND GENERAL ECOLOGY

Atherina bonariensis Valenciennes, 1835;
Atherinichthys bonariensis Eigenmann, 1894;
Odontesthes bonariensis Hubbs and Marini

As was mentioned in the Introduction, *Odontesthes bonariensis* had been known previously to the author's work from the La Plata region (Figure 1), where it inhabits fresh waters in both Argentina and Uruguay. Eigenmann (1894) described the species as *Atherinichthys bonariensis* from specimens collected in eastern Brazil, without mention of locality. It seems that this species occurs in the southern part of Lagoa Mirim, near the border of Uruguay, from which Eigenmann's specimens may have been taken. One or more species of "peixe-rei" occur in the fresh-water part of Lagoa dos Patos, and its affluent, the River Guaiba; their identity has apparently not been established in the literature.

The present description of the biology of *Odontesthes bonariensis* is based on observations and studies made on the populations found in Lagoa Itapeva, Lagoa dos Quadros and Lagoa das Malvas, located in the northern part of the Tramandai Basin (Figure 3). The identity of the species in these waters was established at the request of the author by Dr. Carl L. Hubbs, in 1941. In this basin *O. bonariensis* is confined to the three lakes given. During the seven years of investigations it has not been captured in any of the more southern lakes of the

region, in spite of repeated attempts to collect it. Nor is its occurrence known in the lakes of the more northern Mampituba Basin, which has no connection with the Tramandai area, and drains into the ocean independently at Torres.

Chemical analyses of the lakes of the Tramandai drainage reveal no basic differences in ecological conditions except for chlorinity (Table 1).

Table 1. - Average values of six ecological factors in five lakes of the Tramandai area observed during stagnation periods for surface and bottom layers, 1941 - 1947

Source of sample	Temperature (°C.)	O_2 p.p.m.	CO_2 p.p.m. (free)	CO_2 in HCO_3 p.p.m. **	CaO p.p.m.	Cl' p.p.m.
L.Itapeva (9) *						
surface	20.1	8.00	2.30	12.30	8.01	trace
bottom	19.1	7.31	2.61	14.42	10.00	15.23
L.Quadros (14) *						
surface	21.2	8.10	2.71	12.21	7.76	trace
bottom	20.1	7.71	2.42	15.31	10.01	16.51
L.Malvas (7) *						
surface	22.0	7.76	2.23	12.01	7.43	trace
bottom	20.6	7.10	2.61	15.98	9.80	16.00
Passo Lagoa (6) *						
surface	22.7	7.65	2.16	11.98	7.16	0.10
bottom	21.0	7.00	2.53	14.72	9.85	18.01
L.Cadeia (6) *						
surface	22.7	7.55	2.16	11.87	6.79	4.32
bottom	21.1	6.89	2.50	13.58	8.88	22.65

* Number of Observations on which all items for both surface and bottom conditions are based

** Bicarbonates expressed as CO_2 (p.p.m.).

Whereas maximum chlorinity observed during stagnation periods in the water above the bottom does not exceed 18 p.p.m. in the three upper lakes of the basin, this value increases rapidly from Lagoa das Malvas southwards down to Lagoa Tramandai. The latter is brackish on occasion, depending on the volume of discharge of the lakes, on tides, and on wind action. It seems that this increasing chlorinity constitutes a barrier for the distribution of Odontesthes in these lakes, at least the fish is absent from the lower lakes of the drainage where the salinity consistently exceeds 16.0 p.p.m.

Additional ecological characteristics of the lakes of the Tramandai Basin are given throughout the text in connection with the biological features of Odontesthes upon which they impinge.

III. REPRODUCTION

In lakes Itapeva, Quadros, and Malvas O. bonariensis spawns mostly from late April to the end of August, and most intensively from mid-June to the end of July. I have no information on spawning behavior. No correlation could be found between chemical, physical, or climatic conditions and the act of spawning. It is true that the peak of spawning is reached after the temperature of the water attains its lowest value. On the other hand, considerable spawning activities were observed during some years in the month of May, when temperatures are still relatively high (Table 2).

Table 2. - Average monthly temperatures of the surface water in Lagoa dos Quadros at collecting station "Coroa", between 9 a.m. and 9 p.m., 1941 - 1947.

Month	Temperature (°C.)
January	24.1
February	23.8
March	23.0
April	19.1
May	17.0
June	15.2
July	14.1
August	14.6
September	16.1
October	17.4
November	20.4
December	22.9

Although spawning takes place in many different environments in the lakes, the most intensive reproductive activities occur in the vicinity of the river mouths and the wide reed belts (Scirpus riparius) which almost completely surround the lakes of the region. At the beginning of the spawning season when most of the fish are feeding on the dense population of the bivalve Corbicula limosa in the central part of the lake, spawning takes place there. Since the peak of reproductive activity coincides with the period of strong westerly winds, it is difficult to ascertain whether migration towards the river mouths and reed belts is part of the spawning habit, or is induced by the action of strong currents and turbulence set up by the wind in these shallow lakes. Contrary to the situation with many fish, O. bonariensis feeds actively during the spawning period.

Mature ovarian eggs average 1.72 mm. in diameter. They swell to 2.2 mm. during hydration (water hardening). The eggs are spherical and have 3 or 4 elastic filaments, 2 to 3 mm. long, which serve to attach them to aquatic plants or other objects. The color of the eggs when released by the female varies from yellowish-green to yellow. They are cast at random and are abandoned by the parents. Widespread distribution of the eggs on the bottom, suggests that the female releases them while swimming at a fair speed rather than while relatively stationary. The eggs have never been found agglutinated in nature. However, when they are stripped from a female, their filaments tend to adhere so that a large single mass of eggs and filaments is formed.

The number of eggs in the ovaries counted in two-year-old fish was 15 to 16 thousand. The number of mature eggs during the spawning season depends upon the size of the fish. All eggs mature at one time. Those not mature at stripping will not be spawned that year (Table 3).

Table 3. - Relationship between body weight, weight of ovaries, number of stripped eggs, and total number of ovarian eggs in Odontesthes bonariensis from Lagoa dos Quadros, 1941 - 1947

Weight of fish (gms.)	Number of fish	Average weight of ovary (gms.)	Average number of stripped eggs	Average total number of eggs in ovary
450-499	8	40	2,000	9,250
500-549	13	44	2,650	10,000
550-599	14	46	3,300	12,400
600-649	13	48	4,400	13,950
650-699	17	52	6,050	14,300
700-749	17	53	7,800	15,000
750-799	15	55	9,000	15,000
800-849	12	56	9,850	15,350
850-899	10	58	10,900	15,100
900-949	11	60	11,050	15,700
950-999	14	61	12,200	15,700
1000-1049	12	63	14,100	15,850
1050-1099	9	64	15,000	16,200

The proportion of stripped eggs to the total number of eggs increases with the weight of the fish (Table 4); in other words, the larger the fish the greater the average number of eggs which may be obtained by stripping. First spawning of females takes place during the first winter after hatching, so that a one-year-old fish will reproduce its first offspring, although egg production is small during the first spawning season (Table 4).

Table 4. - Relation of body weight (gms.) and stripped eggs given as a percentage of the average total number ovarian eggs in O. bonariensis (Computed from Table 3)

Weight of fish (gms.)	Average percentage of stripped eggs in relation to average total number of ovarian eggs
450-499	21.7
500-549	26.5
550-599	26.6
600-649	31.5
650-699	42.3
700-749	52.0
750-799	60.0
800-849	64.3
850-899	72.2
900-949	70.4
950-999	77.7
1000-1049	89.0
1050-1099	92.6

Males also become sexually mature at the end of the first year of life. The weight of the testes of 112 fish with body weight from 465 to 775 grams fluctuated between 3 and 9 grams during the breeding season. There was no correlation between the weight of the testes and that of the body. It is probable that testis weight depends largely upon the physiological state of the organ. When stripped, the volume of milt obtained in any one operation is rarely more than five to ten drops, generally less. Removal of the testes after stripping demonstrates that very little milt is left in the organ. It was not possible to measure this small amount. It is not known whether or not a subsequent mass of milt could be generated by such a fish could it survive handling and stripping.

The viability of the unfertilized eggs and of the sperm is limited in natural lake water (Table 5).

Table 5. - Viability of unfertilized eggs (stripped from one live female) and of sperm (taken from one live male) of *Odontesthes bonariensis* in natural lake water at 18°C.

Eggs		Sperm	
Time (minutes) in water before fertilization (all milt freshly stripped) - batches of 100 eggs	Percentage of eggs fertilized by one drop of milt (based on formation of blastodisc)	Time (minutes) in water before fertilization (all eggs freshly stripped) - one drop of milt in one drop of water	Percentage of eggs fertilized by sperm-water mixture (based on formation of blastodisc)
0	100	0	100
0.5	95	0.5	52
1	72	1	28
2	61	2	3
3	60	3	0
4	32	-	-
5	10	-	-
6	1	-	-
7	0	-	-

If after entering the water, the eggs are not fertilized within one minute, they lose their capacity to be fertilized. It is therefore to be expected that fertilization in nature occurs immediately after the release of the eggs by the female. Natural fertilization appears to be poor on occasions. In order to ascertain the percentage of impregnation in nature, eggs were collected from reeds cut off at random along the spawning grounds in Lagoa dos Quadros, and also from artificial reed mats which were made by attaching whole plants of Scirpus riparius to a wooden frame covered with chicken wire. These frames were placed in selected localities, and lifted for inspection and collection of the eggs. Twelve counts were made in 1942 and 16 more in 1943. Whereas some counts reveal 100 percent fertilization, others are much less (Table 6). Whether the volume or physiological condition of the sperm or other factors are responsible is not known.

Table 6. - Percentage of fertilized eggs of O. bonariensis on natural and artificial reed mats in Lagoa dos Quadros, June - July 1942 and 1943

Nature of bottom and depth	Number of eggs collected (*)	Percentage of fertilized eggs (**)	Number of observations
Hard sand 0.80 m.	1,400	100	3
	900	72	1
	1,000	64	1
Hard sand 0.50 m.	800	100	1
	1,300	90-99	3
	600	81	1
	500	73	1
	500	69	1
Plant detritus 0.85 m.	1,800	100	4
	3,200	90-99	5
	700	88	1
	700	79	1
	600	75	1
	700	72	1
	300	69	1
Grand total	15,000	88.5	26

(*) Estimated by volumetric measurements
(**) Mean of percentage for individual observations

Embryonic development and its rate depend upon the temperature (Table 7). Low temperatures are detrimental to the normal development of the embryo. Large mortalities occur when the temperature of the water drops below 15°C., and hatching is often abnormal. Mortality as high as 90 percent occurs when the temperatures drop to 5 or 6°C., a temperature not uncommon in the lakes during the month of July. Optimal temperature in the laboratory was 18°C. The developmental period at this value is 11 days, and mortality is least (Table 7).

Table 7. - Temperature of incubation and mortality of eggs in O. bonariensis as observed in the laboratory on eggs stripped from one female and fertilized by sperm from one male. Batches of 500 eggs; total number 4,500

Stage of development	Percentage of eggs surviving when incubated at temperatures of		
	15°C.	18°C.	20°C.
Blastodisc fully developed	100	100	100
First cleavage	93	100	100
Second cleavage	81	98	95
Third cleavage	78	98	95
Periblast formed	62	96	93
Pulsation of bulbus	39	86	81
Internal circulation	21	86	80
Hatching	20	86	80
Larvae alive after 12 hs.	4	86	80

The difference between established optimal temperatures for the development of the eggs in the laboratory, and the temperature recorded at the spawning grounds in nature is remarkable (Table 8). The average of the diurnal temperatures in nature in June and July seldom reaches 18°C. If the readings had been taken during all of the 24 hours in each day, the average would have been lower still. The evidence suggests that temperature may be a factor in the mortality of eggs in nature.

