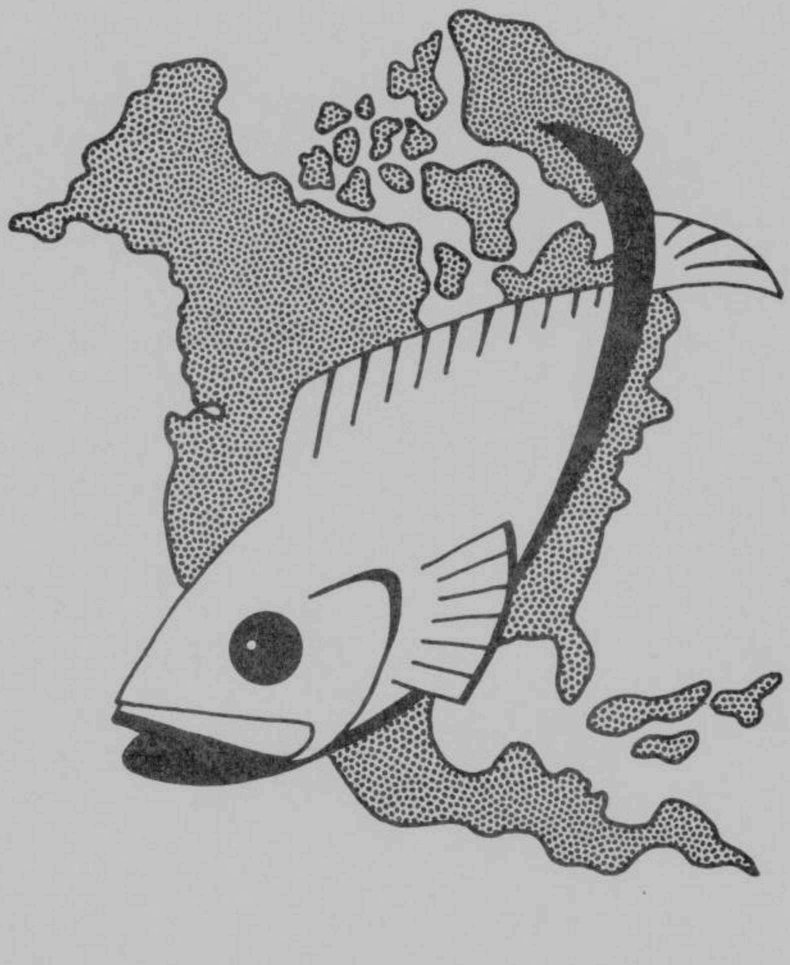
ANNUAL PROCEEDINGS
of the
TEXAS CHAPTER
AMERICAN FISHERIES SOCIETY



SEPTEMBER 27, 1980
COLLEGE STATION, TEXAS

VOLUME 3

KURZAWSKI

TEXAS CHAPTER

OF THE

AMERICAN FISHERIES SOCIETY

The Texas Chapter of the American Fisheries Society was organized in 1975. Its objectives are those of the American Fisheries Society--conservation, development, and wise utilization of recreational and commercial fisheries, promotion of all branches of fisheries science and practice, and exchange and dissemination of knowledge about fish, fisheries, and related subjects. A principal goal is to encourage the exchange of information by members of the Society residing within the State of Texas. The Chapter holds at least one meeting annually at a time and place designated by the Executive Committee.

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Persons interested in the Texas Chapter and its objectives are eligible for membership and should apply to the existing Secretary-Treasurer, Patricia L. Johansen, Texas Parks and Wildlife Department, P.O. Box 1707, Rockport, Texas 78382. Annual membership dues are $5 for Active Members and $4 for Students.

ANNUAL PROCEEDINGS
OF THE
TEXAS CHAPTER

September 27, 1980
Arlington, Texas

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SUMMER DRAWDOWN AS A FISHERIES MANAGEMENT TOOL IN FLOODWATER RETARDING STRUCTURES.

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ABSTRACT

During summer, 1977, six flood prevention lakes in central Texas were drawn down for determination of effects on fish, waterfowl, and water quality. The lakes were drawn down to approximately 50 percent of normal surface area and studied over a 3-year period. In spite of drought conditions, planted and natural vegetation became established on the exposed lake bottoms. Following refilling, water clarity, alkalinity, and hardness generally increased. The 1977 year class of most fish species was reduced, but year classes for the years following refilling were typically large and fish condition improved. By early- to mid-1979, most fish populations were similar in abundance and size composition to their pre-drawdown conditions. Summer drawdown appeared to be of less value for fisheries managers than has been reported for fall drawdown in larger reservoirs. The effects of summer drawdown on waterfowl utilization were not evaluated because drought conditions caused low water levels to persist through the time of waterfowl migrations.

INTRODUCTION

Annual variations in the water levels of most lakes and streams occur in nature due to variations in rainfall. Fish populations in these surface waters respond to these increases and decreases in water level with changes in their reproductive rate, survival of offspring, rate of growth, and recruitment into the adult population (Keith 1975). Artificial manipulation of water levels could be an important management tool to provide desirable fish populations. Fall drawdown of large reservoirs has been effectively utilized for control of aquatic vegetation and excess forage fishes in the southern U.S. (Keith 1968; Wegener and Williams 1975).

Floodwater retarding structures constructed by the Soil Conservation Service constitute important resources for fish and waterfowl throughout the state of Texas (Noble _et al_. 1979). Currently, there are over 1760 of these structures in the state with some projects still to be completed. Due to their size, outlet construction, and private ownership, these flood prevention lakes lend themselves well to the use of water level manipulation as an inexpensive means of fisheries and waterfowl management. This technique has not yet been investigated as a management tool in flood prevention lakes in Texas.

During the summer of 1977, 10 flood prevention lakes of central Texas were drawn down. Six of these were studied to determine the effects of water level reduction on fish populations, water quality, and waterfowl utilization. This paper summarizes changes which occurred in certain water quality characteristics and fish populations. Because drought conditions caused low water conditions to persist into the following year, no waterfowl utilization data were obtained for evaluation.

This study was conducted under Texas Agricultural Experiment Station Project S-6206, supported in part through the U.S. Soil Conservation Service. We gratefully acknowledge the assistance of William C. Hobaugh

in obtaining permission for the study from numerous cooperative landowners, and that of Bobby W. Farquhar in conducting the drawdowns.

MATERIALS AND METHODS

Study Area

The Chambers, Grays, and Richland Creek watersheds of the upper Trinity River drainage in north-central Texas support 254 floodwater retarding structures (Hobaugh and Teer 1981). During 1976, an extensive survey of fish populations was conducted at 56 flood prevention lakes (Farquhar 1977; Farquhar *et al*. 1980). Of these lakes, six were selected for drawdown study and sampled for changes in fish populations and water quality. Criteria for selection of lakes included number of owners, lakeowner cooperation, ease of draining, and utilization of lake by owner. Each lake is designated according to watershed (C = Chambers, R = Richland) and site number. Age of the six lakes (Table 1) ranged from 5 to 20 years. Surface area ranged from 12.8 to 24.0 ha, and mean depth ranged from 0.85 to 1.21 m. Shoreline development ranged from 1.08 to 2.08, and the drainage area to surface area ratios (watershed ratios) ranged from 17.7 to 64.5 ha of watershed per hectare of water.

Drawdown

Drawdown was initiated on 18 May and completed by 1 June 1977. Lakes were drawn down to approximately 50 percent of normal sediment pool area (Noble *et al*. 1979) by opening control valves on the principal spillway for 4 to 9 days. Refilling of all lakes did not occur until late winter, 1977/78.

Plantings

During the week of 27 June 1977, seedbed preparation and planting were accomplished on the drawdown lakes, except that R-12 was not planted. After the exposed lake bottoms had dried sufficiently, portions of each were lightly disked, and broadcast seeded with approximately equal plots of grain sorghum (Sorghum bicolor) (11.2 kg/ha) and Japanese millet (Echinochloa crusgalli) (33.6 kg/ha). Plots ranged in size from approximately 0.4 to 1.2 ha of each seed type. Following seeding, each plot was disked lightly to cover the seeds. Seeds were also broadcast in wet areas along the edge of the water next to the plots. Prior to germination of the seeds, those plots accessible to grazing were enclosed in electric fencing.

Water Quality

The primary water quality characteristic of interest was water clarity. Transparency was periodically measured during the summers, a time of low rainfall, with a 20-cm diameter Secchi disk. In addition, pH, total alkalinity, and total hardness were measured when the fish populations were sampled.

Fish

Two sampling schedules were followed to determine changes in fish populations. All lakes had been sampled in the summer of 1976 in conjunction with Farquhar's (1977) extensive survey. Three of the lakes (C-102, R-12, R-100A) were sampled similarly in the summers of 1978 and 1979. Three other lakes (R-19, R-20A, R-26A) were sampled prior to drawdown in the spring of 1977, and similarly in the spring of 1978 and 1979.

Sampling was conducted at specific stations using gillnetting, electrofishing, and seining. Two experimental gillnets, 45.5 m long by 2.4 m deep, consisting of six equal panels with bar mesh ranging from 25.4 to 88.9 mm in 12.7 mm increments, were set for 24 hours in each lake. Both nets were set perpendicular to shore, one out from the dam near the principal spillway, the second out from one side of the lake. Two to four electrofishing transects were established on each lake and sampled using a hand-held 250 volt, non-pulsed D.C. electrofishing unit. Sampling was performed during the day or during both day and night. Time of day and the number and length of transects shocked were constant over the study for each lake. To the extent feasible, all fish stunned were collected. Three quadrant seine hauls were made at each lake with a 6.1 m long by 1.2 m deep, 6 mm bar mesh seine, except at sites R-19, R-20A and R-26A where 6 hauls were made during 1977, 1978 and 1979. Seining was not performed at R-100A in 1976 due to the abundance of submergent aquatic vegetation. Large fish were weighed to the nearest 1.0 g and measured to the nearest 1.0 mm total length in the field. Smaller fish were preserved in 10 percent formalin and returned to the lab, where weights to the nearest 0.1 g and total lengths to the nearest 1.0 mm were recorded.

RESULTS

Plantings

Due to unusually dry weather conditions in 1977, germination of planted seeds varied greatly. Only two lakes (R-19, C-102) had immediate germination of seeds. Germination in the remaining lakes was delayed at least until rains fell in late August. Establishment of native species was extensive, especially in areas where no seedbed preparation was done. Chufa (Cyperus spp.) and cocklebur (Xanthium strumarium) were the most common wild plants to establish stands, with balloon-vine (Cardiospermum sp.), dallisgrass (Paspalum dilatatum), goatweed (Croton sp.), Johnson grass (Sorghum halepense), native millet (Echinochloa sp.), and pigweed (Amaranth sp.) being less abundant. Fencing to exclude livestock was generally successful; cattle occasionally gained access to the vegetation, damaging the plantings, but some recovery occurred before reflooding.

Water Quality

Post-drawdown water clarity was greater in all lakes (Table 2). Secchi disk transparencies more than doubled after refilling of the lakes and flooding of vegetation. In most lakes, water clarity measurements were as great in 1979 as they were in 1978, the year of refilling.

Total alkalinity and total hardness showed similar trends (Table 2). The lowest measurements recorded for these two parameters generally occurred during the pre-drawdown period, particularly during 1976. High measurements were generally recorded during 1978, dropping off somewhat in 1979. Measurements of pH showed no apparent trend (Table 2).

Fish

The number of each species collected in gillnets at each lake indicate that the adult fish populations were quite stable (Table 3). Total numbers of fish caught were similar in both pre-drawdown and post-drawdown samples, except at R-26A which experienced a decline in catch during 1979 when capture of white crappie decreased. None of the species showed any consistent trend in abundance among lakes during this study.

In contrast to the gillnet data, electrofishing and seining data show that a number of changes occurred. These data were interpreted by dividing the six lakes into two groups (Table 4): lakes sampled in the spring (R-19, R-20A, and R-26A), and those sampled in the summer (R-12, R-100A, and C-102). Lakes sampled in the spring showed a consistent marked decline in abundance of fish from 1977 to 1978, indicating that reproduction and/or survival of most species was suppressed during drawdown. The 1979 data indicate that this reduction continued during 1978. Reductions in number and relative abundance were pronounced for sunfishes (*Lepomis* spp.); black bullheads appeared to be the only species to markedly increase in abundance. Seine and shocker data from lakes sampled during the summer showed a different trend. Total numbers of fish in samples consistently increased in 1978. These increases were primarily due to markedly higher catches of sunfishes and red shiners. Size distributions of these fish suggest that they were primarily fish of the 1978 spawn, and therefore indicative of conditions during the year following drawdown. Increased catches were again obtained by 1979.

Population size structure

Length-frequencies were examined for most species to determine whether substantial changes in population structure occurred, and if so, whether changes in recruitment could be detected. Not all species occurred in all lakes, and many species were represented by too few individuals for any conclusions to be drawn.

Largemouth bass. Absence of bass from R-20A resulted in data being available from only five lakes. Of these, only one lake (R-100A) appeared to have a strong year class produced in 1977. Of the lakes which had high bass populations and diverse size groups prior to drawdown (R-19, R-26A, R-12) only the population in R-19 appeared to decline following drawdown. Those lakes with low populations prior to drawdown both remained low, although each had a strong year class produced during the study (R-100A in 1977; C-102 in 1978).