Table 8. - Temperature of water in Lagoa dos Quadros in reed belt at west shore near the Limnological Station, in June and July 1943.

Date	Temperature (°C.)			
	9 a.m.	3 p.m.	9 p.m.	Average
June 18	16.8	17.4	16.8	17.0
19	16.3	17.8	17.5	17.2
20	16.9	18.5	18.0	17.8
21	17.3	20.4	18.9	18.9
22	18.2	19.9	19.0	19.0
23	17.9	18.5	18.0	18.1
24	16.7	19.2	16.3	17.4
25	15.0	16.0	15.1	15.4
26	15.8	16.8	15.0	15.9
27	15.3	17.1	16.7	16.4
28	16.6	18.4	17.5	17.5
29	17.8	-	-	-
-	-	-	-	-
July 7	13.5	17.0	14.6	15.0
8	14.2	15.7	14.5	14.8
9	14.8	15.4	14.5	14.9
10	14.5	16.0	15.3	15.3
11	15.3	17.1	16.2	16.2
12	-	17.1	16.2	-
13	16.6	20.3	16.2	17.7
14	16.6	20.0	15.6	17.4
15	14.4	17.1	15.5	15.7

Certain facts suggest further that natural mortality of the eggs serves sharply to limit the size of the population in these lakes since food is plentiful and important predation on the young and adults of the species could not be proved. Eggs are eaten by small fish (Chapter VII) but the importance of their inroads is not known. It is also to be noticed, for example, that in spite of the very selective feeding habits of O. bonariensis, the populations of the two main food organisms, Corbicula (a bivalve) and Littoridina (a snail) are still large. Furthermore, fishing activities are practically non-existent in these lakes. Although the species is abundant, factors other than food supply, space, or predation must play a role in keeping the species at its present population level. The possibility of deficient natural reproduction, apparently rare in nature according to rapidly increasing evidence, should be given consideration here, especially when it is kept in mind that this species, in the lakes studied, is at the limit of its northward geographical distribution.

IV. DEVELOPMENT OF THE EGG TO HATCHING

The development of the egg of Odontesthes bonariensis was studied in eggs stripped from a fish and fertilized artificially. The eggs utilized in this study were incubated at 15°, 18° and 20°C. (± 0.5°C.) by the jar culture method commonly employed for whitefish (Coregonus spp.) in North America. Eggs were withdrawn at regular intervals depending upon the stage of development, and examined fresh without removal of their coverings under dissecting and compound microscopes (Table 9, Figures 5, 6 and 7).

Table 9. - The embryological development of O. bonariensis at 15, 18 and 20°C. as observed in the laboratory

Description of stages	Time in hours and minutes, to the nearest 5 minutes, after fertilization at		
	15°C.	18°C.	20°C.(*)
Blastodisc fully developed	2.50	2.00	1.30
Elongation of blastodisc	3.30	2.30	1.50
First cleavage at right angle to longer axis of blastodisc	4.30	3.10	2.30
Second cleavage at right angle to first. Four symmetrical cells of approximately the same size	6.30	4.50	3.50
Third cleavage parallel with the first one. Eight cells.	7.25	5.10	4.40
Periblast formed. Cleavage cavity visible	23.00	18.00	15.15
Broadening of embryonic pole	27.30	22.00	18.00
Differentiation of germ ring	30.30	24.00	19.30
Embryonic shield visible	32.45	25.30	20.45
Embryonic keel differentiated	36.00	27.00	23.00
Blastoderm covers yolk sphere	-	31.00	26.00
Blastopore closed	59.00	43.00	36.15
Somites differentiated; eye capsules visible	79.30	59.00	47.30
Pulsation of cardiac bulbus (81 pulsations per minute at 18°C.)	112.00	82.00	64.30
Melanophores on dorsal aspect. Circulation in vitellum	138.00	101.00	78.30
Internal circulation. Pigmentation of eyes	171.00	123.00	92.00
Movements of mouth	300.00	220.00	176.00
Hatching	358.00	271.00	211.00

(*) (± 0.5°)

EMBRYONIC DEVELOPMENT OF ODONTESTHES BONARIENSIS

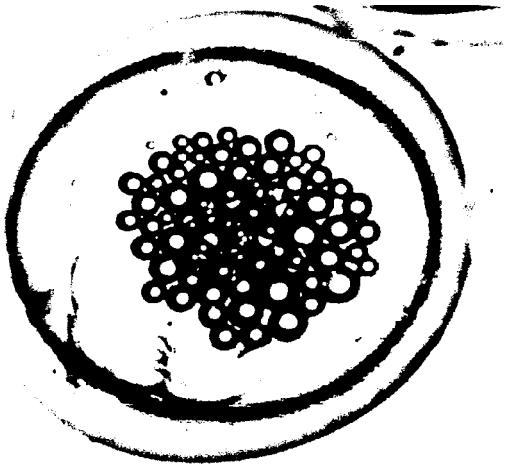
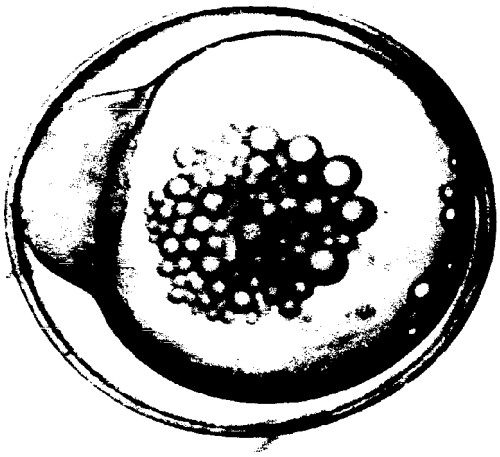


FIGURE 5.-
FIRST CLEAVAGE

FIGURE 6.- BLASTODISC SEVEN HOURS AFTER FERTILIZATION AT 18°C.



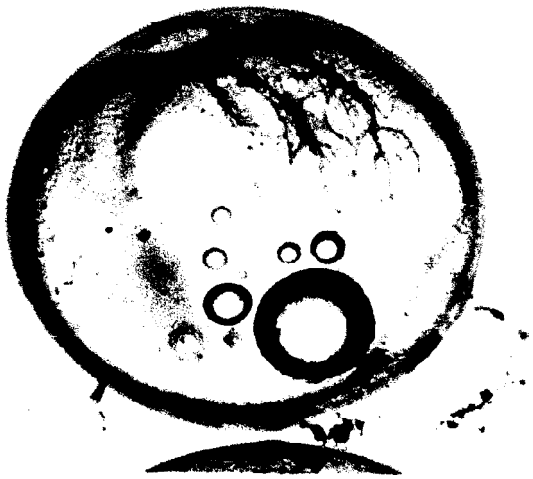


FIGURE 7.- EMBRYO 82 HOURS AFTER FERTILIZATION AT 18°C.

The membrane of the egg becomes very hard after hydration, and is clear and transparent. Thirty to sixty oil globules, which color intensively with Sudan III, are present in the egg (Figures 5, 6 and 7). These droplets obstruct the view into the egg from the top. It is therefore necessary, on occasions, to observe the egg from the side by leveling the ocular tube of the microscope to horizontal, and placing the egg in a glass chamber clamped to the vertical microscope stage.

The number of fatty droplets in the egg decrease with advancing incubation. At 18°C. the development is complete at the end of the eleventh day when the sum of the daily accumulated temperature units (A.T.U.)[1] has attained values between 200° and 210°C.

In the laboratory or hatchery, hatching invariably takes place after sunset, around 7 to 8 p.m. regardless of the exact A.T.U. value attained. Experiments demonstrated that light or darkness are not the main factors, and perhaps not factors at all, in this peculiar timing of hatching. Eggs which had reached the necessary A.T.U. number during the day would not hatch when placed in the dark, but would do so only in the evening at about the time mentioned.

Hatching is preceeded by violent movements of the embryo. Rupture of the membrane and hatching of the larva is mostly simultaneous and takes place in a fraction of a second, as observed in a slow-motion microcinematographic picture. In other eggs a bulging of the membrane may be observed which

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1 One A.T.U. equals an average incubation temperature of 1°C. for 24 hours.

preceeds rupture a few seconds to several minutes. Occasionally, part of the head is pushed out through the initial break in the membrane, and remains in that position for several seconds before hatching is completed. When incubation takes place at low temperature (15°C. and less) the few embryos which complete development often do not hatch. Rupture of the membrane does not take place, and the embryo dies. Under such temperature conditions, partial hatching is also common, in which only part of the embryo succeeds in passing through the opening in the membrane. The protruding part is mostly the anterior portion of the body back to the greatest distension of the yolk sac. Such embryos die within a few minutes.

V. EARLY LARVAL LIFE

Studies on early larval life (8 to 10 mm.) were made only on materials in the laboratory since I was unable to observe these early stages in nature.

After hatching, the early larva remains motionless on the bottom of the tray or tank for a few seconds. It then begins movements which bring it to the surface of the water in an irregular, somewhat spiral course. The periods of activity are short in the beginning, and do not commonly exceed a few seconds. Rest periods of a few seconds occur between the periods of activity. Gradually the periods of movement become longer, and in water of 18° to 20°C. the larva is in continuous activity within five minutes after hatching. It struggles to retain position near the surface of the water. At lower temperatures (12° to 15°C.), rest periods are longer, whereas at 5°C. early larvae become completely inactive and remain on the bottom of the container for at least four hours (the maximum time of observation). Light increases the activity of newly hatched larvae. Inspection of trays containing a large number of newly hatched individuals at night often revealed that most of the animals were at rest. Sudden illumination of the tray stimulated these inactive larvae to activity.

Feeding starts in the early larval stage; the fish hatches with open mouth. Smears made of the content of the digestive tracts in young larvae, 48 hours after hatching, and kept in lake water, disclosed rotifers, unicellular algae, and an

occasional diatom. Other remains could not be identified. Microcrustaceans were never found in fish shorter than 10 mm. At the end of the third to fourth day of life the yolk sac is completely absorbed. The larvae are then about 11 mm. long.

VI. POSTLARVAL AND ADULT LIFE

During calm days fry may be observed practically everywhere in the surface water of the lakes where they can be caught with large plankton nets (1 m. diameter). The movements of the fish ripple the surface of the water over wide areas. When waves are set up by wind action the fish disappear from the surface and none are to be caught by plankton nets at various depths. They can always be found during the winter season and in early summer in the shallow bays and river mouths, where dense mats of Eichornia, Pontederia, and Scirpus riparius form extensive shelters and breeding grounds for numerous invertebrates (Figs. 8 and 9). Although no quantitative data were obtained, direct observations indicate that in Lagoa dos Quadros the mouths of the rivers Maquine and Cornelios are the main feeding grounds for the young of O. bonariensis up to a size of 120 mm.

1. Food and Feeding Habits. From 10 mm. upwards, micro-crustaceans begin to dominate the food, and soon make up most of it by bulk (Table 10).