White crappie. Four lakes (R-19, R-26A, R-100A, C-102) had substantial white crappie populations (Figure 1). All lakes except R-19 experienced a reduced 1977 year class, but R-19 appeared to be in a state of expanding population during the study. Only one white crappie was collected from R-19 during the 1976 survey and few in 1977, whereas they comprised 15-20% of the fish samples in 1978, and were even more dominant in 1979. By the time of the last sample, the population in R-19 was comprised of a variety of sizes of white crappie up to 335 mm long. R-19 also had a population of black crappie, but this population did not experience any substantial expansion during the study. In spite of the low recruitment of 1977 year class fish in the remaining three lakes, size composition in the final samples was consistently more diverse than at the beginning of the study. Maximum sizes of crappie following drawdown also approached or exceeded those prior to drawdown.

Bluegill. Spring sampling at R-19, R-20A, and R-26A indicated that bluegills maintained a greater variety of size classes in 1977 (Figure 2). Yearling fish dominated the populations. Following drawdown, small bluegills decreased greatly in abundance indicating a weak 1977 year class, but lengths of these fish were consistently greater than in pre-drawdown samples. Mean size of adult bluegills changed very little. Samples from R-12 and C-102, collected during the summer, produced few bluegills in the 75-150 mm range in 1978, also indicating a weak 1977 year class. However, few fish in this range were collected prior to drawdown. Following refilling of these two lakes, young-of-the-year bluegills were more abundant than during pre-drawdown sampling. Lake 100-A consistently had neglible numbers of bluegill.

Other sunfishes. Green sunfish occurred in all six lakes. Green sunfish of the 1977 year class were absent from lakes R-19 and R-20A in 1978, however, R-12 samples indicated that some reproduction had occurred there in 1977. In other lakes, green sunfish populations remained low throughout the study.

Longear sunfish were collected in four lakes. Large increases in catch which occurred in two lakes (R-12 and C-102) were due to large year classes produced in 1978 and 1979. In contrast, the population in R-26A remained fairly stable and that in R-20A steadily declined as a result of two consecutive year class failures.

Data on other sunfish species were too sparse for analysis. Hybrid sunfish, mostly bluegill-green sunfish hybrids, occurred primarily in samples taken after drawdown and were likely of the 1977 year class. The frequency of these hybrids was so low, however, that drawdown conditions were unlikely to have had much effect in light of the overall reduced spawning success in 1977.

Channel catfish. All six lakes contained substantial populations of channel catfish (Figure 3). Each was comprised of a variety of sizes of fish, suggesting that reproduction had occurred regularly. Length-frequency analyses indicated that reproduction was suppressed in 1977 during drawdown in all lakes except R-20A, but resumed in 1978 in at least three lakes. Data were insufficient for detection of changes in growth rate, but populations appeared to be of comparable size distribution before and after drawdown.

Black bullhead. Large numbers of young black bullheads survived drawdown, resulting in populations dominated in 1978 by fish in the 150-200 mm length range. This relationship was most apparent in R-19, R-20A, and C-102, where large numbers appeared in the 1979 gillnet catches.

Gizzard shad. This species was present only in R-100A and C-102. Summer sampling of these lakes in 1978 indicated a strong 1978 year class. The near absence of adults in 1978 indicates that successful spawning did not likely occur in 1977, however abundance and size distribution of shad in 1979 were similar to those of pre-drawdown populations.

Condition

Coefficients of condition (K_{TL}, Carlander 1977) for four species were examined to determine if condition was affected by drawdown. Due to possible changes in condition with time of year, results were analyzed separately from lakes sampled in the spring and summer. Largemouth bass, bluegill, and white crappie data were subdivided into size classes and compared to remove bias resulting from changes in body length. Channel catfish data were not subdivided due to the uniformity of condition over their entire length range.

At the three lakes sampled in the spring, largemouth bass, bluegill, white crappie, and channel catfish responded to drawdown by variable changes in condition (Table 5).

Condition factors increased following drawdown and refilling for all size classes of all four species in the three lakes sampled during the summer (Table 5), except at C-102 for bluegills (110-177 mm) and white crappie (137-192 mm). Improved condition of these species was likely due to the increased abundance of forage fishes spawned in 1978. At C-102, condition of adult bluegills and white crappie was highest in 1976 when other sunfishes were lowest in abundance. Increases in the number of orangespotted sunfish, longear sunfish, redear sunfish, and even bluegill, likely resulted in increased competition for food causing reduction in condition in this lake following drawdown.

DISCUSSION

Although fall drawdowns have been used effectively in fisheries management to improve fish populations, the summer drawdown used in this study appears to have been of substantially less benefit. General year class failures in the year of drawdown included game fish species as well as forage fishes; consequently the benefits, if any, would likely be related to general increased reproduction following refilling. For most long-lived species, the study was perhaps too short for those effects to be detected. Another apparent beneficial effect was that of reducing white crappie populations. Farquhar, et al. (1980) indicated that crappie overpopulation occurred in over 25 percent of the flood prevention lakes he studied in central Texas.

Long-term beneficial effects on fish populations may also be related to increased water clarity. Many lakes of the area are typically turbid, and productivity is likely limited by low light penetration. The vegetation which established naturally appeared to be of substantially greater biomass than that resulting from our plantings. Consequently, we recommend that the additional time and expense of planting be eliminated if fish management is the only objective of drawdown.

Summer drawdown, with food plantings, may be of greater value for waterfowl than fish, if drought conditions do not occur. In general, if summer drawdown is employed, our study indicates that it can be done with little, if any, adverse effect of fish populations. A serious fish kill, however, did occur at one lake (R-9C), not included in this study, due to the drought in conjunction with a summer drawdown.

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Table 1. Physical characteristics of six drawdown lakes in the Chambers (C) and Richland (R) Creek watersheds of north-central Texas.

	R-19	R-20A	R-26A	R-12	R-100A	C-102
Surface Area (ha)	12.8	13.6	17.2	21.2	20.0	24.0
Mean Depth (m)	0.94	1.09	0.97	0.85	1.21	1.00
Shoreline Development	1.08	1.33	1.20	1.69	2.08	1.30
1977 Age (yr)	20	19	15	11	5	17
Watershed Ratio	30.8	17.7	29.9	53.4	54.8	64.5

Table 2. Water quality data collected at six drawdown lakes in the Chambers (C) and Richland (R) Creek watersheds of north-central Texas, 1976-1979. Except for Secchi disk depth, each parameter was measured once each year at each lake (* indicates mean of measurements on two dates).

Parameter/Year	Lakes R-19	 R-20A	 R-26A	 R-12	 R-100A	 C-102
Secchi Disk Depth (cm)						
1976 Summer	15	37.5*	25	5	15	20
1977 Spring	12	12	12	----	----	----
1978 Spring	17	27	32	----	----	----
Summer	32	38	43	17*	29*	32.5*
1979 Spring	10.5	20	9.5	----	----	----
Summer	32.5	51	45.5	18	18.5*	27
Total Alkalinity (mg/l)						
1976	60	102	72	106	144	118
1977	100	100	100	----	----	----
1978	120	90	110	180	190	150
1979	110	110	90	120	120	90
Total Hardness (mg/l)						
1976	62	112	112	130	150	134
1977	90	140	120	----	----	----
1978	120	150	170	170	160	140
1979	120	170	140	150	120	100
pH						
1976	8.5	9.7	9.0	8.7	8.9	9.0
1977	8.7	8.7	8.7	----	----	----
1978	8.7	8.7	8.5	9.0	8.7	9.0
1979	8.2	8.0	7.8	9.3	8.8	9.6

Table 3. Number of each species caught in gillnets at each drawdown lake in the Richland (R) and Chambers (C) Creek watersheds of north-central Texas. Data for R-19, R-20A and R-26A are from June/July 1976 and April/May 1977-1979. Data for R-12, R-100A and C-102 are from July/August 1976, 1978 and 1979.

	Lakes																				
	R-19				R-20A				R-26A				R-12			R-100A			C-102		
Species	76	77	78	79	76	77	78	79	76	77	78	79	76	78	79	76	78	79	76	78	79
Gizzard Shad <u>Dorosoma</u> <u>cepedianum</u>																12	1	14	3	1	2
Channel Catfish <u>Ictalurus</u> <u>punctatus</u>	7	23	10	4	39	32	10	11	26	17	5	5	4	13	20	10	11	13	38	52	29
Black Bullhead <u>I</u>. <u>melas</u>	3	1		1	2	1	2		4	13	7	3	8	6	5	3	2	1	1		12
Yellow Bullhead <u>I</u>. <u>nebulosus</u>																	1				
Largemouth Bass <u>Micropterus</u> <u>salmoides</u>	3	1	1						4	2			9	4	11	1	17			2	2
White Crappie <u>Pomoxis</u> <u>annularis</u>		4	2	4			1	1	150	162	176	41				50	52	60	22	3	12
Black Crappie <u>P</u>. <u>nigromaculatus</u>	2	2		1																	
Bluegill <u>Lepomis</u> <u>macrochirus</u>	1	1		1		2		2	8	3	3			7	2				7	2	4
Orangespotted Sunfish <u>L</u>. <u>humilis</u>												1									
Longear Sunfish <u>L</u>. <u>megalotis</u>						1								2							1
Green Sunfish <u>L</u>. <u>cyanellus</u>				1		10	1	1		1						1					
Hybrid Sunfish <u>Lepomis</u> sp.	1																				
Carp <u>Cyprinus</u> <u>carpio</u>																6	2	2			
Golden Shiner <u>Notemigonus</u> <u>crysoleucas</u>									4	15	7	7									
River Carpsucker <u>Carpiodes</u> <u>carpio</u>													4	3	27				1		
Total Number	17	32	13	12	41	46	14	15	196	213	198	57	25	35	65	83	86	90	72	60	62

Table 4. Number of each species caught by seining and electrofishing at each drawdown lake in the Richland (R) and Chambers (C) Creek watersheds of north-central Texas. Data for R-19, R-20A and R-26A are from June/July 1976 and April/May 1977-1979. Data for R-12, R-100A and C-102 are from July/August 1976, 1978 and 1979.

	Lakes																				
	R-19				R-20A				R-26A				R-12			R-100A			C-102		
Species	76	77	78	79	76	77	78	79	76	77	78	79	76	78	79	76	78	79	76	78	79
Gizzard Shad																32	154	19	16	11	9
Channel Catfish	1	9	8	5	2	21	34	14	1		3	2		1	3		5		2		3
Black Bullhead		3	12	15	1	31	95	49		1	1			1						3	2
Yellow Bullhead																				4	
Largemouth Bass	5	8	5						2	11	2	6	10	2	2	3	2	2	7	8	5
White Crappie	1	2	23	30					2	34	29	3				2	8	18	5	2	1
Black Crappie			5	2																	
Bluegill	11	128	40	33	16	101	15	3	28	44	18	11	4	5	5	1		1	5	142	12
Orangespotted Sunfish	7	21	11	3					2	4		3	15	43	27		2	15		2	8
Longear Sunfish					8	45	8		4	4	4	1	6	14	36					135	52
Redear Sunfish *L. microlophus*		6							5	7	8	1								3	7
Green Sunfish	51	130	8	24	6	53	52			2	1	5	8	13	52	1	5	1	2		2
Hybrid Sunfish	3		1	5		1	2							1			1			1	
Carp																1	6	3			
Red Shiner *Notropis lutrensis*			1			413	52	66		15		4	32	92	174	10	28	68	51	45	308
Bullhead Minnow *Pimephales vigilax*													4	17	20						
Golden Shiner	1	13	4	6	4	162	20	151	4	5	12	18		1				1			
Mosquitofish *Gambusia affinus*	9	8							15	1			1	3	51						1
River Carpsucker																					1
Total Number	89	328	118	123	37	827	278	283	63	128	78	54	80	193	370	50	211	128	88	356	411

Table 5. Mean condition factors and number of fish examined (in parenthesis) for four species of fish in drawdown lakes in Richland (R) and Chambers (C) Creek watersheds of north-central Texas. R-19, R-20A and R-26A were sampled in April/May, 1977-1979. R-12, R-100A and C-102 were sampled in July/August, 1976, 1978 and 1979.

Site	Species	TL Range (mm)	1977	1978	1979
R-19	Largemouth bass	192-472	1.30 (9)	1.21 (6)	---- (0)
	Bluegill	31-68	2.01 (66)	2.08 (4)	---- (0)
		70-146	2.21 (44)	2.10 (36)	2.01 (34)
	Channel Catfish	179-590	0.73 (31)	0.66 (17)	0.74 (9)
	White Crappie	129-197	1.25 (6)	1.15 (18)	1.19 (6)
		207-338	---- (0)	1.22 (5)	1.43 (5)
R-20A	Bluegill	70-137	1.80 (25)	2.07 (15)	1.86 (5)
	Channel Catfish	122-450	0.64 (31)	0.74 (43)	0.72 (25)
R-26A	Largemouth bass	136-280	1.29 (10)	1.32 (1)	1.01 (5)
		415-498	1.57 (2)	---- (0)	1.70 (1)
	Bluegill	30-89	1.90 (34)	---- (0)	2.17 (6)
		100-168	2.11 (12)	2.04 (19)	2.15 (5)
	Channel Catfish	340-486	0.87 (16)	0.77 (8)	0.86 (7)
	White Crappie	140-193	1.25 (58)	1.02 (80)	0.97 (31)
		204-385	1.44 (6)	1.15 (1)	1.49 (6)

Site	Species	TL Range (mm)	1976	1978	1979
R-12	Largemouth Bass	140-430	1.35 (17)	1.44 (3)	1.36 (11)
	Bluegill	18-60	1.60 (2)	1.60 (5)	1.70 (5)
		155-168	2.36 (1)	2.44 (3)	2.36 (2)
	Channel Catfish	263-610	0.85 (4)	0.80 (14)	0.89 (18)
R-100A	Largemouth Bass	105-385	1.26 (4)	1.38 (18)	1.16 (2)
	Channel Catfish	170-676	0.75 (10)	0.77 (9)	0.72 (12)
	White Crappie	156-197	1.12 (30)	1.20 (1)	1.13 (29)
		202-275	1.32 (8)	1.50 (40)	1.29 (14)
		285-375	1.60 (6)	1.99 (2)	1.51 (11)
C-102	Largemouth Bass	77-87	1.29 (7)	1.30 (3)	---- (0)
	Bluegill	110-177	2.25 (9)	1.93 (2)	2.16 (6)
	Channel Catfish	228-705	0.80 (24)	0.84 (40)	0.80 (28)
	White Crappie	137-192	1.22 (19)	1.17 (3)	1.07 (7)
		301-395	1.58 (1)	1.79 (2)	1.59 (2)

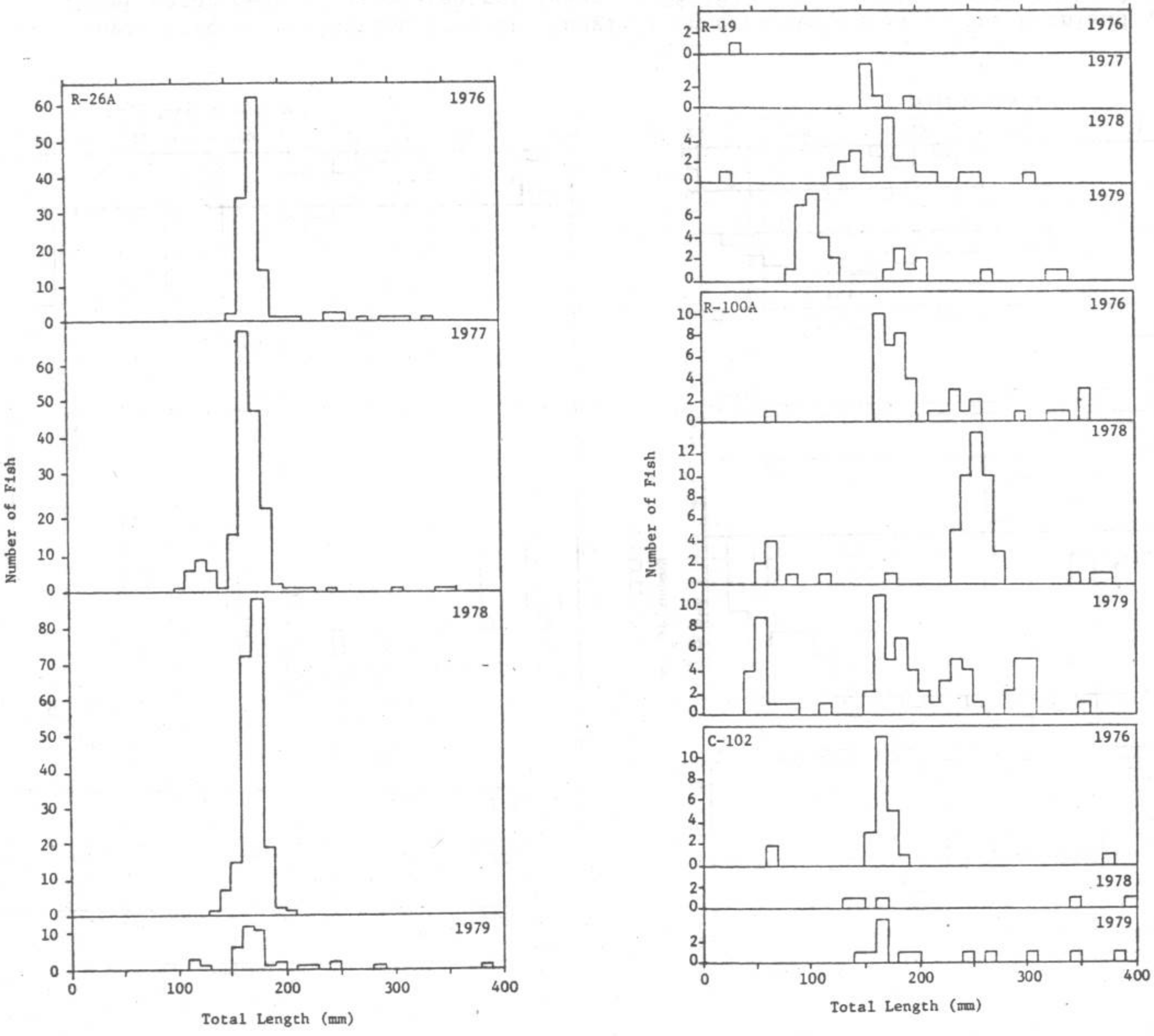

Figure 1. Length-frequency distributions of white crappies in drawdown lakes in the Richland (R) and Chambers (C) Creek watersheds of north-central Texas, 1976-1979. No samples taken at R-100A and C-102 in 1977.

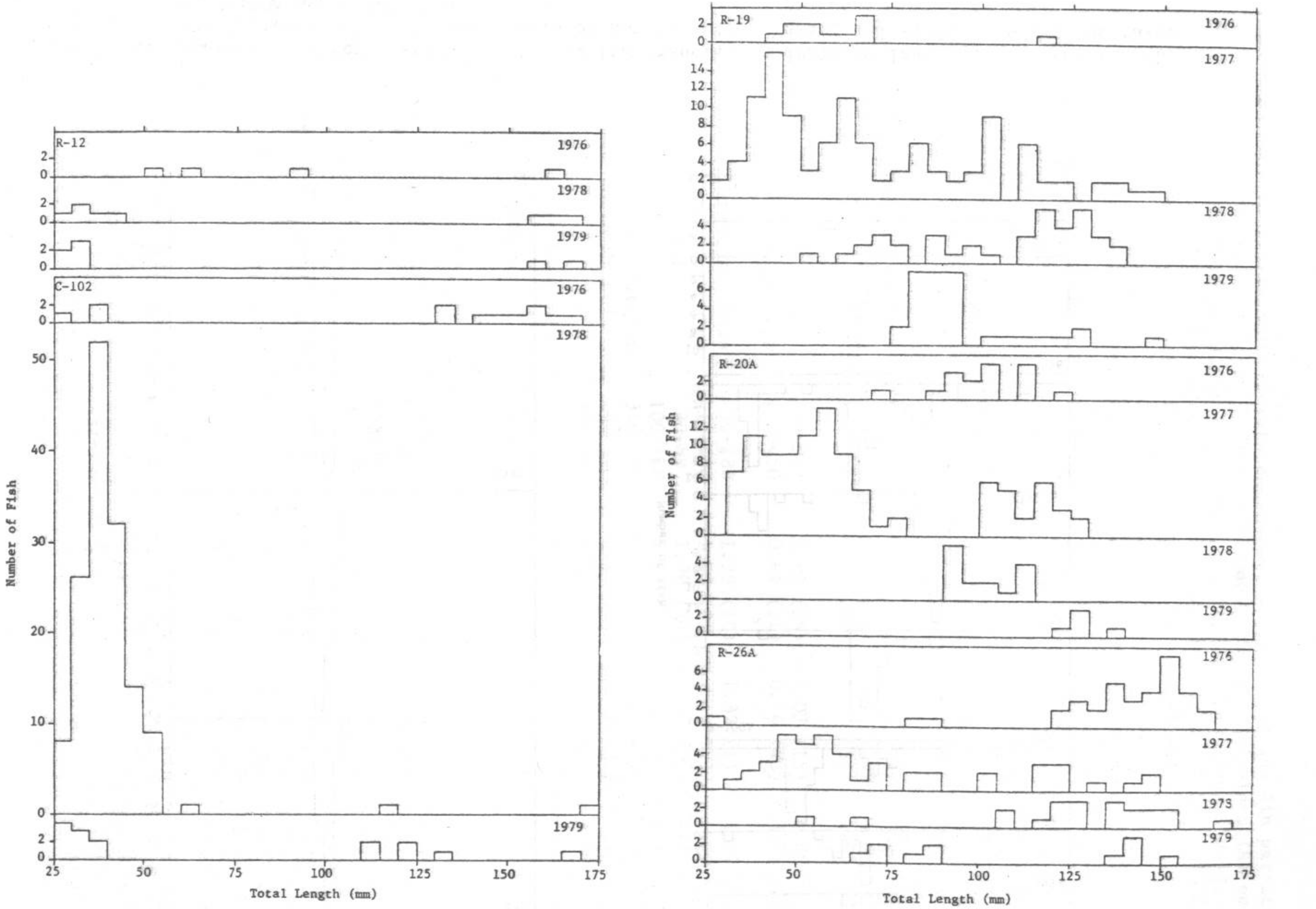

Figure 2. Length-frequency distributions of bluegills in drawdown lakes in the Richland (R) and Chambers (C) Creek watersheds of north-central Texas, 1976-1979. No samples taken at R-12 and C-102 in 1977.

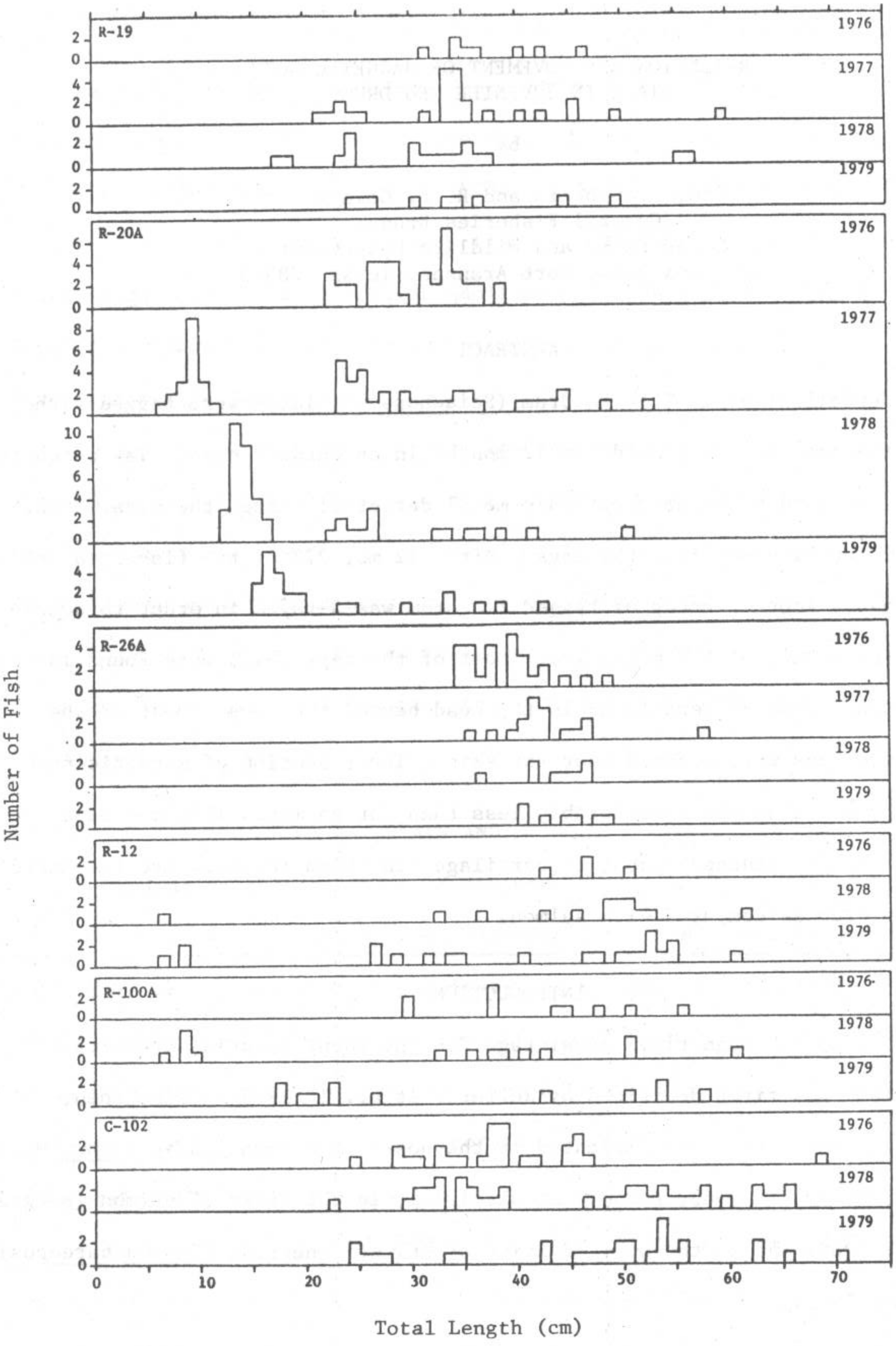

Figure 3. Length-frequency distributions of channel catfish in drawdown lakes in the Richland (R) and Chambers (C) Creek watersheds of north-central Texas, 1976-1979. No samples taken at R-12, R-100A and C-102 in 1977.

RETENTION AND MOVEMENT OF MAGNETIC NOSE TAGS IN JUVENILE RED DRUM

by

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ABSTRACT

Juvenile (~50 mm TL) red drum (Sciaenops ocellata) were tagged with magnetic nose tags and held for 12 months in an outdoor pond. Tag retention was determined using an electronic metal detector. After the first 3 mo, 41% of the fish retained the tags. After 12 mo, 27% of the fish retained the tags. Another group of tagged red drum was X-rayed in order to determine the extent of tag migration. Most of the tags (84%) were found in the snout area; 8% were found in the head beyond the eyes. Most of the magnetic tags were located near the skin. The retention of magnetic nose tags by red drum was considerably less than for salmon. This may be a result of the reduced amount of cartilage (in which the tags are implanted) in red drum as compared with salmon.