FIGURE 8.- EICHORNIA MATS NEAR MOUTH OF THE RIVER CORNELIOS

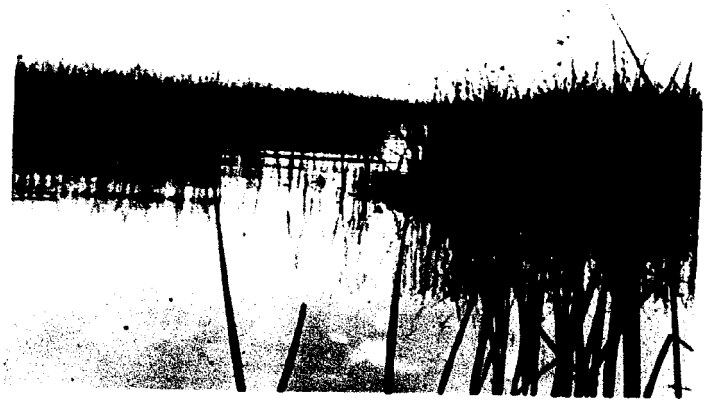


FIGURE 9.- SCIRPETUM AT THE MOUTH OF THE RIVER SANGA FUNDA

Table 10. - The food of *O. bonariensis* in specimens ranging from 10 to 120 mm. total length in Lagoa dos Quadros. Based on stomach analyses in 10 specimens of each size group, taken with seines, June - July, 1943. (1 = present; 2 = approx. 1/3 of total bulk; 3 = approx. ½ of total bulk; 4 = approx. ½ to 2/3 of total bulk; 5 = approx. total bulk)

Length of fish (mm.)	Food organisms									Remarks		
	Diatoms	Unicellular algae	Rotifers	Nauplii	Plankton Crustacea	Hyalella	Littoridina	Insects	Unidentified			
10-14	2	2	1	1					1	10	stomach	contents pooled
15-19	1	1	2	2	1				1	10	"	"
20-29	1	1	1	2	2	1			1	10	"	"
30-39	1	1	1	2	3	1			1	10	"	"
40-49	1	1	1	1	4	2			1	10	"	"
50-69	1	1	1	1	4	2			1	10	"	"
70-89	1	1	1	1	4	2			1	4	"	"
					5					3	"	"
						5				2	"	"
					2	4	1			1	specimen	
90-120					4	1		2		2	stomach	contents pooled
	1	1	1	1	4	1	2	1	1	3	"	"
						1	4	2		5	"	"

Seasonal surges in the abundance of Melosira granulata, a diatom, are reflected in the stomach contents of the fish. Plankton constitutes the main food for the young fish up to a length of 120 mm. Hyalella azteca, an amphipod inhabiting the roots of water hyacinth, is commonly represented in large numbers. Besides this crustacean, numerous larvae and nymphs of insects are to be found in stomachs of young from 100 to 120 mm., as well as occasional green algae (Spirogyra) and plankton.

When a length of about 120 mm. is passed, the diet of the fish begins to change (Table 11).

Table 11. - The food of Odontesthes bonariensis in fish ranging from 120 to 459 mm. standard length, according to season, in Lagoa dos Quadros and Lagoa Itapeva. Based on stomach analyses in 710 fish captured with gill nets, 1941 - 1947. Number of observations in parentheses. Values given are percentages of total stomach contents by volume. Roman figures represent months

Food item	Months	Length of fish (millimeters)		
		120-149	150-189	280-459
Plankton crustaceans	V-IX	-	5 (20)	0 (459)
	IX,X,XII-IV	14 (29)	7 (22)	0 (96)
	XI	0 (18)	0 (10)	0 (56)
Littoridina	V-IX	-	81	78
	IX,X,XII-IV	72	83	11
	XI	1	3	1
Corbicula limosa	V-IX	-	0	17
	IX,X,XII-IV	0	1	85
	XI	0	0	2
Mayfly nymphs	V-IX	-	2	1
	IX,X,XII-IV	1	4	2
	XI	21	26	20
Mayfly imagos	V-IX	-	0	0
	IX,X,XII-IV	3	3	1
	XI	71	70	72
Lycengraulis	V-IX	-	4	4
	IX,X,XII-IV	0	1	1
	XI	0	0	3
Miscellaneous food, and not identified	V-IX	-	8	0
	IX,X,XII-IV	10	1	0
	XI	7	1	2

Plankton becomes a minor and only occasional constituent of the stomach content, whereas two mollusks begin to form the main, and later, almost exclusive food of the adult fish. These mollusks are Corbicula limosa, a bivalve, and Littoridina charruana, a gastropod. The first species is a typical inhabitant of sandy and firm bottoms, whereas the second one is most often associated with loose bottom deposits having a high content of plant detritus. Although both species may occur together, they are normally part of characteristic biocenoses in which one or the other predominates. Younger fish (120 to 200 mm. total length) feed first only on Littoridina, which is smaller than Corbicula. The small gastropods are eaten whole, and are not crushed. The intestine is usually found distended with the blackish-brown shells from which the larger part of the soft tissues has been dissolved by the digestive juices.

When fully grown (220 to 459 mm. total length), the fish starts to feed on Corbicula, which is considerably larger than Littoridina. The shells are always crushed thoroughly, and are swallowed together with the soft parts. This feeding habit is different from that of other fishes which feed on mollusks, for example, the North American centrarchid, Lepomis gibbosus, which does not typically swallow the crushed shells. In this size-group again, the whole digestive tract is usually distended with crushed shells, many of which have sharp cutting edges. Fully grown fish usually feed on either Littoridina



or Corbicula alone, but the presence of both species in the same tract is not exceptional.

The frequency of Corbicula in stomach contents is considerably higher during the warm season (September to May) than in the winter (June to August) - (Table 11). In the warmer months adult fish seem to prefer the central parts of the lakes where hard sand bottoms and dense populations of Corbicula exist. The frequency of Littoridina increases during the colder months, when the fish concentrate around the reed belt along the shores of the lakes and the river mouths. Bottom fauna analyses made during the winter and summer seasons do not reveal appreciable changes in the numbers of individuals in either Littoridina or Corbicula associations (Table 12). It seems therefore, that the occurrence of larger quantities of Littoridina in the diet during the winter months is the result of seasonal migration of the fish towards the more protected shores and river mouths where that mollusk predominates.

Table 12. - Fluctuations during winter and summer in the number of Corbicula and Littoridina in their respective associations in Lagoa dos Quadros. (Based on average counts made at "Coroa" and "Barra dos Cornelios" in 1941, 1943, and 1945)

Item	Number of organisms per square meter					
	1941		1943		1945	
	Winter	Summer	Winter	Summer	Winter	Summer
	Corbicula association					
	(10)(*)	(9)	(8)	(7)	(10)	(4)
Corbicula	1,600	1,100	1,000	900	1,400	1,100
Littoridina	2,150	2,200	1,800	1,900	2,400	2,400
	Littoridina association					
	(7)	(8)	(5)	(5)	(7)	(3)
Corbicula	600	500	400	400	600	650
Littoridina	7,200	7,500	6,800	6,200	7,800	7,000

(*) Number of square-meter samples analyzed.

Some food preferences are shown by O. bonariensis. Stomach analyses of fish caught in areas where the territories of Corbicula and Littoridina approach each other, indicate that there is a definite preference for Corbicula on the part of the fish (Table 13). This mollusk has therefore to be considered, at least in Lagoa Itapeva and Lagoa dos Quadros, as the main food source for the "peixe-rei", except at the time of the emergence of mayflies.

Table 13. - Percentage of *Littoridina* and *Corbicula* in stomachs of 34 specimens of *O. bonariensis* collected at "Coroa da Casa das Telhas" (border area between *Corbicula* and *Littoridina* associations), northwest shore of Lagoa dos Quadros, compared with that of 24 fish collected at "Barra dos Cornelios" (*Littoridina* association), July 1944

Percentage of stomach contents by volume			
Littoridina		*Corbicula*	
Casa das Telhas	Cornelios	Casa das Telhas	Cornelios
10	74	83	13

The stomach content of fish which has fed exclusively on mollusks may consist to a large extent on shells. For example, 46.9 percent of the weight of the stomach contents of fish which had fed on Corbicula alone consisted of shells. For Littoridina this percentage was 52.0.

A shift away from a predominantly molluskan habit of O. bonariensis starts generally in early November when Ephemeroptera begin to emerge. These insects temporarily constitute the main food of the fish (Table 11). Three species of mayflies occur in the lakes of the region: Hexagenia albivitta, Campsurus brasiliensis, and Campsurus assimilis. The subimagos of these species emerge invariably around 8:00 p.m. in very large numbers. At such a time no other food is to be found in the stomachs of the peixe-rei. It was noticed that the flavor of the fish was affected unfavorably by this diet.

Besides mollusks and emergent mayflies, the following food organisms appear occasionally in the stomach contents of O. bonariensis: nymphs of mayflies; larvae or the young of other fishes (especially of the herring Lycengraulis grossidens); and young of their own species. The occurrence of fish of any kind, with the possible exception perhaps of L. grossidens is so rare that the peixe-rei can hardly be considered a predator of other fishes. It must be classified as omnivorous with definite bottom feeding proclivities.

Because of the major position of Corbicula limosa in the diet of Odontesthes, it was held desirable to make a series of observations regarding the food of this mollusk. The digestive tract

was examined in animals from different localities in the lakes and during all seasons. It was observed that this bivalve feeds almost exclusively on diatoms, with particular preference for Melosira granulata, which was the only organism present in most digestive tracts. Since these mollusks were examined immediately after collection, better digestibility of certain of its other food organisms could not account entirely for the persistent predominance of Melosira. The occurrence of diatoms in the diet of fresh-water bivalves as well as highly selective feeding were also observed by Churchill (1924).

Corbicula limosa is viviparous, producing seven young in each pair of gills. The young are released when 5 to 7 mm. long, when they have a well developed and relatively thick shell. The release of the young seems to take place at any time during the summer, but the incidence of animals bearing young shows that most of the young are released in early spring (September) - see Table 14. Young Corbicula are rare in the stomach contents of Odontesthes.

Table 14. - Percentage of "gravid" Corbicula limosa according to time of year in Lagoa dos Quadros, 1942 - 1945. Based on collections made with a tow dredge in different areas in the lake.

Month	Number of individuals	Percentage gravid	Length of embryo (millimeters)
January	28	74	2-3
March	34	76	-
April	68	73	4
June	40	78	5
July	18	73	5
August	67	58	-
September	65	28	5-6 (*)
October	43	5	1-2
December	21	69	-

(*) Also a few 1 mm. long.

The average weight of the stomach contents in Odontesthes bonariensis is a nearly constant percentage of the body weight in fish weighing from 451 to 700 grams. The total food content of the stomach in 760 fishes of different sizes and weights was determined. The fish were taken by gill nets in Lagoa dos Quadros during all seasons from 1941 to 1947. The stomachs were removed and weighed while fresh. The organ was then opened lengthwise, the contents removed, and the stomach weighed again (Table 15). The percentage of the body weight composed by stomach contents is constant for fishes from 451 to 700 grams (average 2.16 percent with a range of 2.0 to 2.3 percent). A sudden increase in the percentage of stomach contents occurs at a body weight of 700 to 800 grams (average 3.7 percent with a range of 3.5 to 3.9 percent. By breaking down the weight groups into smaller intervals than 50 grams it was attempted to establish where the sharp increase occurs but the results were inconclusive, probably because of the small number of fish at certain intervals.

Table 15. - Relationship of body weight to weight of stomach contents of Odontesthes bonariensis in Lagoa dos Quadros, 1941 - 1947.