INTRODUCTION

The use of magnetized metal tags for the identification of macroorganisms was first described by Jefferts et al. in 1963. Since then, magnetic tags have been implanted in the noses of salmon (Oncarhynchus sp.) (Jefferts et al. 1963, Bergman et al. 1968), in the backs of salmon (Bergman et al. 1968) and in the body cavities of Atlantic herring (Clupea harengus) (Winter 1977).

Red drum (Sciaenops ocellata) were first tagged with magnetic nose tags in 1978 when researchers at the Texas Parks and Wildlife Department Marine Fisheries Research Station (MFRS) in Palacios, Texas tagged 4886 hatchery-raised fingerlings. These fish were released in St. Charles Bay, Texas (Figure 1). Since then, an additional 24,290 tagged red drum fingerlings have been released in Texas bays. Five tagged red drum have been recovered.

In order to use tagging information to determine, for example, population size or survivorship, the rate of tag loss from fish must be determined. Losses of tags from salmon (Jefferts et al. 1963, Bergman et al. 1968) and Atlantic herring (Winters 1977) have been noted. Tag loss from red drum has not been investigated; therefore, a study was conducted to estimate the magnetic tag retention rate of red drum fingerlings.

MATERIALS AND METHODS

According to the technique of Bergman et al. (1968) magnetic tags (1 mm long, 0.25 mm diameter) were injected through a hollow needle into the snouts of 223 red drum fingerlings (~50 mm TL). The tagged fish were stocked in a 0.1-ha outdoor pond at the MFRS on 7 September 1979. Ponds were drained and tag retention was determined at 3-mo intervals using an electric coil metal detector (Jefferts et al. 1963). After 6 mo, untagged fish were removed from the ponds.

A regression analysis describing the relationship between time and percent of fish retaining was performed. Tag retention data were adjusted for mortality by subtracting percent mortality from percent of tags lost.

A group of 24 red drum (50-80 mm TL) which reacted positively when passed through the metal detector was X-rayed in order to determine the location of the metal tags.

RESULTS

Of the 223 red drum fingerlings tagged and placed in the pond, 41% (92 fish) retained the tags after 3 mo (Table 1), 30% (67) retained the tags after 6 mo and 27% (61) retained the tags after 9 mo and 12 mo. Fish mortality was 4% during the first 3 mo (Table 1), 21% during the second 3 mo, 11% during the third 3 mo and 0% during the last 3 mo. Therefore mortality accounted for a considerable portion of the tags lost during the study. The regression equation was:

$$Y = 1.99 - 0.17\,X \qquad \text{where}$$

$Y = \log\%$ of fish retaining tags and $X = \log\,(\text{day} + 1)$.
The correlation coefficient was 0.994.

Among the 24 X-rayed fish, 85% of the magnetic tags were located in the area between the eyes and the end of the snout; 8% of the tags were located behind the eyes (Figure 2). The tags could not be located in 8% of the fish even though these fish reacted positively when passed through the metal detector. Most of the tags in the snout area were located near the skin.

DISCUSSION

Although Jefferts et al. (1963) observed some tags working their way through the skin of salmon, only 5% of their fish lost tags during an 11-mo study. There was only an additional 1% loss during the next 10 mo. They concluded that the loss was due to misplacement of the tag too close to the skin. Bergman et al. (1968) reported that 27% of the metal tags placed in dermal tissue of salmon were lost as a result of tag migration; 15% of the tags placed in muscle tissue moved but were not lost and tags placed in cartilage did not move. They concluded that their salmon were adversely affected by handling during tagging but not by the presence of the tags. Moring and Moring (1976) reported tag losses of 3-28% among salmon tagged in the head with metal tags. Winters (1977) placed metal tags in the body cavity of Atlantic herring and concluded that the loss rate, which was as high as 96%, was a result of the fish's spawning.

Loss of metal tags from red drum during the present study was considerably higher than losses from salmon, perhaps of a result of the reduced amount of cartilage in red drum as compared with salmon. Although metal tags have not been placed in the body cavities of red drum, the work with Atlantic herring indicates that this method would result in even higher tag losses.

Magnetic nose tags also exhibit lower retention rates than other types of tags used on red drum. For example, Elam (1971) tagged 51 red drum (>250 mm TL) with internal anchor tags and reported 94% tag retention after 3 mo and 87% tag retention after 9 mo. Weaver (1976) tagged 46 red drum (340-700 mm TL) with Floy tags and reported 61% tag retention after 3 mo. Although tag retention rates are higher with internal anchor tags and Floy tags, it should be kept in mind that these tags cannot be used on very small (<200 mm TL) fish.

The advantages of magnetic nose tags for identifying fish are that they can be used on very small fish and that a greater number of fish can be tagged in a shorter period of time than with other types of tags. In addition, once the tag retention rate is quantified, information obtained from tagging operations can be adjusted to account for tag loss, thereby permitting more accurate estimates of population size, survivorship and other parameters necessary for fishery management.

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Table 1. Tag retention of nose-tagged red drum.

Day	No. tagged	No. not tagged	No. dead	% tags retained
0	223	0	0	0%
90	92	122	9	41%
180	67	102[a]	45	30%
270	61	1	4	27%
360	61	1	0	27%

[a] Untagged fish removed from pond

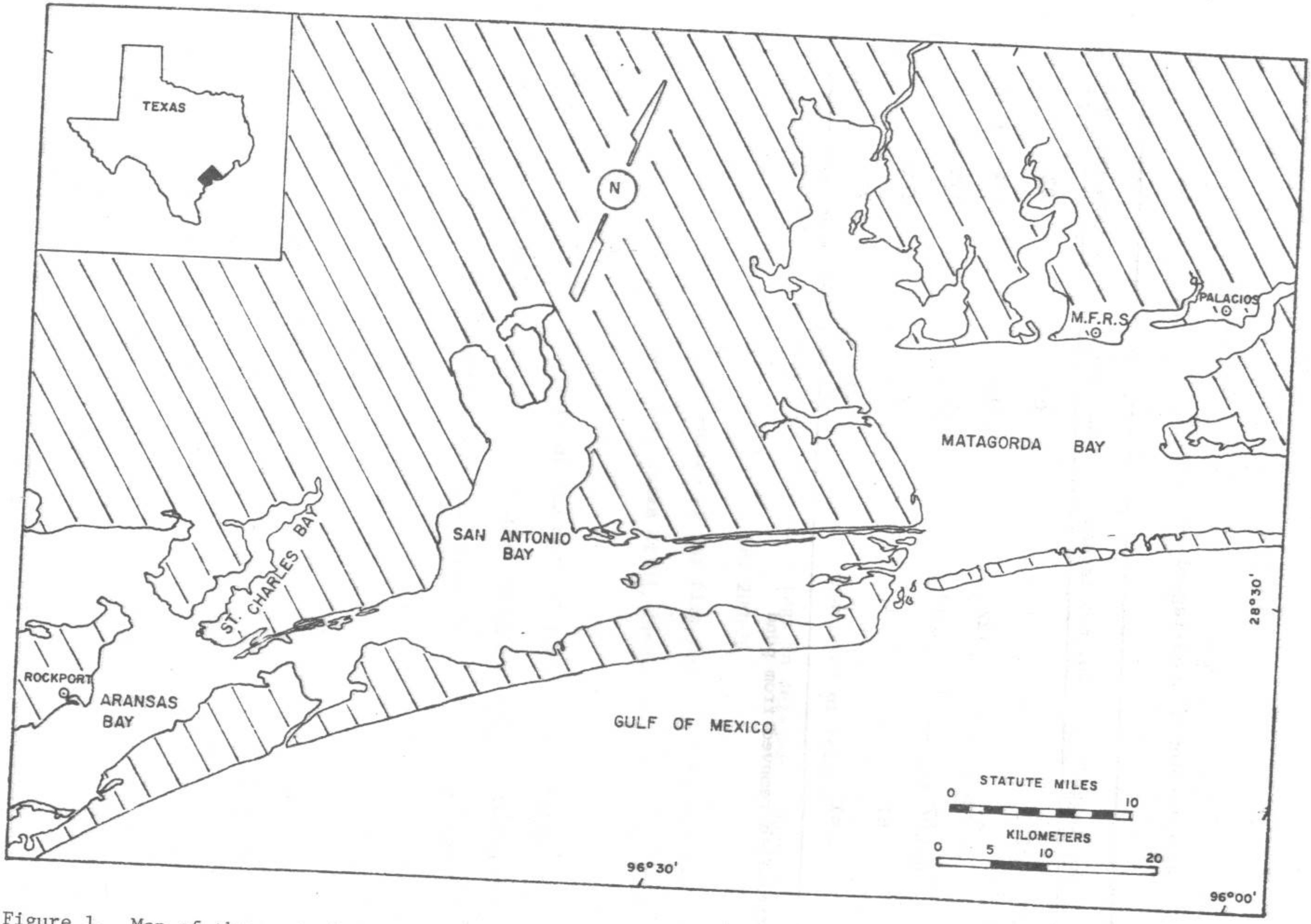

Figure 1. Map of the central Texas coast showing St. Charles Bay and the Marine Fisheries Research Station (MFRS).

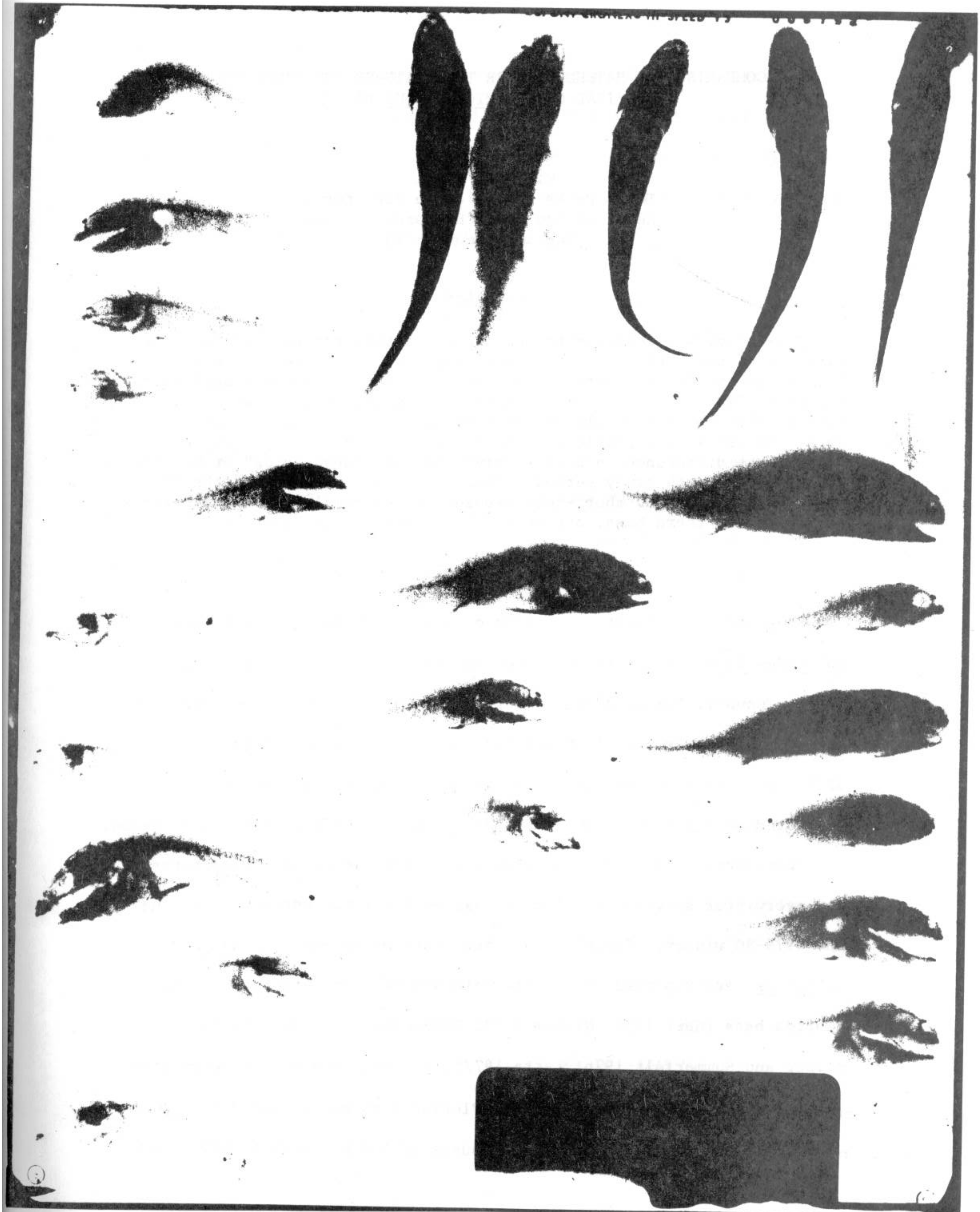

Figure 2. X-ray of tagged red drum showing location of magnetic nose tags.

COMPARISON OF HATCHERY WATER TEMPERATURES AND OVERWINTER SURVIVAL OF TWO *MICROPTERUS* BASSES

by

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ABSTRACT

This study was designed to compare water temperatures and overwinter survival of adult Florida intergrades and northern largemouth bass on Lewisville and Eagle Mountain State Fish Hatcheries in Texas during the winter of 1979-80. Water temperatures on Lewisville were typically more extreme than those on Eagle Mountain and when water temperatures declined to 4 C or below, Lewisville was significantly colder. There was no significant difference in bass survival between "subspecies" or hatcheries during the 4-month study period. These results indicate that the Florida intergrades withstood short-term exposure to extremely cold temperatures as well as northern bass, but showed less increase in condition.

INTRODUCTION

Substantial mortalities of Florida largemouth bass (*Micropterus salmoides floridanus*) were reported on Lewisville State Fish Hatchery (Denton County, Texas, 33°4' N) during the 1978-79 winter, but were negligible on nearby Eagle Mountain State Fish Hatchery (Tarrant County, 32°53' N). Water temperature differences between hatcheries were suspected as a possible cause, but data were not available for comparison.

Therefore, this study was conducted to compare water temperatures and overwinter survival of Florida bass on these two hatcheries during the 1979-80 winter. Since the northern largemouth bass (*M. salmoides salmoides*) are reported to be more tolerant of cold temperatures than Florida bass (Hart 1952; Graham 1973; Stevenson 1973; Johnson 1975; Reiger and Summerfelt 1976; Latta 1977), a comparison of the overwinter survival of this subspecies with the Florida bass was included in the study. However, lateral-line scale counts of the hatchery Florida bass suggested considerable hybridization in these populations; therefore, they will be referred to as Florida intergrades in this report.

Appreciation is expressed to all hatchery personnel on Lewisville and Eagle Mountain State Fish Hatcheries who collected the winter water temperature data used in this study.

METHODS

Each of three adjacent ponds (each approximately 0.2 hectares; 1.5 m average depth) on Lewisville and Eagle Mountain State Fish Hatcheries were stocked with 10 Florida intergrades and 10 northern largemouth bass adults on 17 October 1979 (Table 1). Each fish was anesthetized, weighed, measured, and pelvic fin-clipped to aid in "subspecies" identification before being stocked. Approximately 60-95 kg goldfish (Carassius auratus) fingerlings were concurrently stocked in each pond.

Each morning (0930 h) and evening (1630 h) from 13 December 1979 through 17 February 1980, water temperatures were taken from all ponds using standardized mercury thermometers and Applied Research FT3 thermistors for surface and bottom temperatures, respectively. Temperatures were measured in the pond's kettle approximately 0.3 m below the water surface and 0.3 m above the pond bottom; incoming water temperatures were also taken. Surface and bottom temperatures were also measured near the center of the middle pond on both hatcheries.

Air temperature measurements used in the study were provided by NOAA's Environmental Data and Information Service. These temperatures were measured at 3-hour intervals daily at the Dallas-Fort Worth Regional Airport.

Each pond was observed daily to determine the occurrence of fish mortalities. Ponds were drained on 17 February 1980 and fish were separated into "subspecies", counted, weighed and measured.

Analysis of variance (ANOV) tests showed no differences ($P < 0.05$) among water temperatures on replicated ponds on each hatchery. Therefore, to simplify water temperature data analyses, only temperature data from the middle pond on each hatchery were used; these comparisons were analysed using paired-sample t-tests. Differences in bass survival among "subspecies" and between hatcheries were analysed using a two-way ANOV test.

RESULTS AND DISCUSSION

Surface and bottom mid-section water temperatures on the Lewisville hatchery were typically warmer on warm days and colder on cold days than those on Eagle Mountain (Fig. 1 A & B). Mean mid-surface and bottom water temperatures for morning and evening periods were cooler on Lewisville (Table 2). Examination of water temperatures at or below 4.0 C occurring on either hatchery showed Lewisville to be significantly ($P < 0.05$) colder during cold periods, in most cases.

There was no significant difference in survival between "subspecies" or hatcheries during the 4-month study period (Table 1). Survival was high for both "subspecies" on both hatcheries and only one death (Florida intergrade) could be attributed to overwinter mortality. On three occasions water temperatures declined to 1.0 C or less for short periods (Fig. 1 B). These results indicate Florida intergrades can withstand short-term exposure to extreme cold temperatures as well as northern bass.

Condition (K_{TL}) increased for both "subspecies" at both hatcheries during the study but the Florida intergrade exhibited less increase than northern bass (Table 1) and this difference was significant at the 0.10 level (F=5.32; df=1,8). This is in contrast to reports that hatchery "Florida" bass feed more aggressively than northern bass during winter months and reach spawning condition approximately 2 wk earlier than northern bass (D. L. Campbell, Tyler State Fish Hatchery; personal communication). However, factors that could have caused this include difference in feeding efficiency between subspecies, unequal sex ratios between subspecies, intrasubspecific competition, or temperature-related stress. If the winter had been more severe, this possible stress response could have manifested itself as fish mortality.

Comparison of air temperatures show that the 1978-79 winter was significantly ($P < 0.05$) colder than in 1979-80 (Fig. 2). The period of extreme cold in January 1979 was considerably longer than any in 1979-80. Johnson (1975) and this author (unpublished data) demonstrated under laboratory conditions that Florida bass cannot survive prolonged exposure to cold temperatures (≤ 4.0 C) as well as northern bass. Water temperatures were probably colder on both hatcheries during the 1978-79 winter and, as found in 1979-80, more extreme on Lewisville than Eagle Mountain hatchery. These apparent colder temperatures may have contributed to greater hatchery "Florida" bass mortalities on the Lewisville hatchery during the 1978-79 winter.

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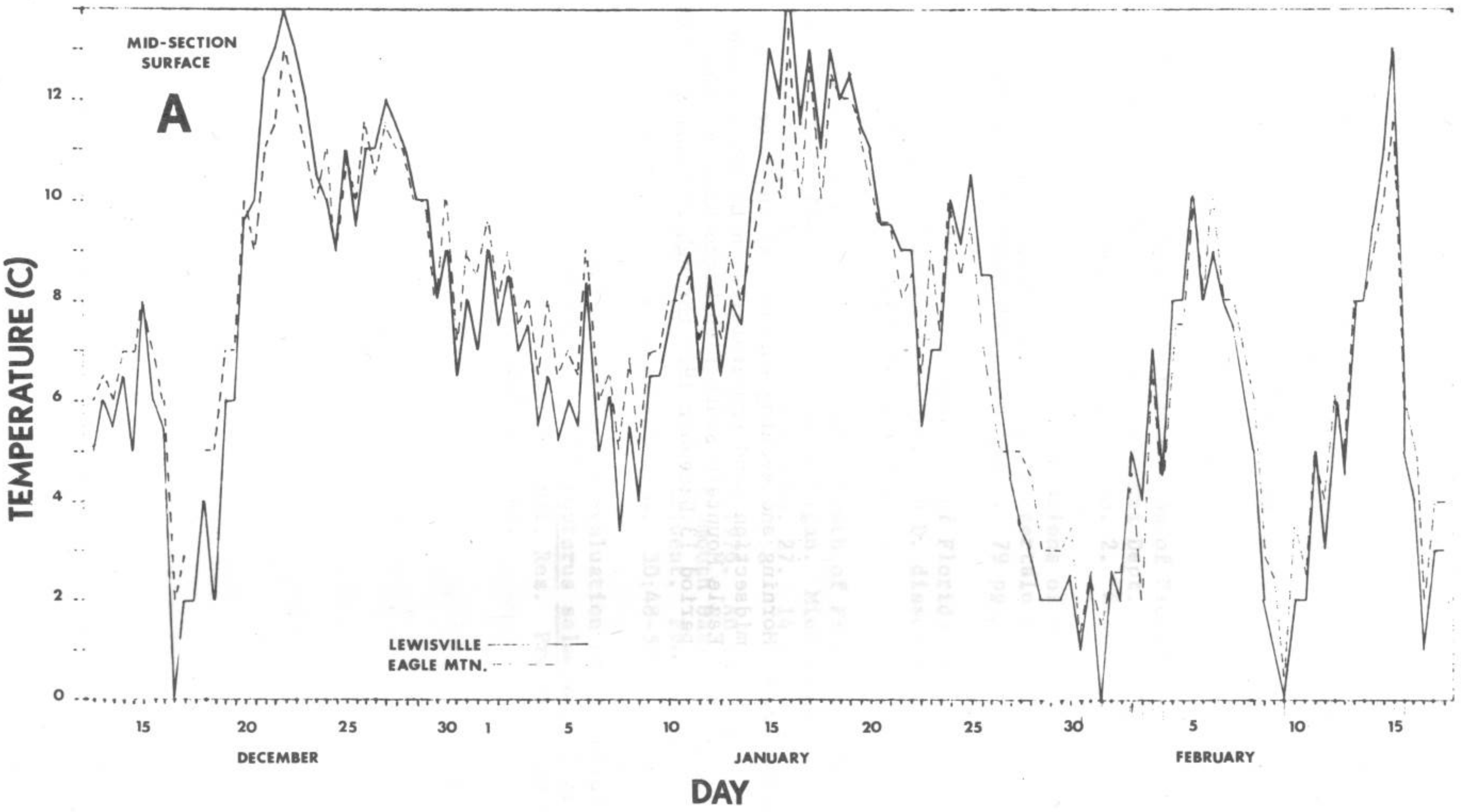
Figure 1. - Morning and evening surface (A) and bottom (B) midsection pond temperatures on Lewisville and Eagle Mountain State Fish Hatcheries for the period 13 December 1979 through 17 February 1980.


MID-SECTION
SURFACE
A
TEMPERATURE (C)
0
2
4
6
8
10
12
15
20
25
30
1
5
10
15
20
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10
15
DECEMBER
JANUARY
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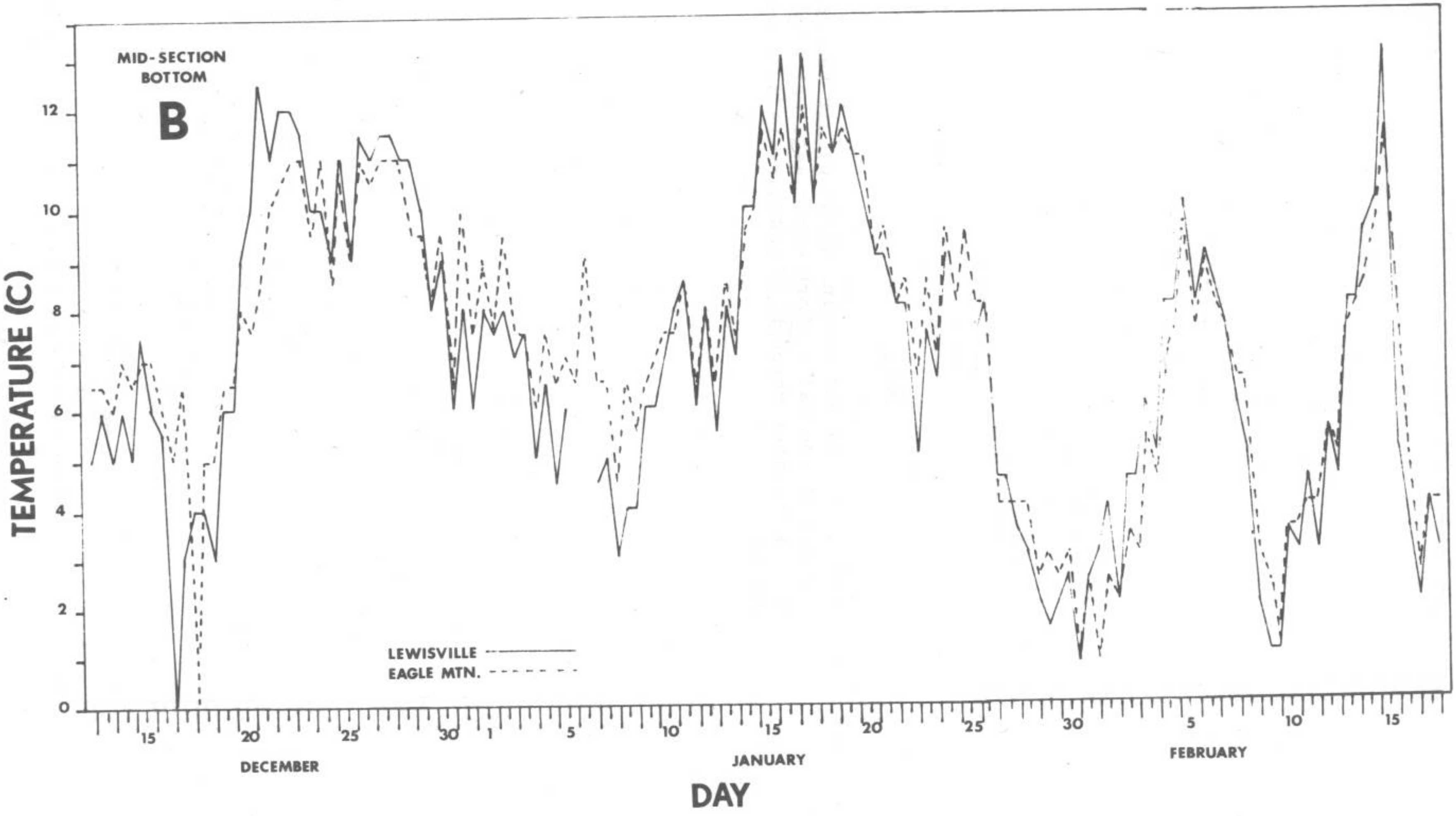
DAY
LEWISVILLE
EAGLE MTN.