Number of fish	Weight of fish (grams)	Average weight of stomach contents (grams)	Percentage of body weight
20	451-500	12.0	2.3
103	501-550	11.6	2.2
129	551-600	11.8	2.0
120	601-650	14.7	2.3
145	651-700	13.4	2.0
170	701-750	25.7	3.5
73	751-800	29.4	3.9

O. bonariensis is preeminently nocturnal in its feeding habits (Table 16). Repeated samples of fish from gill nets placed in different localities in the lakes, established the period of most active feeding to be between 8:00 p.m. and midnight. It was in this interval when the largest number of completely filled or nearly filled stomachs was collected. By 7:00 a.m. most of the stomachs of fishes caught in gill nets were empty, whereas a comparable number from fish taken from the same net at midnight were full.

Table 16. - Feeding time and duration of digestion in O. bonariensis, in Lagoa dos Quadros, 1941-1944. Based on fish taken from gill nets at different hours of the night in ten collections.

Time nets were lifted and number of fish	Number of hours net had fished (*)	Stomachs completely filled		Stomachs approximately half-filled		Empty stomachs	
		Number	Percentage	Number	Percentage	Number	Percentage
8:00 p.m. (42)	2	2	4.8	7	16.7	33	78.5
10:00 p.m. (81)	2	39	48.1	30	37.0	12	14.8
12:00 p.m. (106)	2	96	90.6	8	7.5	2	1.9
4:00 a.m. (124)	3	90	72.6	34	27.4	0	0
7:00 a.m. (181)	2½	30	16.6	41	22.6	110	60.8

(*) ± 30 minutes.

2.Migrations. Besides the main seasonal migrations in the lake, which were already mentioned in relation to feeding habits, more frequent and irregular movements were observed, which seem to be provoked by the currents resulting from wind action. Due to the small depth of the lakes, mixing produced by wind affects most of the mass of water, so that areas of refuge are relatively small, and are restricted mostly to the leeward side of the lake. Accordingly, it was observed that following strong winds from one direction the fish moved leewards and remained there until calm weather set in. This movement was particularly noticeable after periods of "minuano", strong winds of westerly direction which prevail during the winter season. As the water of the lakes becomes very turbid during such periods of strong and prolonged winds, it is probable that the fish try to escape these unfavorable conditions. This same wind-imposed migration was also observed in most of the other species of fish in the lakes especially in Rhamdia sebae. It was therefore easy to select the proper sites for the setting of gill nets during and immediately after such periods of strong wind. When these periods were much prolonged, the fish entered the deeper river mouths, as if to await change of conditions.

During calm weather the fish move around considerably, but seemingly without following a definite pattern. By observing the direction in which the captured fish had hit the gill nets set at various angles in relation to the shore, it was established that, at least during calm periods, the fish were swimming

at random.

On certain occasions not related to heavy winds, it was noticed that large schools of Odontesthes descended the River Cornelios from Lake Itapeva and into Lake dos Quadros. The conditions which produced these migrations could not be established.

Another type of migration was observed (in great detail) in young from 20 to 80 mm. long, which consisted in diurnal movements between the lake shores and the open water of the lake. On calm days just before sunset large schools of young fish would move from the open water towards the shore and the belt of Scirpus riparius, where the depth of the water is only a few centimeters. The muddy shores containing large amounts of plant detritus were avoided. A clear and hard sand bottom seems to be what was sought. The fish would remain within the reed belt until 3 to 4 a.m., when they would leave in the direction of deeper water,(1) and soon, disappear. This movement may be observed every night as long as the water is calm and wave action slight. As soon as the water movements begin to stir up the bottom along the shores, not a single fish enters this zone. Temperature observations and chemical analyses were made at regular intervals during the nights, with the purpose of ascertaining whether such ecological conditions in the deeper water or shore water would explain these diurnal movements. Although extensive data of these kinds were collected, correlation between them and the movements of the fish is not demonstrable (Table 17).

(1). Deeper than 1.25 m.

Table 17. - Comparison of temperature and chemical conditions between shore water and water in the open lake during nocturnal migration of young of O. bonariensis. October 31, 1941

Locality	Time (p.m.)	Temperature (°C.)	Diss. O_2 p.p.m.	Free CO_2 p.p.m.	Bicarb. CO_2 p.p.m.	pH	Cl' p.p.m.	CaO p.p.m.
Deeper (60 cm.) margin of Scirpetum zone	8:15	21.5	7.13	2.59	15.4	7.1	6.1	13.3
Shallower (15 cm.) margin of Scirpetum zone	8:25	21.8	7.34	2.52	-	7.1	-	-
Open lake water, about 100 m. outside Scirpetum	9:00	21.0	7.45	2.32	12.4	7.7	4.1	10.1

Hubbs (1921) and Cahn (1927) observed similar diurnal migrations in Labidesthes sicculus, a North American freshwater atherinid. Cahn found that these migrations are coincident with changes in temperature and the hydrogen-ion concentration of the water. Also phototropism was found to be a factor. Hubbs was unable to ascertain such correlation between ecological conditions and the diurnal movements of the young fish. In a review of Cahn's paper (Hubbs, 1928) he does not agree with Cahn's conclusions. My observations on Odontesthes show no correlation between migrations and the ecological conditions studied.

It was established further that the digestive tract of the fish arriving at the shores in the early evening were completely filled with plankton. The pursuit of food along the shores could hardly therefore be a factor in this movement. It is possible that these movements are a protective measure against predators which would require deeper waters than those found along the shores. This peculiar habit of the young of this species made it possible to seine large numbers for study of growth and feeding habits.

3. Age and Growth. Any previous studies on the age and growth of this species that may have been conducted are unknown to the author. Some scattered data on lengths and weights of isolated specimens are found in the literature dealing with the culture of this fish and with stocking in the La Plata countries.

Since one of the main purposes of the present biological and ecological study was to ascertain the economic possibilities of introducing Odontesthes into bodies of water outside the basin here described, information on the age and growth of the species in its natural habitat was highly desirable. Such information would make it possible to compare growth of the fish in new environments, as well as to recommend the proper means of utilizing the stock existing in the lakes studied.

The lack of facilities during the first half of the investigations, as well as illiteracy among fishermen and available workmen restricted considerably the scope of the age and growth studies. All gill nets were hand woven by local fishermen and their families. The relatively high temperature of the fresh water limited the life of the nets to periods from three to eight weeks in the summer. These and other difficulties account in part for the limitations of my data on this subject.

Materials and Methods. For the study of age and growth in O. bonariensis in Lagoa dos Quadros the scales of 754 fish were examined and measured. These fish were captured in all seasons during 1941, 1942, and 1947, although the largest number was obtained from April to October in each year. The data for the study of the length-weight relationship were

obtained from 4,054 fish collected during the same periods. All adult fish, which constitute the largest part of the collections, were caught by means of gill nets with mesh sizes 60, 75, and 80 mm. stretched measure after shrinking. Young a few months old were caught by means of cast nets (Figure 10), whereas those a few days to a few weeks old were captured with fine-meshed seines during the evening (Figure 11).

Gill nets were set in the afternoon and lifted the next morning. In Lagoa dos Quadros nets were set mostly along the western and northern shores, at the mouth of the River Cornelios, and in the central part of the lake on the hard sand banks inhabited by Corbicula. Occasionally nets were set at other places.

Net casting was done in the river mouths, where the young of the species gather around the Eichornia mats (Fig.10). Sight in these fish is extremely well developed and successful casting requires great skill. Seines made of mosquito netting were used on calm evenings when the very young fish come to the lake shores among the reeds, and can be captured easily (Fig. 11).

The scales of 454 fish were used for the study of the relationship between the body length and the anterior measurement of the scales.(2).

All fish were weighed and measured very shortly after capture. In the beginning a ruler was used, but it was later replaced by a conventional fishery measuring board. All measurements were

(2). The Dahl-Lea method was used. See Lagler, 1949, p.209.

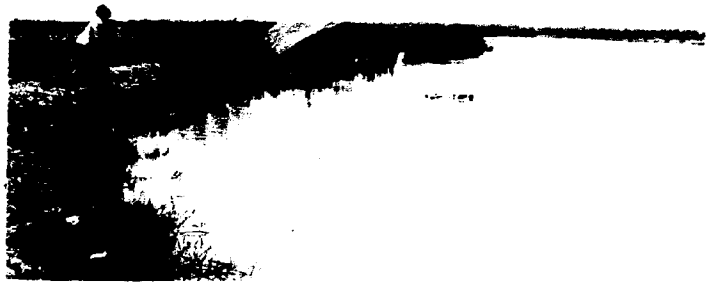


FIGURE 10.- YOUNG OF ODONTESTHES FROM 120 TO 200 MM. STANDARD LENGTH ARE CAUGHT IN A CAST NET NEAR THE RIVER MOUTHS



FIGURE 11.- YOUNG UP TO 120 MM. ARE CAUGHT WITH SEINES ALONG THE LAKE SHORES AND RIVER MOUTHS.

made in millimeters. For very young fish, up to 50 mm. standard length, which were captured in large numbers by seining, another procedure was followed. They were placed on millimetric graph paper and so measured. Length records included both standard length and fork length measurements. Weights were determined on a spring scale which was calibrated by 5-gram intervals, and which was frequently checked. When laboratory facilities became available, this scale was replaced by a platform balance, also calibrated by 5-gram intervals. Very young fish were first grouped together into length groups of 5-mm. intervals, and then weighed in groups after which the individual weights were computed. These weighings were done on so-called postal scales, sensitive to one gram. As the amount of adhering water plays a role in weighing fish of less than one gram, even when in groups of many individuals, these small fish were first dried by rolling them about on blotting paper.

Scales used in this study were mounted in a glycerin-gelatine medium or readings were made of their impressions on cellulose acetate, produced under pressure with or without the application of heat as needed. These impressions include the whole scale in this species, without loss of the extreme margins. As the focal parts of the scales in Odontesthes contain a large number of crystals, which obstruct the field, and can not be removed without destroying the texture of the scales, the cellulose acetate impression is especially valuable as it is much more clear than the original and apparently without distortion. Scale measurements were made, for the most part, on a microprojection apparatus, at the magnification X 41.5. Some measurements were made at

other magnifications and by other means. All data so obtained were converted to equal an enlargement of 41.5 diameters. The smallest scales, taken from very young fish with standard lengths from 15 to 40 mm., were measured directly with the aid of a binocular microscope and a camera lucida.

The establishment of the validity of annuli as year marks was made in 1945 and 1946 by studying the scales of fish of known age which were obtained from private and public dams and ponds previously stocked with fry. These control fish were taken from fish ponds owned by Mr. Segundo Mandelli, and from a municipal dam, all located at Caxias, in the state of Rio Grande do Sul. Further controls were obtained from the fish tanks at the station at Lagoa dos Quadros. Fish of age-groups I and II were so obtained. As Odontesthes did not occur naturally in the region, and careful records were kept of the stockings, the exact age of these fish was known. Fry a few days old, planted in June of each year, had a well defined annulus in June of the following year. In the artificial environment of the hatchery tanks annulus formation takes place at the end of the summer, in the months of February to April. Annulus formation in nature appears to occur during the same general period but somewhat later. The exact time could not be established.

Body-scale relationship. Key scales were not used for this study, but all scales were taken from a lateral area between the tip of the pectoral fin and the dorsal midline. The measurements used are the average of at least six scales from each fish (Table 18).

Table 18. - Relationship between standard length (l) and the anterior measurement (Sc) of at least six scales taken at random from a lateral area between the pectoral fin and the dorsal midline, of Odontesthes bonariensis from Lagoa Itapeva and Lagoa dos Quadros, 1941 - 1947.

Number of fish	Standard length (millimeters) (L)	Scale length (millimeters x 41.5) (Sc)	Average L/Sc ratio
12	15-19	8.2	2.09
21	20-24	13.0	1.69
30	25-29	14.6	1.85
21	30-34	19.7	1.62
39	35-39	22.8	1.62
15	40-44	28.0	1.50
18	45-49	28.5	1.65
18	50-54	30.7	1.69
6	55-59	34.4	1.65
9	60-64	44.5	1.39
6	65-69	44.5	1.50
3	70-74	45.9	1.57
.....	.....	.....	.....
3	90-94	65.0	1.41
...	...	...	...
4	305-309	131.0	1.58
3	310-314	178.0	1.75
4	315-319	182.0	1.74
3	320-324	204.0	1.58
12	325-329	187.9	1.74
6	330-334	195.2	1.70
6	335-339	180.0	1.87
17	340-344	202.3	1.69
18	345-349	193.8	1.79
15	350-354	197.7	1.78
18	355-359	210.3	1.65
24	360-364	196.7	1.84
30	365-369	210.8	1.74
27	370-374	208.9	1.78
21	375-379	216.6	1.74
15	380-384	220.1	1.69
6	385-389	211.4	1.83
9	390-394	193.9	1.92
...	.....	.....	....
12	400-404	216.6	1.74
3	405-409	240.8	1.69
Number of fish 454	Average body-scale ratio: 1.70		

The grand average value of the body-scale ratio is 1.70. The discrepancies from this grand average are not large but are most notable in the lower length groups through 209 mm., where the ratio is consistently smaller with exception of the 15 to 19 and 25 to 29 mm. length groups. The extent of the variations of the relative size of the scales is shown in Figure 12, in which the line L = 1.70 Sc. The relatively small discrepancies here revealed seem to justify the calculation of growth from the assumption that the body-scale ratio is constant at all lengths.

Age Composition and Length Frequencies. In this discussion age-group 0 refers to fish whose scales do not have an annulus, and are in their first year of life. Fish of age-group I have one annulus, and are therefore in their second year of life, etc. The data for the collections of the different years were not combined in view of the great divergence in age-group dominance between the 1941, 1942, and 1947 samples (Table 19).

FIGURE 12. – RELATIONSHIP BETWEEN THE STANDARD LENGTH OF ODONTESTHES BONARIENSIS AND THE MEASUREMENTS OF MAGNIFIED SCALES.

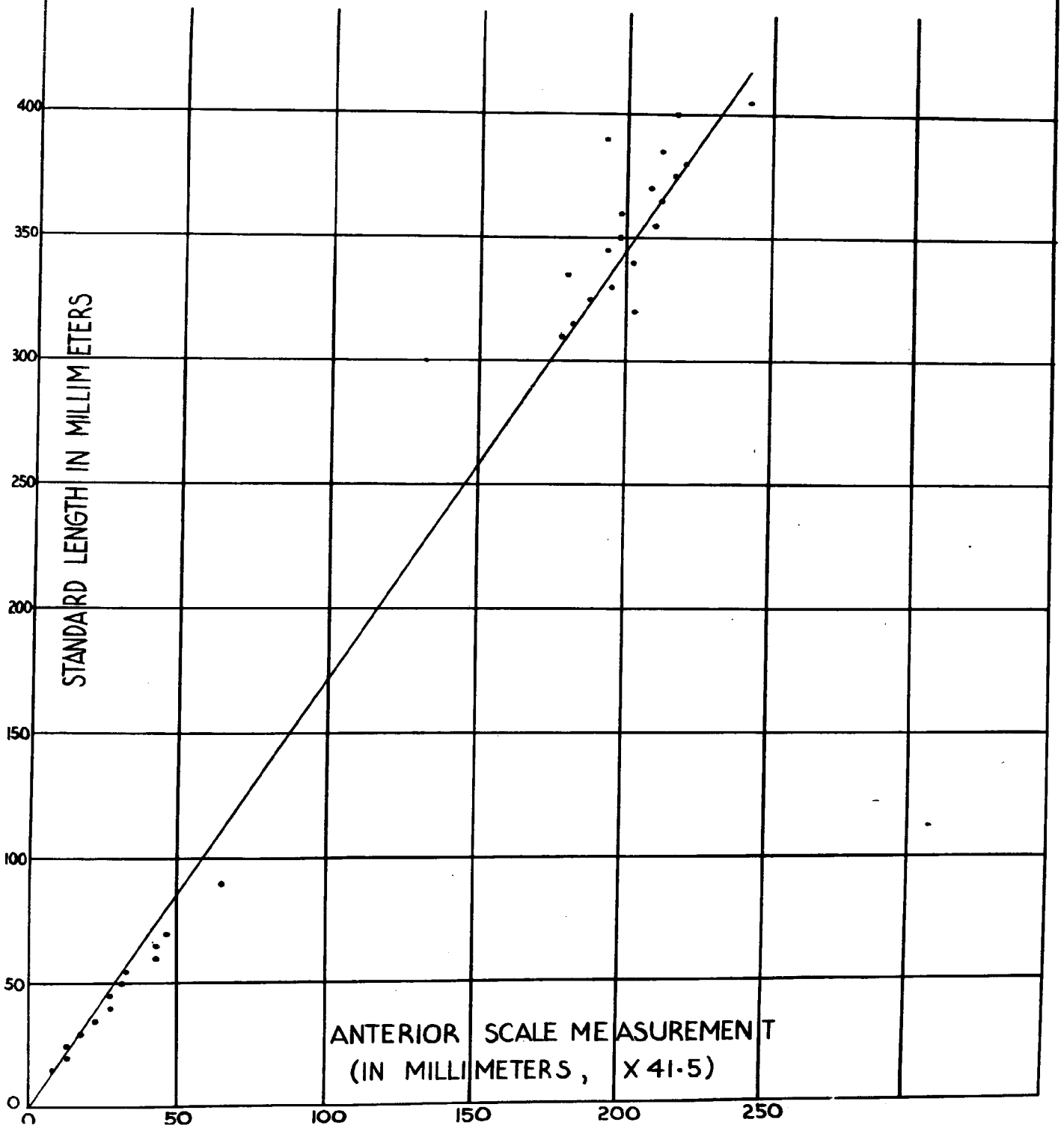


Table 19. - Age and year-class composition of collections of *Odontesthes bonariensis* in Lagoa dos Quadros.

Year of capture	Item	Age group								
		I			II			III		
		♂	♀	both sexes	♂	♀	both sexes	♂	♀	both sexes
1941	Number of fish	10	14	24	13	15	28	3	0	3
	Percentage of sample	0	48.2	31.1	81.2	51.8	62.2	18.8	0	6.7
	year class	1940			1939			1938		
1942	Number of fish	14	42	56	70	84	154	7	42	49
	Percentage of sample	15.3	25	21.6	76.9	50	59.4	7.8	25	19.0
	year class	1941			1940			1939		
1947	Number of fish	119	215	334	54	47	101	5	0	5
	Percentage of sample	66.8	82.3	76.0	30.4	17.7	23.0	2.8	0	1.0
	year class	1946			1945			1944		

Whereas in 1941 and 1942 age-group II predominated, in 1947 age-group I was dominant. In 1941 age-group II was dominant with 62.2 percent against 31.1 percent of age-group I; age-group III was very sparsely represented. In 1942 the composition of the sample became 59.4 percent for age-group II, with an almost equal representation of age-groups I and III (21.6 and 19.0 percent respectively). In 1947 these values changed to 76.0 percent for age-group I, 23.0 percent for age-group II, and 1.0 percent for group III. For all samples combined age-groups I and II make up the largest part. It will be noticed that females predominate in all age-groups represented by more than a few individuals. The percentages of males were rather large in age-group II in all three years, and small in age-group I, and in age-group III in 1942, which is the only year with a fair number of fish in this age-group. On no occasion were fish older than III years caught in any of the lakes of the basin inhabited by the species. Selectivity of the gear is probably not responsible because never was any fish taken in gill-nets with meshes larger than 80 mm. neither did seining in the river mouths ever land fish older than age-group III. It is mentioned in Argentine publications dealing with stocking, that specimens of eight years have been found in that country. Since such information apparently was not collected by qualified biologists, it seems doubtful whether it is correct.

The 1939, 1940, and 1946 year classes seem to have been strong, although the available data are not sufficient for an

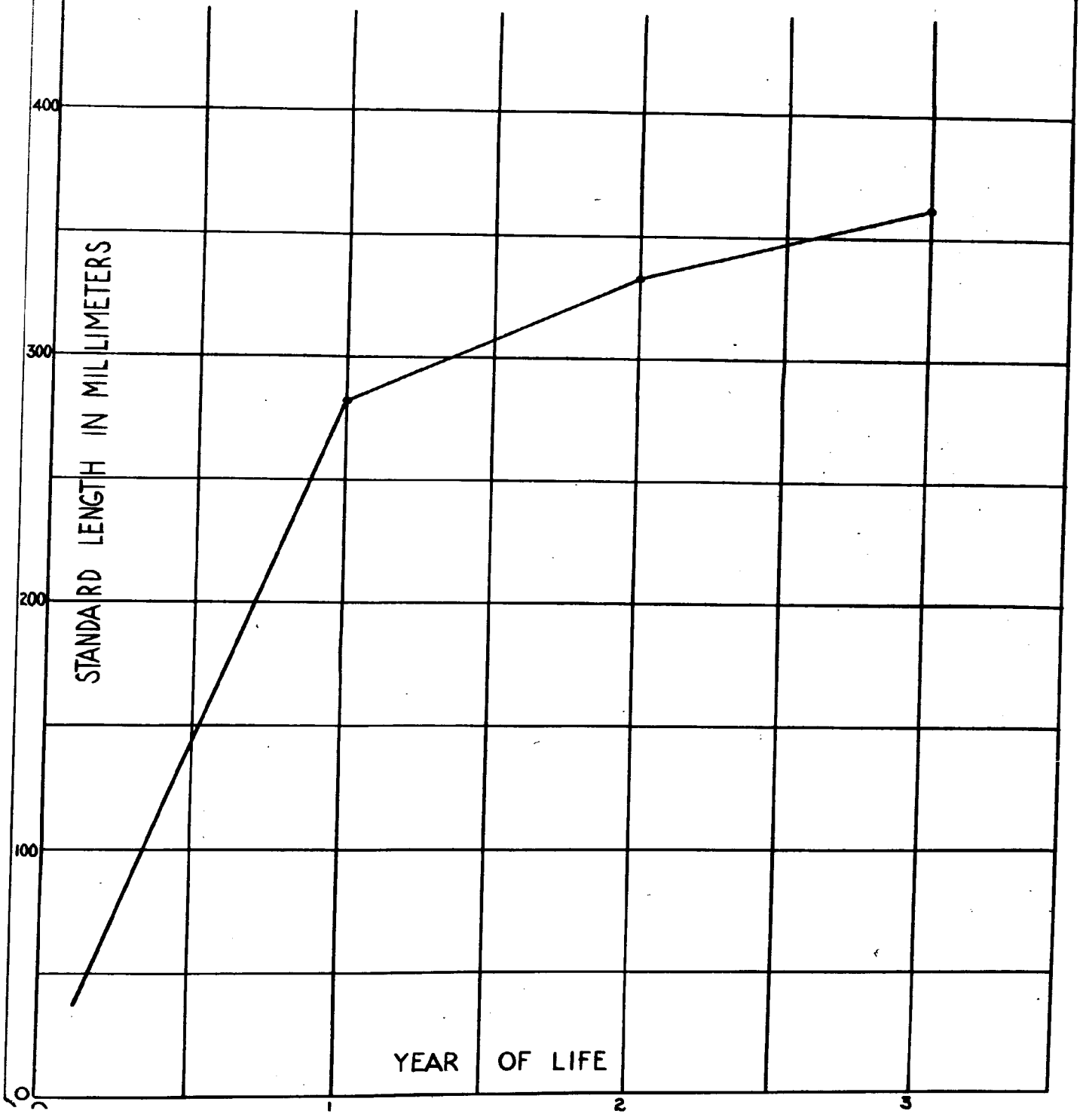
exact analysis of the relative abundance of the year classes. The 1939 year class was twice as well represented as the 1940 year class, while, in the 1942 sample, the 1940 year class was almost three times as strong as the 1941 year class. In the 1947 sample, the 1946 year class was more than three times as strong as the 1945 year class.