MID-SECTION
BOTTOM
B
TEMPERATURE (C)
0
2
4
6
8
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12
15
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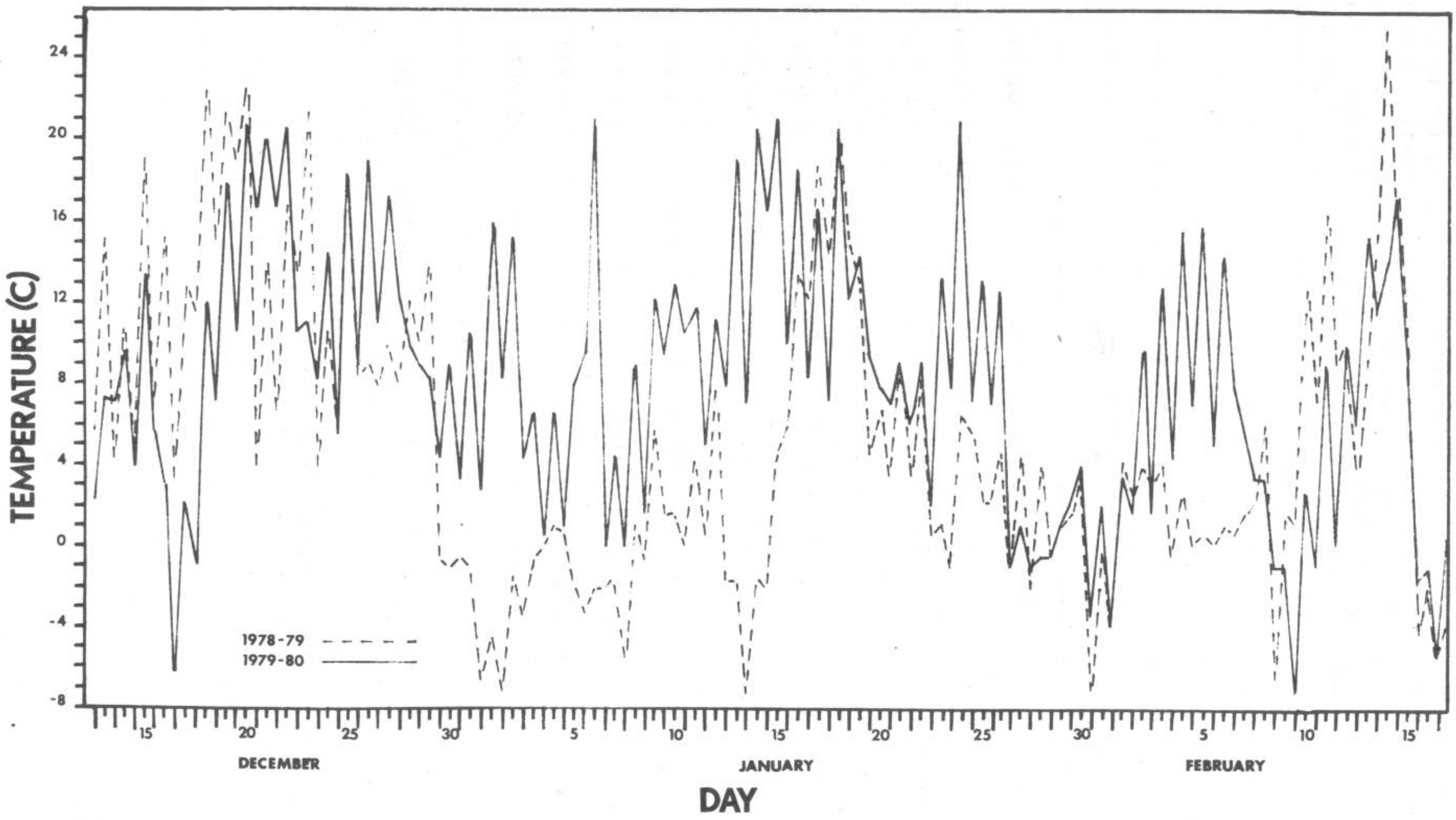
25
30
1
5
10
15
20
25
30
5
10
15
DECEMBER
JANUARY
FEBRUARY
DAY
LEWISVILLE
EAGLE MTN.

Figure 2. - Morning (900 h) and evening (1500 h) air temperatures recorded at the Dallas-Fort Worth Regional Airport from 13 December through 17 February 1978-79 and 1979-80.


TEMPERATURE (C)
24
20
16
12
8
4
0
-4
-8
1978-79
1979-80
15
20
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5
10
15
20
25
30
5
10
15
DECEMBER
JANUARY
FEBRUARY
DAY

Table 1. Mean total lengths (TL in mm) and weights (Wt in g) with standard errors in parentheses, condition factors (K_{TL}) and percentage survival (%) of Florida intergrades (FI) and northern (NB) largemouth bass stocked in three adjacent ponds each on Lewisville and Eagle Mountain State Fish Hatcheries on 17 October 1979 and removed on 17 February 1980.

Hatchery	Pond	Species	17-10-79			17-2-80			%
			TL	WT	K_{TL}	TL	WT	K_{TL}	
Lewisville	1	NB	398(13)	938(110)	1.43	393(10)	980(93)	1.59	90[1]
		FI	393(10)	896(77)	1.44	398(11)	1056(116)	1.63	90[1]
	2	NB	392(8)	901(65)	1.49	393(9)	1049(71)	1.72	90[1]
		FI	391(7)	904(56)	1.50	395(7)	1024(57)	1.65	100
	3	NB	366(6)	714(42)	1.45	366(5)	839(41)	1.69	100
		FI	379(8)	805(39)	1.47	385(8)	953(54)	1.66	100
Eagle Mountain	1	NB	403(12)	1106(81)	1.68	418(7)	1338(65)	1.89	100
		FI	405(6)	1123(60)	1.67	413(3)	1266(37)	1.77	90[2]
	2	NB	424(15)	1250(115)	1.56	436(15)	1444(130)	1.71	100
		FI	410(5)	1148(44)	1.66	413(5)	1238(67)	1.75	100
	3	NB	404(10)	1109(105)	1.63	412(10)	1302(123)	1.82	100
		FI	410(4)	1157(32)	1.68	416(3)	1333(4)	1.85	100

[1] Fish died within 1 month after being stocked.
[2] Fish died shortly before ponds were drained.

Table 2. Mean water temperatures (C) and mean temperatures for those occurring at 4 C or below from 13 December 1979 through 12 February 1980 on Lewisville (L) and Eagle Mountain (EM) State Fish Hatcheries for morning (am) and evening (pm) periods. Asterisk denotes significant differences at the 0.05 level.

Temperature Location	Time	Overall $\bar{x}$ temp.		4 C or below	
		L	EM	L	EM
Surface	am	6.7	7.0*	2.3	3.1*
	pm	7.9	8.0	3.2	4.0*
Bottom	am	6.4	6.7	2.6	3.2
	pm	7.5	7.6	3.2	3.9*

TEMPERATURE TOLERANCE OF THE PEACOCK BASS (*Cichla temensis*)

by

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ABSTRACT

Effects of temperature on survival of *C. temensis* fingerlings were examined in the laboratory. Fish were acclimated at 25, 30 or 35 C prior to testing. The lower and upper lethal temperatures were 17.1 and 39.0 C, respectively when the temperature change from acclimation was 1 C/day. Acclimation temperature significantly affected the temperature at which peacock bass began losing equilibrium (LE_{50}) and dying (CTMin) when fish were exposed to a 1 C/h decrease. LE_{50}'s for the 35, 30 and 25 C acclimation temperatures were 17.9, 16.7 and 14.0 C, respectively. *C. temensis* can withstand rapid temperature decreases as long as water temperatures do not decline below their lower lethal temperature.

INTRODUCTION

The Texas Parks and Wildlife Department have selected two peacock basses, *Cichla ocellaris* and *C. temensis* for possible introduction into selected electro-power plant lakes to provide quality sport fisheries. These introductions could improve angling by providing new species for harvest and expand fishing pressure to additional predator fish. However, before introduction, the temperature tolerance of these two exotics needs investigation to determine proper stocking sites and the potential habitat range of the exotic if it proves detrimental to indigenous fishes. Temperature tolerance limits have been determined for C. ocellaris (Swingle 1966; Devick 1970; Guest et al. In press), but not for C. temensis. This paper reports the effects of temperature on survival of C. temensis in the laboratory.

METHODS

Fingerling C. temensis (74-94 mm total length) were collected from a pond at Heart of the Hills Research Station, Kerr County, Texas during September 1978 and maintained indoors in 400 or 1500-l holding tanks receiving a continuous flow of aerated spring water. Laboratory lighting was regulated with timers to provide a 12-h photoperiod. Fish were fed live fathead minnows (Pimephales promelas) daily and tanks were cleaned as needed. Fish mortalities were negligible during this holding period.

Two experiments were conducted to determine the temperature tolerance of C. temensis fingerlings. In both experiments, fish were acclimated to 25, 30 or 35 C. Fish were contained in 18-l aerated aquaria suspended in 700-l water baths in which water temperatures were thermostatically controlled with heaters and chillers. Two test aquaria and one control aquarium each containing four or five fish, were used for each acclimation temperature in each experiment. Small sample sizes were necessary because of difficulty in providing suitable sized live prey for large numbers of fish. During the acclimation process, water temperatures were raised from an ambient temperature of 24±1 C to acclimation at a rate of 1 C/day. Fish were held a minimum of 2 wk at acclimation before testing. Fish were fed daily during acclimation and testing and aquaria were cleaned daily.

The first experiment determined lower and upper lethal temperatures as defined by Otto and Rice (1977), through adjustments from acclimation at the rate of 1 C/day. The temperature at which fish stopped feeding was noted and number surviving was recorded daily. Effect of acclimation temperatures on lethal temperatures was analyzed by analysis of variance techniques. The temperature at which 50% of the fish had died was determined by regression analysis (arcsine transformation was made on all percentage data) for determination of the lower and upper lethal temperatures.

The second experiment determined the effect of a rapid temperature decline (1C/h) on fish survival. Becker et al. (1977) stated that this cooling rate represented a minimum temperature decline in many situations involving terminated heated discharges. In this experiment, temperatures at which fish began losing equilibrium and died were determined by continuous observation. Regression analyses were used to calculate the temperature at which 50% of the fish had lost equilibirum (LE_{50}) and died (critical thermal minimum; or CTMin). Covariance analyses were used to examine the effect of acclimation temperature on LE_{50} and CTMin values.

RESULTS AND DISCUSSION

In the first experiment, there was no difference in mortalities between replicates and acclimation temperatures had no significant effect on lethal temperatures so they were combined to compute lethal temperatures. No mortalities occurred in controls.

As temperatures decreased, reduced feeding was noted at 18.5 C and feeding ceased below 17.0 C. Fish began dying at 17.5 C and all were dead at 16.0 C (Fig. 1). As the temperature increased, fish began dying at 38.5 C and all had died at 40.0 C. The lower and upper lethal temperatures for *C. temensis* fingerlings were calculated to be 17.1 and

39.0 C, respectively. The lower lethal temperature for C. ocellaris was determined to be between 15 and 16 C (Swingle 1966; Devick 1970) and Guest et al. (In press) determined their upper lethal temperature to be 37.9 C. If this data comparison were valid, it suggests there are differences in lethal temperatures between these two closely related species. But examination of confidence limits around lethal temperatures for C. temensis (Fig. 1) show there is some overlap in lethal temperatures between these two species which require us to conclude that these two species have different but very similar lethal temperature limits.

In the second experiment where temperatures were decreased rapidly (1 C/h), the acclimation temperatures significantly affected LE_{50} and CTMin values (Fig. 2). As acclimation temperatures decreased, the temperatures at which fish lost equilibrium and died also decreased. Fish acclimated at 35 C began losing equilibrium at 18.0 C; whereas those acclimated at 25 C began losing equilibrium at 14.0 C. Results of this test suggest that some C. temensis fingerlings can withstand a temperature decline rate depicting a wintertime power plant shutdown as described by Becker et al. (1977) as long as water temperatures do not decline below their lower lethal temperature. However, examination of water temperature data from several Texas power plant lakes reveal winter water temperatures typically decline well below the lower temperature tolerance of C. temensis before the power plants resume generation. This fact makes the possibility of establishing a population of peacock bass in a Texas heated reservoir very unlikely and indicates the termination of a heated discharge into these lakes could be used as a control mechanism if these fish were found undesirable.