At the end of their first year of life females are slightly longer than males (Table 20). This difference disappears at the end of the second year, whereas at the end of the third year males are longer than females. For both sexes combined the standard lengths at the end of the first, second, and third year are respectively 284 mm., 334 mm., and 361 mm. (Figure 13).

Table 20. Av. Calculated standard length in millimeters at the end of each year of life for O. bonariensis in Lagoa dos Quadros, 1941 - 1947. Number of fish in parentheses.

Sex	Length at end of year (millimeters)		
	1	2	3
Males	280 (295)	336 (152)	364 (15)
Females	287 (459)	333 (188)	359 (42)
Both sexes	284 (754)	334 (340)	361 (57)

FIGURE 13. – CALCULATED GROWTH IN LENGTH (DATA FOR SEXES COMBINED) OF ODONTESTHES BONARIENSIS IN LAGOA DOS QUADROS, 1941–1947.



A study of the increments of standard length of Odontesthes during the calendar years of 1938 to 1947 seems to indicate that the year 1941-1942 was a relatively poor year for growth whereas the year 1946-1947 was a good one (Table 21).

Table 21. - Increments of standard length in O. bonariensis according to year of life and calendar year, 1938 to 1947.

Year of life	Calendar years								
	1938 1939	1939 1940	1940 1941	1941 1942	1942 1943	1943 1944	1944 1945	1945 1946	1946 1947
3			59	26					57
2		90	92	78				84	105
1	279	283	286				283	277	285

4. Length-weight Relationship and Length-frequency Distribution. The present analysis of the length-weight relationship for Odontesthes bonariensis is based on materials for both sexes from Lagoa dos Quadros collected in 1941, 1942, and 1947 (Tables 22, 23, 24, 25, 26, and Figures 14 and 15) Fish of standard lengths from 90 to 189 mm. were caught by seines and cast nets. All others were captured with gill nets. Because the analyses of the data from the separate fishing localities showed only minute differences, the data from all stations were combined for final study. Both the males and females of the 1942 collection were relatively heavier in almost all length groups than those of the 1941 and 1947 collections.

Females were heavier than males in almost all length groups. The available data seem to indicate that the difference in average weight between males and females is not constant during the year for a particular length group. When the data for 1941, 1942, and 1947 were broken down and computed for each month of the year, it was found that the difference in average weight was highest in the month of July, when the difference of weight for all length groups captured in gill nets attained 81 grams. The lowest difference (29 grams) was found in the beginning of May. From July to May the difference decreased gradually. This variation suggests that the difference in weight is due to different feeding habits, and to the development of the eggs in the female, the ovaries of which mature at the period of greatest discrepancy in weight. This hypothesis seems to find support in the fact that there is no difference in weight be-

FIGURE 14 - LENGTH WEIGHT RELATIONSHIP OF ODONTESTHES BONARIENSIS IN LAGOA DOS QUADROS, 1941-1947. SEXES COMBINED.

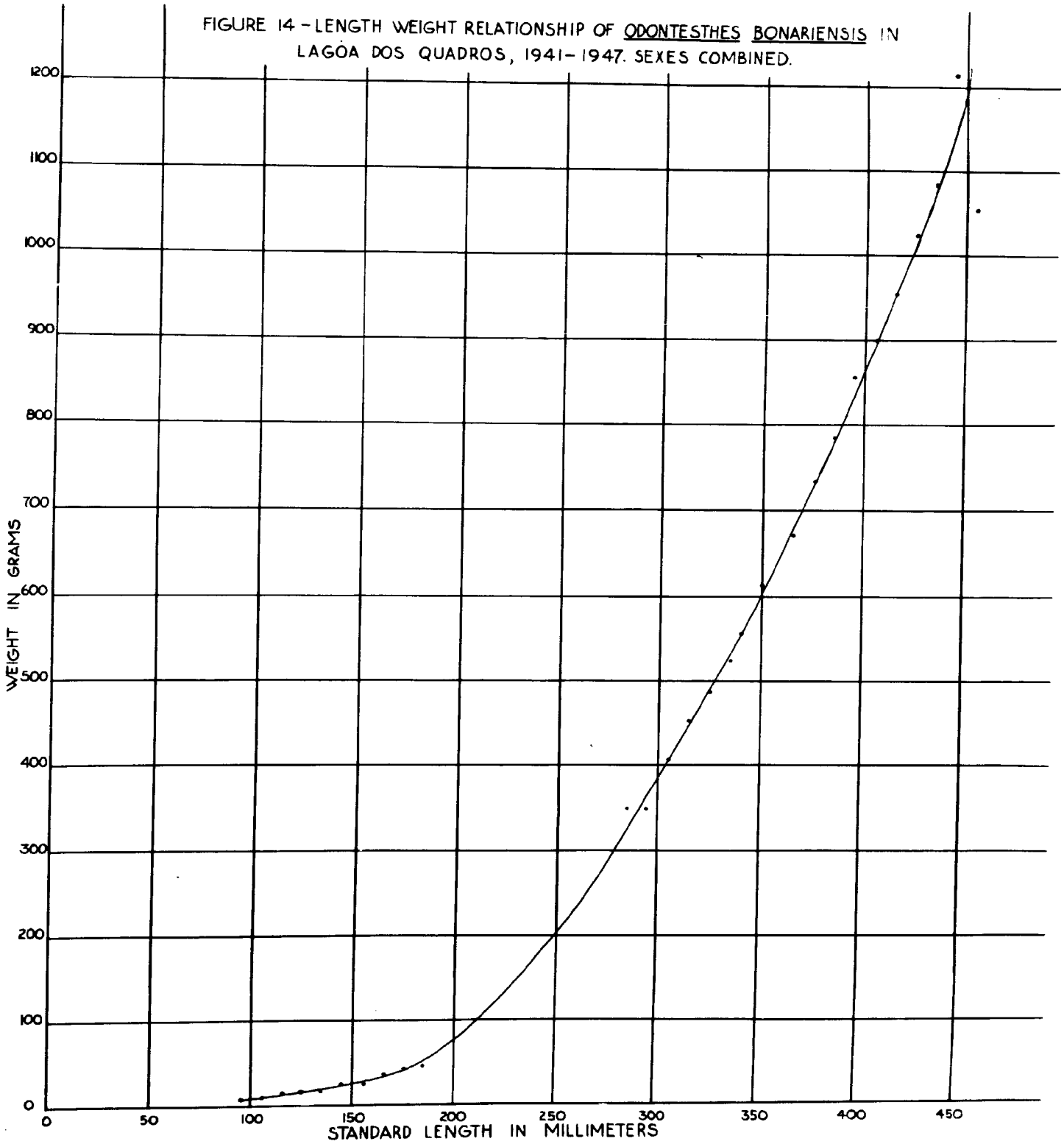
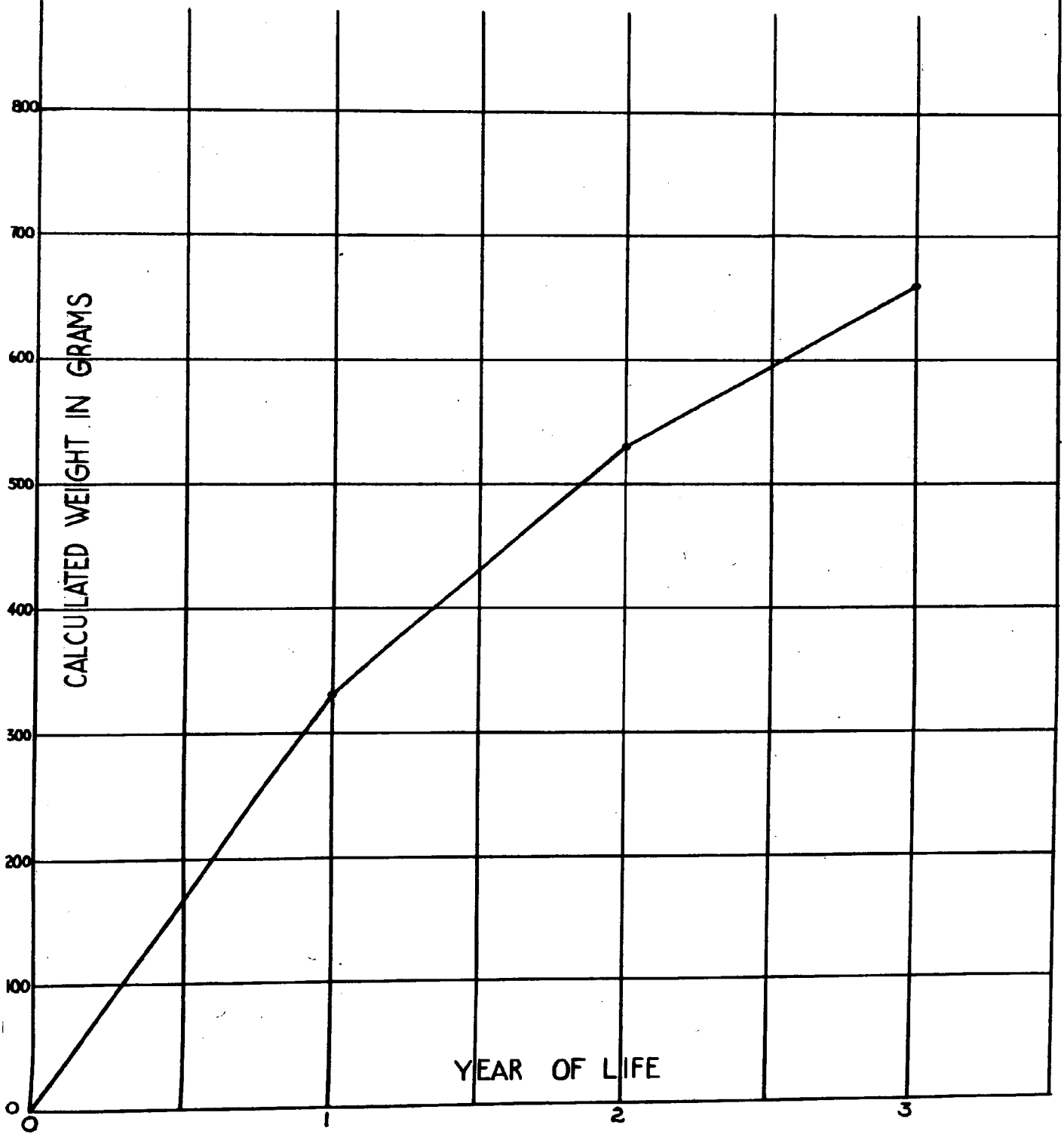


FIGURE 15.— CALCULATED GROWTH IN WEIGHT (DATA FOR THE SEXES COMBINED) OF ODONTESTHES BONARIENSIS IN LAGOA DOS QUADROS, 1941-1947.



tween the sexes in immature fish. The magnitude of ovarian weight has been given previously (Table 3). That the difference in weight between the sexes is not entirely due to the weight of the developed eggs is demonstrated by the gradual decrease in this difference after October, which is the end of the spawning season.

Table 22. - Length and weight of males of *Odontesthes bonariensis* at capture, in Lagoa dos Quadros. Number of fish in parentheses.

Standard length (millimeters)	Average weight in grams		
	1941 Collections	1942 Collections	1947 Collections
cast net			
90-99	-	9 (27)	-
100-109	-	11 (20)	-
110-119	-	14 (20)	-
120-129	14 (3)	20 (7)	-
130-139	20 (3)	19 (3)	-
140-149	24 (10)	-	-
150-159	26 (10)	-	-
160-169	37 (27)	-	-
170-179	40 (10)	-	-
180-189	44 (3)	-	-
gill net			
300-309	375 (7)	467 (10)	-
310-319	450 (3)	438 (13)	483 (7)
320-329	550 (4)	475 (34)	493 (11)
330-339	470 (1)	532 (48)	505 (14)
340-349	565 (35)	608 (11)	565 (47)
350-359	605 (37)	631 (44)	603 (20)
360-369	665 (31)	685 (54)	650 (34)
370-379	700 (24)	741 (75)	696 (23)
380-389	728 (44)	777 (58)	707 (9)
390-399	792 (14)	820 (68)	698 (6)
400-409	843 (23)	867 (51)	818 (6)
410-419	1025 (13)	861 (30)	930 (2)
420-429	-	996 (31)	-
430-439	1100 (2)	-	-
440-449	-	-	-
450-459	-	1000 (3)	-

Table 23. - Length and weight of females of Odontesthes bonariensis at capture, in Lagoa dos Quadros. Number of fish in parentheses.

Standard length (millimeters)	Average weight in grams		
	1941 Collections	1942 Collections	1947 Collections
Cast net			
90-99	-	8 (47)	-
100-109	-	9 (55)	-
110-119	-	15 (10)	-
120-129	19 (1)	16 (7)	-
130-139	-	-	-
140-149	-	28 (3)	-
150-159	-	-	-
Gill net			
280-289	-	350 (2)	-
290-299	-	350 (1)	-
300-309	300 (1)	400 (13)	-
310-319	425 (5)	464 (24)	-
320-329	550 (3)	492 (82)	482 (11)
330-339	550 (1)	530 (115)	510 (10)
340-349	505 (3)	565 (97)	538 (51)
350-359	600 (14)	626 (112)	585 (41)
360-369	664 (24)	699 (183)	640 (85)
370-379	639 (31)	763 (262)	665 (64)
380-389	742 (58)	824 (285)	696 (17)
390-399	814 (23)	890 (251)	780 (24)
400-409	869 (27)	936 (156)	790 (7)
410-419	917 (12)	970 (144)	-
420-429	1025 (7)	1034 (73)	-
430-439	1000 (4)	1095 (35)	-
440-449	-	1267 (3)	1050 (1)
450-459	-	1225 (2)	-

Table 24. - Length and weight of *Odontesthes bonariensis* in Lagoa dos Quadros, sexes combined. In some length groups the number of fish is larger than the sum of males and females, as shown in the foregoing tables, because of the inclusion of fish of unknown sex. Number of fish in parentheses.

Method of collection and standard length (millimeters)	Average weight in grams		
	1941 Collections	1942 Collections	1947 Collections
Cast net and seine catches			
90-99	-	9 (92)	-
100-109	-	10 (123)	-
110-119	-	14 (59)	-
120-129	17 (7)	18 (30)	-
130-139	20 (3)	19 (7)	-
140-149	24 (11)	28 (3)	-
150-159	27 (14)	-	-
160-169	37 (31)	-	-
170-179	41 (16)	-	-
180-189	44 (5)	-	-
Gill net catches			
280-289	-	350 (2)	-
290-299	-	350 (1)	-
300-309	350 (8)	429 (23)	-
310-319	433 (8)	455 (37)	483 (7)
320-329	550 (7)	487 (116)	487 (22)
330-339	510 (2)	530 (163)	507 (24)
340-349	550 (38)	569 (108)	551 (98)
350-359	603 (51)	627 (156)	591 (61)
360-369	665 (55)	695 (237)	643 (119)
370-379	666 (55)	758 (337)	673 (87)
380-389	718 (102)	816 (343)	700 (26)
390-399	804 (37)	875 (319)	762 (30)
400-409	857 (50)	916 (207)	804 (13)
410-419	979 (25)	951 (174)	930 (2)
420-429	1025 (7)	1023 (104)	-
430-439	1033 (6)	1095 (35)	-
440-449	-	1267 (3)	1050 (1)
450-459	-	1053 (5)	-

Weight increases gradually up to 49 mm. standard length (Table 25). A sudden increase is noted from 50 mm. upwards which may be due to the small number of fish measured.

Table 25. - Average weight for successive 10 mm. groups of standard length in O. bonariensis from 20 to 89 mm. length. Lagoa dos Quadros, September 1941

Standard length (millimeters)	Average weight (grams)	Number of fish
20-29	0.15	558
30-39	0.30	302
40-49	0.58	27
50-59	1.25	5
60-69	1.50	1
70-79	2.5	2
80-89	6.0	2

Adequate data on the length-weight relationship for this species in other habitats could not be found in the available literature, so that comparisons cannot be made.

For the analysis of length-frequency distribution of Odontesthes in Lagoa dos Quadros fish captured by seines and cast nets are separable from those caught in gill nets on the basis of size (Table 26). Many more fish over 90 mm. in standard length were caught by gill nets than by the other two methods. The data from gill nets with different mesh sizes were combined in Table 26. The length-group 380-389 mm. is strongest in both the 1941 and 1942 collections, which comprise respectively 62.2 and 59.4 percent of fish of age-group II, whereas the length-group 360-369 mm. is strongest in the 1947 collection, of which 76 percent is represented by age-group I (See Table 19 for the age composition of the samples).

Table 26. - Length-frequency distribution of *Odontesthes bonariensis* in Lagoa dos Quadros, according to sex and year of capture.

Method of Collection and standard length (millimeters)	1941		1942		1947	
	♂	♀	♂	♀	♂	♀
Cast net and seine catches						
90-99	-	-	27	47	-	-
100-109	-	-	20	55	-	-
110-119	-	-	20	10	-	-
120-129	3	1	7	7	-	-
130-139	3	-	3	-	-	-
140-149	10	-	-	3	-	-
150-159	10	-	-	-	-	-
160-169	27	-	-	-	-	-
170-179	10	-	-	-	-	-
180-189	3	-	-	-	-	-
Gill net catches						
280-289	-	-	-	2	-	-
290-299	-	-	-	1	-	-
300-309	7	1	10	13	-	-
310-319	3	5	13	24	7	-
320-329	4	3	34	82	11	11
330-339	1	1	48	115	14	10
340-349	35	3	11	97	47	51
350-359	37	14	44	112	20	41
360-369	31	24	54	183	34	85
370-379	24	31	75	262	23	64
380-389	44	58	58	285	9	17
390-399	14	23	68	251	6	24
400-409	23	27	51	156	6	7
410-419	13	12	30	144	2	-
420-429	-	7	31	73	-	-
430-439	2	4	-	35	-	-
440-449	-	-	-	3	-	1
450-459	-	-	3	2	-	-

The coefficient of condition, K, was calculated for 1,108 fish by 10-mm. intervals of standard length by the formula $K = \frac{W \times 10^5}{L^3}$, in which W is weight in grams, and L is standard length in millimeters. Table 27 presents K for males and females captured at one fishing station in Lagoa dos Quadros, from 1941 to 1947.

Table 27. - Coefficient of condition, K. according to length of the male and female of Odontesthes bonariensis in Lagoa dos Quadros, 1941-1947. Number of fish in parentheses.

Method of collection and standard length (millimeters)	K	
	Males	Females
Cast net and seine catches		
80-89	1.01 (1)	-
90-99	0.98 (8)	0.96 (14)
100-109	1.01 (2)	0.99 (7)
110-119	1.00 (7)	0.97 (3)
120-129	1.10 (2)	0.83 (2)
130-139	-	0.86 (1)
140-149	-	0.98 (1)
Gill net catches		
280-289	-	1.51 (1)
290-299	-	1.43 (1)
300-309	1.59 (5)	1.37 (5)
310-319	1.47 (9)	1.55 (13)
320-329	1.44 (14)	1.45 (27)
330-339	1.46 (22)	1.43 (43)
340-349	1.42 (39)	1.37 (48)
350-359	1.38 (35)	1.39 (57)
360-369	1.39 (43)	1.42 (86)
370-379	1.39 (39)	1.42 (105)
380-389	1.35 (34)	1.43 (106)
390-399	1.35 (30)	1.46 (85)
400-409	1.33 (27)	1.42 (65)
410-419	1.29 (13)	1.38 (46)
420-429	1.33 (13)	1.37 (24)
430-439	1.38 (1)	1.31 (14)
440-449	-	1.51 (5)
450-459	1.08 (2)	1.33 (2)
460-469	0.92 (1)	-

Computations of data from fish collected at the other stations did not show consistent differences. Fish from this particular station (called locally "Coroa") were selected because they represent catches made during all the seasons of the years of collecting.

As pointed out in the discussion of the length-weight relationship, females are relatively lighter, and therefore less robust than males, in the length groups up to 149 mm. Unfortunately, fish of intermediate lengths were not caught, so that there is no information on fish in the 150 to 280 length groups. It is apparent that K must increase rather suddenly in that interval. K is consistently higher in females in the 280 to 430 mm. length groups. The small number of fish in the higher length groups makes it impossible to come to conclusions on condition of these fish, although the few data suggest a decrease in robustness.

The coefficient of condition was also calculated for a sample of fish captured in Lagoa Itapeva in order to ascertain possible differences between the populations of the two lakes. The grand average of K for those fish was 1.38, and is therefore not different from the value found for the fish in Lagoa dos Quadros.

The fluctuations in the value of K in fish larger than 280 mm. standard length are relatively slight, and would probably be smaller if a larger number of fish were taken for the calculation of this coefficient (Table 27).

5. Sex ratio. Table 28 shows the percentage of males in the combined catches from 1941 to 1947, according to length. The larger and smaller length groups were omitted from this table because of the small number of fish. The sex of fry was unknown. It is apparent from the data in Table 29 that the percentage of males decreases in the larger length groups.

Table 28. - Representation of the sexes of Odontesthes according to length. Combined catches in Lagoa dos Quadros, 1941 - 1947

Standard length (millimeters)	Number of females	Number of males	Percentage males
300-309	17	17	50.0
310-319	58	40	40.8
320-329	182	94	34.1
330-339	243	124	33.8
340-349	280	170	37.8
350-359	301	184	37.9
360-369	474	237	33.3
370-379	578	215	27.1
380-389	578	186	24.3
390-399	468	165	26.1
400-409	348	144	29.3
410-419	282	79	21.9
420-429	127	68	34.9
430-439	67	5	6.9

By analyzing the available data according to the time of capture, an attempt was made to ascertain the effect of spawning activities on the segregation of the sexes (Table 29).