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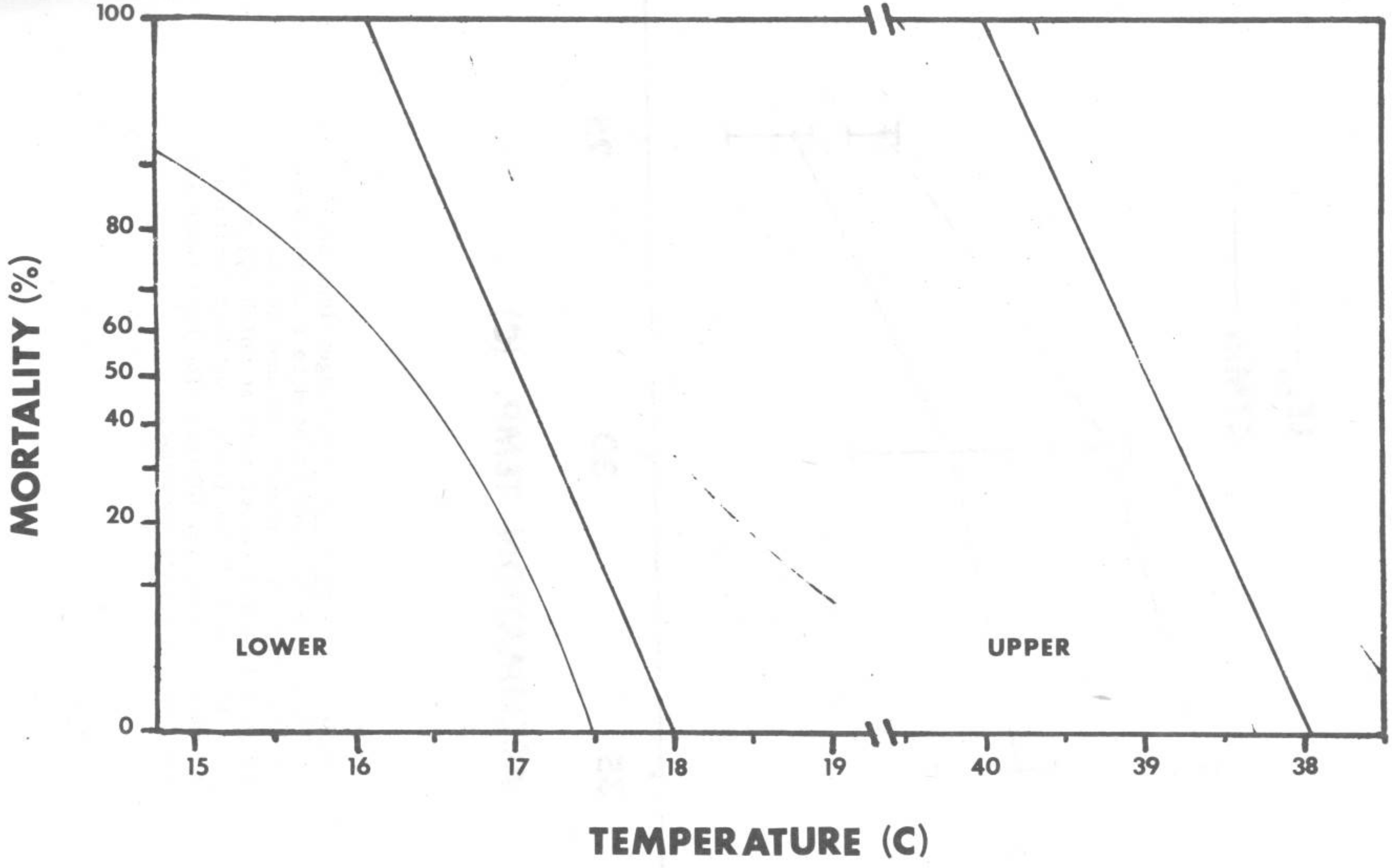

Figure 1. Graph of temperature vs. cumulative mortality for *Cichla temensis* fingerlings exposed to 1 C/day temperature changes. Regression lines with 95% confidence limits used to determine ultimate lethal temperatures are significant ($P < 0.05$).

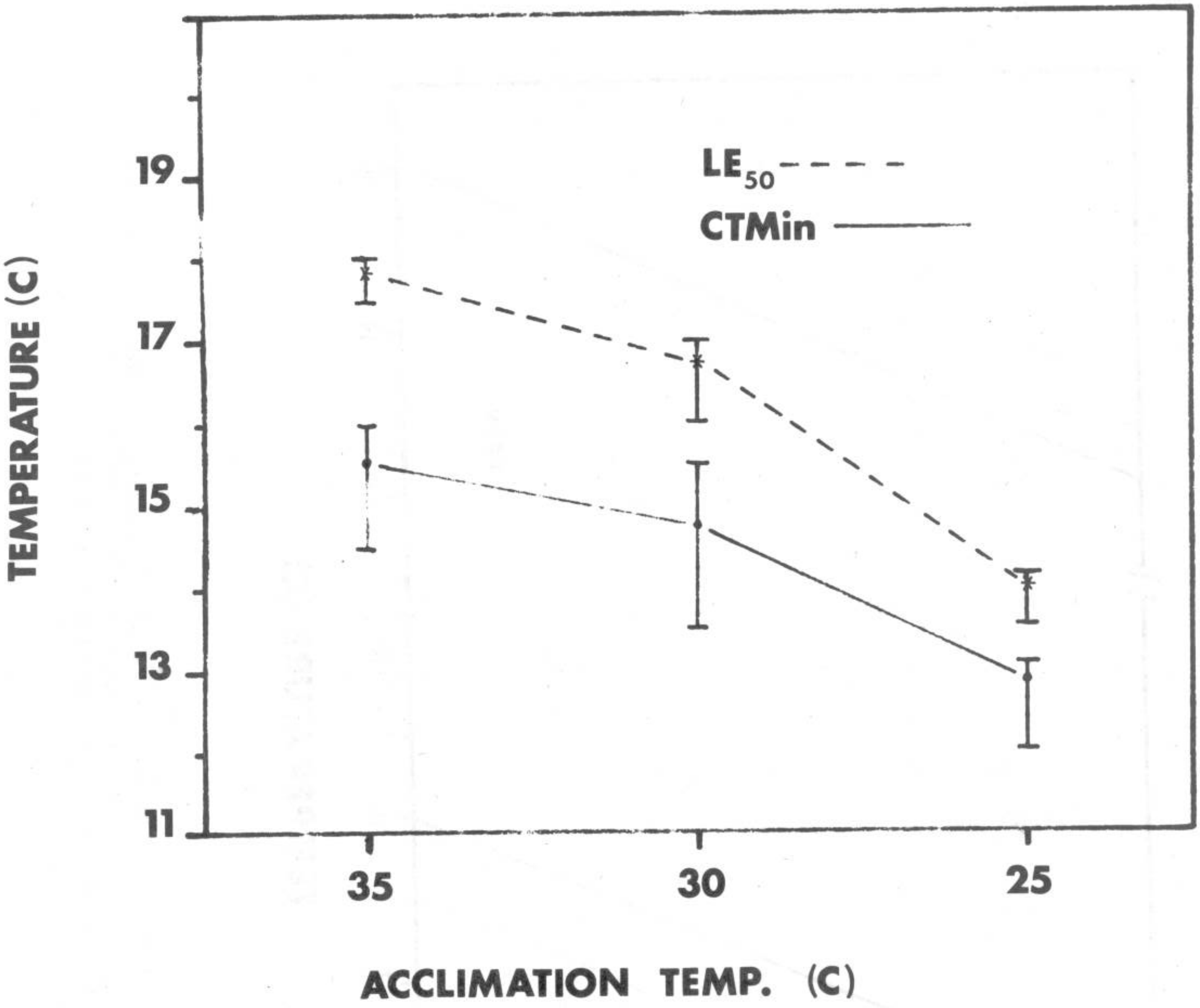

Figure 2. Response of Cichla temensis fingerlings acclimated at 25, 30 and 35 C and exposed to a temperature decline of 1 C/h. Regression analyses were used to calculate the temperature at which 50% of the fish lost equilibrium (LE_{50}) and died (critical thermal minimum, ie. CTMin). The bars represent the range for each response.

ELECTROPHORETIC EVALUATION OF FIVE HATCHERY STOCKS OF LARGEMOUTH BASS IN TEXAS

by

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ABSTRACT

Results of an electrophoretic study of two stocks of northern largemouth bass and three stocks of Florida largemouth bass currently being maintained at four different Texas hatcheries suggest that intergradation readily occurs when subspecies are maintained simultaneously at a facility. Examination of liver isocitrate dehydrogenase, glutamate oxalate transaminase, and tetrazolium oxidase allozyme banding patterns revealed significant intergradation in four of these five stocks. Intergradation in Florida largemouth bass stocks may occur after importation. Improved hatchery subspecies segregation procedures are needed.

INTRODUCTION

Since its importation into Texas in 1970, the Florida largemouth bass (*Micropterus salmoides floridanus*) has been maintained and cultured in state and federal hatcheries throughout the state. In many cases, these stocks are maintained and cultured in conjunction with stocks of northern largemouth bass (*M. s. salmoides*). In a study of largemouth bass genetics throughout the United States, intersubspecific contamination in a hatchery stock from Texas was found (D. Philipp, Ill. Nat. Hist. Surv., pers. comm.). More recently, there has been concern that additional intergradation may have occurred in hatchery stocks, and that stocks of imported Florida bass may lack genetic integrity. Lateral line scale counts have been used to separate subspecies and detect intergradation, but this technique may be unreliable (Buchanan 1973, Pelzman 1980). Starch-gel electrophoresis has been found to be a more accurate method of subspecies identification of largemouth bass in a variety of situations (Childers 1975, Pelzman 1980).

At the request of personnel of the U.S. Fish and Wildlife Service, San Marcos, Texas, and the Texas Parks and Wildlife Department, an electrophoretic study of several largemouth bass stocks being cultured in Texas was undertaken at Texas A&M University. The purpose of this paper is to describe the genetic status of five hatchery stocks of largemouth bass and to evaluate the applicability of electrophoretic methodology for genetic studies of hatchery stocks.

Dr. Don Whitmore of the University of Texas--Arlington and Dr. David Philipp of the Illinois Natural History Survey provided technical advice. Allen Forshage, Billy White, David Campbell, and Bill Rutledge of the Texas Parks and Wildlife Department either transported or provided fish used in this study, as did Holt Williamson and Harry Bishop of the U.S. Fish and Wildlife Service. The enthusiastic assistance of Alan Rudd of Texas A&M was greatly appreciated. Funding for this study was provided by Texas Agricultural Experiment Station Project S-6206 and Texas A&M Research Foundation Project 4236.

MATERIALS AND METHODS

Samples of largemouth bass stocks from the U.S. Fish and Wildlife Service laboratory at San Marcos and the Texas Parks and Wildlife Department hatcheries at Jasper, Tyler, and Huntsville, were transported live to laboratory facilities at Texas A&M University. Samples from San Marcos included representatives from stocks of both Florida and native Texas northern largemouth bass, as well as a sample of northern largemouth bass which originated at the U.S. Fish and Wildlife Service laboratory in Marion, Alabama. Samples received from Tyler and Jasper were brought from Florida in 1979. The Huntsville stock was of earlier origin from Florida and included no known northern largemouth bass.

In order to identify electrophoretic difference between *M. s. salmoides* and *M. s. floridanus*, we analyzed three populations which had no known exposure to fish of other subspecies (*M. s. salmoides* from Boenker Lake, Navasota, Texas, and Post Oak Lake, Texas A&M University; *M. s. floridanus* from the Aquaculture Research Center, Texas A&M University). These three populations revealed no evidence of intersubspecific gene flow and were used to provide control specimens in this study.

Upon receipt in the laboratory, each fish was sacrificed and given an identification number. Lateral line scales were counted on each fish, with the exception of the San Marcos Florida bass, using the method of Bailey and Hubbs (1949). Immediately after sacrifice, samples of liver, skeletal muscle, heart, and eye were removed from each fish and stored in labeled containers at -60 C. Tissue samples were homogenized in an approximately equal volume of pH 7.1 buffer solution (Selander et al.

1971) and centrifuged at 12,000 RPM at 4 C for 25 minutes. The supernatant was stored at -60 C except when thawed for electrophoretic analysis.

Starch gels were prepared using 60 g of hydrolyzed potato starch (30 g Connaught Labs, 30 g Sigma) suspended in 500 ml of Tris-citrate buffer, pH 8.0 (Selander et al. 1971).

The suspension was heated to boiling while being constantly swirled, degassed, and poured into a plexiglass gel mold. Gels were then covered with Saran Wrap and allowed to cool and harden overnight for use the following day.

Samples of tissue homogenate were absorbed into a 8 mm x 3 mm strip of #3 filter paper and placed into the gel along a straight line cut into the gel approximately 5 cm from the cathodal edge. Up to 20 samples, each representing an individual fish, were placed into each gel. The samples were run on a horizontal starch-gel electrophoresis apparatus. Electrophoresis chamber reservoirs were filled with 250 ml of Tris-citrate pH 8.0 buffer solution (Selander et al. 1971). Electrophoresis was carried out for 8 hr at 6 C and 75 milliamps constant current.

Upon completion of each run, gels were removed from the apparatus, appropriately trimmed, cut into three 2-mm-thick slices, and each stained for a specific enzyme system. Three loci obtained from liver homogenates were used for identification of subspecies in this study: isocitrate dehydrogenase (IDH), glutamate oxalate transaminase (GOT), and tetrazolium oxidase (TO). Specific biochemical stains used were similar to those described by Shaw and Prasad (1969). Although Childers (1975) and Pelzman (1980) report a unique northern largemouth bass allele at the malate dehydrogenase (MDH) "B" locus in skeletal muscle, our analyses of Texas stocks (unpublished data) indicated such low frequencies of this allele that it was of little use for our purposes.

The system used for designation of allozymes is similar to that described by Greenbaum and Baker (1976). For each locus the allozyme (allele) occurring in the highest frequency in *M. s. salmoides* was designated as 100 with all other alleles at the same locus being designated numerically as to the percent of migration contrasted with the 100 allele. When multiple isozymes were present for a specific biochemical stain, the locus with the greatest migration was designated "1"; loci with progressively slower mobilities received progressively higher numerical designations. Direct, side-by-side comparison of mobilities of all allozymes of each isozyme were used for comparison of alleles.

Isozyme staining patterns were used to test for intergradation in the various hatchery stocks analyzed. The presence of alleles unique to one subspecies in hatchery stocks of the other subspecies was interpreted as resulting from subspecific intergradation.

RESULTS AND DISCUSSION

Allozyme Banding Patterns

Isocitrate Dehydrogenase (IDH). A single liver IDH isozyme was detected in the fish analyzed in this study. Analysis of our control populations indicated that northern largemouth bass were monomorphic for the IDH-1^{100} allele whereas the Florida bass were fixed for the IDH-1^{115} allele. The same pattern of IDH variation has been found in a widespread sampling of northern and Florida largemouth bass populations (D. P. Philipp, Ill. Nat. Hist. Surv., pers. comm.). IDH-1 heterozygotes display both allozymic bands as well as an intermediate heterodimeric band (Figure 1).