Table 29. - Percentage of males in the collections of O. bonariensis taken in Lagoa dos Quadros according to time of capture. Most active spawning occurs in June and July.

Month	Week	Number of females	Number of males	Percentage of males
May	1st			
	2nd	44	48	51.0
	3thd	104	77	42.5
	4th	139	73	34.4
June	1st			-
	2nd	524	199	27.4
	3thd	502	217	26.5
	4th			-
July	1st	300	201	40.1
	2nd	571	191	25.0
	3thd	741	125	14.4
	4th	507	86	14.5
August	1st	295	163	35.6
October	(*)	103	128	55.4
November	(*)	86	67	43.8

(*) all weeks

Data on fish collected in other months of the year were omitted because of paucity of specimens or because the sex of the fish was unknown.

The data in Table 29 point to a relative decrease in the number of males during the spawning season. As collecting was done at the same stations throughout the year, and almost always at the same time, this relative decrease of males in the collections may point to a smaller degree of mobility of the males during the spawning season, or segregation of the male fish in areas outside the established collecting stations which are located mostly on spawning grounds. The possibility exists that the school of spawning females is accompanied by a relatively small number of males, who protect their mates against weaker males. Such behavior could account for the high percentage of females during the spawning season with a maximum during June and July and followed by a drop at the end of July or the beginning of August.

VII. COMPETITORS AND PREDATORS

The eggs of Odontesthes are exposed to the predation by several small species of fish among which are Crenicichla saxatilis Linnaeus, Astyanax bimaculatus Linnaeus, A. fasciatus Cuvier, Asiphonichthys stenopterus Cope. Analyses of stomach contents show that these species feed almost exclusively on eggs of Odontesthes during the spawning period. In still other species of fish, the eggs may be found more or less frequently. Several specimens of different species of waterfowl which were killed to study the feeding habits as related to O. bonariensis had large numbers of eggs in the stomachs. Heaviest predation though, occurs among the fry and young of the species. A large number of fish species shows a greater or lesser frequency of young of Odontesthes in their stomachs during the breeding period of the species. The most important predator is without doubt Hoplias malabaricus, one of the most important carnivores in any type of Brazilian lake water. Its feeding habits can be compared with those of the North American pikes. Since it is a much slower swimmer than the adult peixe-rei, which is probably the fastest swimmer among the fishes of these lakes, the prey of Hoplias is restricted to young fish. Fair numbers of adults are attacked, however, when entangled in the gill nets.

In these lakes as in most other lakes in Brazil, Hoplias occurs in large numbers. Its reproduction is rapid and efficient (Azevedo and Gomes, 1942). It is able to resist prolonged drought by burrowing into the wet mud, and is often the sole survivor

temporary bodies of water. Its eggs hatch in about 50 hours, are adhesive, and easily transported by birds and other animals. The natural enemies of this predator are few in the lakes of the Tramandai region, and probably only Rhamdia sebae will occasionally attack it. However, heavy losses are inflicted by man during its spawning migration. Hoplias feeds heavily on all of the small species of fish which prey on the eggs of O. bonariensis. Since adult Odontesthes is not an important item in the diet of Hoplias, Hoplias may be useful in that it controls the small species which prey on the eggs of O. bonariensis.

A large number of parasites (nematodes, cestodes) were collected from the organs of Odontesthes, but have not been identified as yet. Tumors of unknown cause are occasionally observed, especially in older fish.

None of the fish species inhabiting the lakes of the Tramandai region compete with Odontesthes larger than 200 mm. Corbicula and Littoridina were never encountered in stomach contents other than in those of the peixe-rei. Up to 200 mm. in length Odontesthes has competitors among the young of most other fish species in the lakes as far as they are plankton feeders. The abundance of plankton and of invertebrates in the Eichornia mats does not suggest that this competition is of great importance.

VIII. SUMMARY

1. In the course of a biological and limnological investigation of the lake region in northeastern Rio Grande do Sul, Brazil, from June 1941 to August 1947, under the auspices of the Division of Game and Fish, Federal Ministry of Agriculture, the atherinid fish Odontesthes bonariensis (Valenciennes) was found in some of the lakes of the Tramandai Basin. Because of its importance as a food fish in the La Plata region, the biology of Odontesthes was studied. It was believed that before any management program or the introduction of this species into other bodies of water could be considered, much fundamental knowledge of the species and its natural environment should be obtained.

2. In the Tramandai Basin Odontesthes is confined to lakes Itapeva, dos Quadros, and Malvas in which the chlorinity consistently does not exceed 16 p.p.m.. The fish does not occur in the more southern lakes of the basin in which the chlorinity exceeds 18 p.p.m.

3. O. bonariensis is a winter spawner (May to September). Most intensive spawning activity takes place in June and July when the temperature of the lake water is at its lowest (14.1° to 15.2°C.). The preferred spawning grounds are reed belts (Scirpus riparius) in the lakes, and the river mouths. But spawning also occurs in the central parts of the lakes earlier in the season. The fish feeds actively during the spawning period.

4. Mature ovarian eggs average 1.72 mm. in diameter. They

swell to 2.2 mm. during hydration. The eggs are cast at random; they become attached to plants and other objects by 3 to 4 elastic filaments, 2 to 3 mm. long. The number of mature eggs depend upon the size of the fish (15 to 16 thousand in a two-year-old fish). All eggs mature at one time; those that are not mature at stripping will not be spawned that year. The proportion of stripped eggs to the total number increases with the increase in weight of the fish (21.7 percent in fish weighing 450 to 499 grams; 92.6 percent in fish weighing 1050 to 1099 grams). Females become sexually mature at the end of the first year of life.

5. Males also become sexually mature at the end of the first year of life. There is no correlation between the weight of the testes (3 to 9 grams) and the weight of the body (465 to 775 grams).

6. The viability of unfertilized eggs and of sperm is limited in natural lake water (60 percent after 3 minutes for eggs; 28 percent after one minute for sperm).

7. On occasions impregnation of the eggs in nature seems to be poor. (64 to 100 percent).

8. Embryonic development and its rate depend upon the temperature. Low temperatures are detrimental to the normal development of the embryo. High mortalities occur when the temperature drops below 15° C. A mortality of 90 percent occurs at 5° to 6°C. The optimum temperature is 18°C. At this temperature the developmental period is 11 days, and the mortality is lowest.

9. During June and July the temperature of the water on some of the spawning grounds seldom reaches 18°C. The evidence indicates that temperature may be an important factor in the mortality of eggs in nature.

10. Certain other facts (abundance of food, absence of important predation on adults of O. bonariensis) suggest that natural mortality of the eggs serves to limit sharply the population of Odontesthes in these lakes.

11. The development of the egg of Odontesthes was studied at 15°, 18° and 20°C. and the developmental stages were described.

12. At 18°C. the development is complete when the sum of the daily accumulated temperature units (A.T.U.) has attained values between 200° and 210°C. In the laboratory, hatching takes place after sunset, around 7 to 8 p.m., regardless of the exact A.T.U. value attained. Darkness is not the main factor, and perhaps it is not a factor at all in the timing of hatching. The embryo hatches head first. The mouth is open at hatching time.

13. The young larva starts to feed on rotifers, unicellular algae, and an occasional diatom almost immediately. The yolk sac is absorbed at the end of the third to the fourth day.

14. The mouths of the rivers Maquine and Cornelios are the main feeding grounds for the young of O. bonariensis in Lagoa dos Quadros. From 10 to 120 mm. total length, micro-crustaceans begin to dominate the food. From 120 to 149 mm. standard length, the snails Littoridina charruana and L. australis, mayfly nymphs, and mayfly imagos become the most important part of the diet.

In fish from 280 to 459 mm. standard length, Littoridina, the bivalve Corbicula limosa, mayfly nymphs and imagos, and the herring Lycengraulis constitute the principal parts of the food depending upon the season.

15. Littoridina and Corbicula form two distinct associations in the lakes. A Corbicula association is found on hard sandy bottoms of the central parts of the lakes; a Littoridina association is typical for loose organic bottoms near the shores and the river mouths. Seasonal migrations of O. bonariensis are reflected in the composition of the stomach contents. Corbicula predominates in the diet of the summer months (September to April) except at the time of emergence of mayflies (Hexagenia albivitta, Campsurus brasiliensis, and C. assimilis) which occurs in November.

16. The shells of Corbicula are always crushed thoroughly, and are swallowed together with the soft parts. Littoridina is swallowed whole. Corbicula is the most important food organism for adult Odontesthes and is preferred by the fish.

17. Corbicula limosa is viviparous. Young are released when 5 to 7 mm. long, presumably in September. The bivalve feeds chiefly on Melosira granulata.

18. The average weight of the stomach contents in Odontesthes is a nearly constant percentage of the body weight in fish weighing, from 451 to 700 grams (average 2.16 percent).

19. Odontesthes feeds most actively between 8:00 p.m. and midnight.

20. On calm days the young of Odontesthes (20 to 80 mm. total length) make diurnal movements between the lake shores and the open water of the lake. Just before sunset the fish move towards the shore and the belt of Scirpus where they remain until 3 to 4 a.m. when they leave in the direction of deeper water. Chemical observations did not reveal differences between the shore water and the open lake water at the time of the migrations.

21. The validity of annuli as year marks on scales of O. bonariensis was established by studying the scales of fish of known age which were obtained from impoundments previously stocked with fry.

22. Annulus formation takes place in captivity in the months of February to April.

23. The grand average value of the body-scale ratio in 454 fish of 15 to 409 mm. standard length was 1.70.

24. In 1941 and 1942 age-group II predominated in the catches in Lagoa dos Quadros. In 1947 age-group I predominated. On no occasion were fish older than age-group III caught in any of the lakes.

25. At the end of their first year of life females are slightly longer (287 mm.) than males (280 mm.). At the end of the third year males are longer (364 mm.) than females (361 mm.).

26. There is some evidence that the calendar year 1941-1942 was a relatively poor year for growth, whereas 1946-1947 was a good one.

27. Females are heavier than males in almost all length

groups. The difference in average weight for a particular length group is highest in July, lowest in May, with a gradual decrease from July to May. This variation is attributed to different feeding habits, and to the development of the eggs in the female.

28. Length-group 380-389 mm. is strongest in both the 1941 and 1942 collections, whereas length-group 360-369 mm. is strongest in the 1947 collection.

29. The coefficient of condition, K, varied from 0.83 to 1.10 in fish of 80 to 149 mm. standard length, and from 0.92 to 1.59 in fish of 280-469 mm. standard length, with a grand average of 1.38. Females are less robust than males up to 149 mm., but consistently more robust in the 280 to 430 mm. length group.

30. The percentage of males decreases in the larger length groups. (50 percent males in the 300-309 mm. standard length group; 24.3 percent males in the 380-389 mm. length group). There is a relative decrease in the number of males during the spawning season with lowest numbers in July, and highest numbers in October and November.

31. Several small species of fish predate on the eggs of O. bonariensis (Crenicichla saxatilis, Astyanax bimaculatus, A. fasciatus, and Asiphonichthys stenopterus). Young of Odontesthes are attacked by Hoplias malabaricus which feeds also actively on the above-mentioned small fish species. It is believed therefore that Hoplias is useful in that it controls the species which predate on the eggs of Odontesthes.

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X. APPENDIX A

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