Glutamate oxalate transaminase (GOT). Two isozymes of GOT were found in both northern and Florida bass. The GOT-2 locus was nearly isoelectric under the conditions employed and was monomorphic for the same allozyme in all samples studied.

Three allozymes were detected at the GOT-1 locus. Two alleles, GOT-1^{135} and GOT-1^{150}, were unique to Florida bass and one allele, GOT-1^{100}, was unique to northern bass.

This locus demonstrates six different banding patterns based upon which parental alleles were present (Figure 1). Homozygous individuals demonstrate only a single electromorph, while heterozygotes, whether intersubspecific or intrasubspecific, are characterized by the parental electromorphs and an intermediate heterodimeric band (Figure 1).

Tetrazolium oxidase (TO). A single TO locus was detected in our samples. TO-1^{100} is the common allele in both largemouth bass subspecies. A second allele, TO-1^{63}, is unique to Florida bass. Homozygous individuals demonstrate a single electromorph, while heterozygotes demonstrate both electromorphs and an intermediate heterodimeric band (Figure 1).

San Marcos Largemouth Bass

Samples received at Texas A&M University from the U.S. Fish and Wildlife Service, San Marcos, consisted of 20 fish each of the Florida largemouth bass and northern largemouth bass stocks being cultured at that facility. Additionally, 21 representatives of a northern largemouth bass stock obtained from Marion, Alabama, were received from the San Marcos laboratory. Electrophoretic examination of the stocks revealed that each consisted of at least some individuals with genetic characteristics of both subspecies.

Electrophoretic analysis of 18 fish from the Florida largemouth bass stock at San Marcos revealed three fish with northern bass alleles. One carried the IDH-1^{100} allele and the other two the GOT-1^{100} allele. Lateral line scale counts made previously on this stock indicated a mean of 70.8, with a range of 66-77 (Table 1).

Electrophoretic analysis of 20 bass of the San Marcos northern largemouth bass stock revealed two fish with Florida largemouth bass alleles. One of these fish was homozygous for the typical Florida bass IDH-1^{115} allele. Additionally, this fish was homozygous for the two Florida bass GOT alleles, GOT-1^{135} and GOT-1^{150}. These data suggest that this fish may have been a Florida largemouth bass accidentally introduced into the northern largemouth bass stock. Average lateral line scale counts for the northern largemouth bass sample was 66.0, ranging from 62 to 69 (Table 1).

Of the 21 largemouth bass from the Marion stock, 15 demonstrated genetic intergradation, indicating that this stock is essentially of "hybrid" constitution. Of the remaining six fish, four demonstrated northern largemouth bass banding patterns and two showed Florida bass banding patterns. However, it is not unlikely that these fish were also intergrades, since the number of available enzyme markers is not sufficient to accurately characterize every individual past the F_1 generation. Therefore, the presence of intersubspecific alleles in an individual indicates intergradation, but the converse is not necessarily true. The absence of intersubspecific alleles in these six fish does not definitely signify a "pure" Florida or northern largemouth bass.

The presence of Florida bass alleles in this "northern" bass population may be the result of natural intergradation. The zone of Florida and northern largemouth bass intergradation as described by Bailey and Hubbs (1949) extended well into Alabama. More recent electrophoretic analysis of fish from this zone of intergradation indicates that the zone may extend well into Mississippi (D. Philipp, Ill. Nat. Hist. Surv., pers. comm.).

The average lateral line scale count for these 21 fish was 61.4, ranging from 59 to 65 (Table 1). This is uncharacteristically low for any largemouth bass population and may be due to an unrepresentative sample or artifactual truncating selection (Hartl 1980) for low scale counts by hatchery personnel.

Huntsville Florida Largemouth Bass

Electrophoretic examination of 20 Florida largemouth bass brood fish from the Texas Parks and Wildlife hatchery at Huntsville indicated that this brood stock had been significantly contaminated with northern bass genes (Table 1). Thirteen of 20 fish assayed were found to carry northern bass IDH or GOT alleles. Average lateral line scale count of these 20 fish was 67.2, ranging from 63 to 72.

Tyler/Jasper Florida Largemouth Bass

Fish received from the Texas Parks and Wildlife hatcheries at Tyler and Jasper were samples of a population of Florida largemouth bass brought to Texas from Florida as fingerlings in July, 1979

(David Campbell, Texas Parks and Wildlife, pers. comm.). Larger individuals had been maintained at Tyler, smaller fish in Jasper. Because these fish were representative of a single introduction, they were treated as a single sample in our analysis. Electrophoretic examination of these 20 fish revealed no northern largemouth bass genetic influence. Considering that northern and Florida largemouth bass exhibit fixed allelic differences at two of the loci examined, it is highly unlikely that electrophoretic analysis of 20 fish would have left any intergradation undetected. Average lateral line scale count for these fish was 71.8, ranging from 68 to 76 (Table 1).

Management Implications

The results of this study indicate that intersubspecific stock contamination of largemouth bass has occurred when both subspecies are cultured and maintained at the same facility. The use of genetically "impure" stocks of bass may not be of significance, depending upon the research or management objectives for which they are utilized. A low level of intergradation may not be of concern in reservoir stocking or Florida bass impact studies, but certainly could bias research in such areas as temperature tolerance, population dynamics, and ecology.

The sample of fish analyzed from the Marion, Alabama, largemouth bass stocks suggests that lateral line scale count may, in itself, be unreliable for assignment of fish to subspecific or intergrade status. This "hybrid" stock displayed lateral line scale counts well below those reported by Chew (1975) as being characteristic of intergrade populations. However, shifts in lateral line scale count distributions similar to those found in the Huntsville bass stock may be valid indications that intersubspecific gene flow has taken place.

Lack of contamination in the Florida largemouth bass received from the Texas Parks and Wildlife Department hatcheries at Tyler and Jasper suggests that contamination of stocks may occur after their arrival in Texas. Even so, it is our suggestion that stocks of fish imported into Texas be subjected to routine electrophorectic analysis to ensure the genetic integrity of the stock.

Application of Electrophoresis in Fisheries Evaluations

It is apparent that intersubspecific contamination exists in several stocks of largemouth bass currently being held and cultured in Texas. In light of the many unanswered ecological questions surrounding the Florida largemouth bass and the need to maintain "pure" stocks of largemouth bass, remaining stocks of largemouth bass currently being held at other facilities should be evaluated for genetic integrity. When contaminated stocks are found, their applicability to management should be evaluated before further use. Attempts should be made to revise or implement general hatchery procedures to prevent intergradation of largemouth bass stocks. Such procedures may involve restricting each hatchery to use of a particular bass subspecies.

One of the major drawbacks to the use of starch-gel electrophoresis has been the cost in time and dollars. In this case, all three enzyme markers can be evaluated simultaneously, thereby greatly reducing the cost involved. A single gel can be used to evaluate 20 fish at three enzyme loci. Our data suggest that such analysis provides an accurate assessment of the genetic integrity of largemouth bass stocks.

The use of tetrazolium oxidase as a marker appears to be of limited value in hatchery situations. No fish in the study was found to be an intergrade based on TO alone. However, it has been our experience that the TO locus can be useful in situations where the $TO-1^{63}$ allele is a high frequency allele in parental stocks, e.g., the Tyler and Jasper stocks. When such stocks are utilized in stocking programs or when population impact evaluations are conducted, this allele may indicate the presence of Florida bass genes when other enzyme loci fail to do so.

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Table 1. Electrophoretic and meristic data from largemouth bass stocks at selected state and federal hatcheries, Texas A&M University, and two Texas farm ponds.

	Number of Fish Assayed	Intergradation		Lateral Line Scale Count		
		Number	Est. %	Mean	Range	Std. Dev.
Northern Largemouth Bass						
Boenker Pond (Navasota, Texas)	10	0	0	63.3	57-69	3.86
Post Oak Lake (TAMU Range Area)	15	0	0	63.7	60-66	1.85
Marion, Alabama (via San Marcos)	21	15	75-100	61.4	59-65	1.68
San Marcos	20	2	10	66.0	62-69	1.93
Florida Largemouth Bass						
TAMU Aquaculture Center	23	0	0	69.2	64-73	2.50
Huntsville	20	13	65	67.2	63-72	2.30
Jasper/Tyler	20	0	0	71.8	68-76	2.34
San Marcos	18	3	16	70.8	65-77	2.17

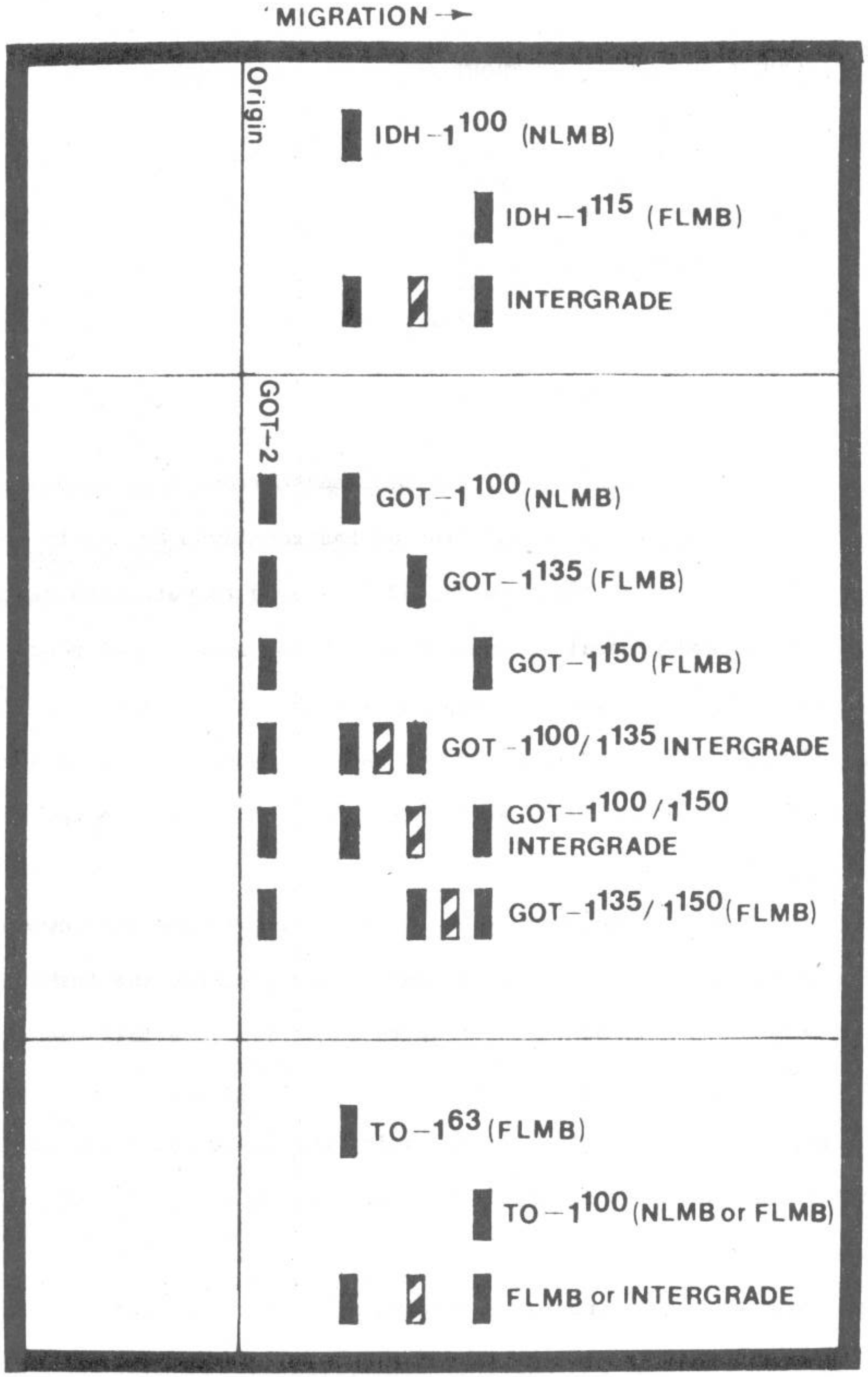

Figure 1. Banding patterns of liver isocitrate dehydrogenase (IDH), glutamate aspartate transaminase (GOT), and tetrazolium oxidase (TO) in largemouth bass. Heterozygosity at any locus results in a third, intermediate, dimeric band (indicated by cross-hatching) not found in homozygotes.

MOVEMENT OF SPOTTED SEATROUT (CYNOSCION NEBULOSUS)
TAGGED IN BASTROP BAYOU, TEXAS

By

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ABSTRACT

During February 1976-April 1978, 736 spotted seatrout (Cynoscion nebulosus) were caught for tagging with hook and line at Bastrop Bayou Marina in the Galveston Bay system. Of 68 tag returns, 57 were used to determine distance traveled, days free and general movement patterns for spotted seatrout.

The average number of days free was 230 with most (82.1%) of the 57 fish being returned within 1 yr. Recaptured spotted seatrout traveled an average of 24 km with the majority (75.0%) being returned from within the Galveston Bay system.

A movement of spotted seatrout from Bastrop Bayou to the shallow Gulf was noted during summer with 57 fish (19.3%) being returned from the inshore Gulf waters. A movement of fish out of Bastrop Bayou during late fall was also detected.

It was hypothesized that fish were leaving the bayou and returning at a later date but analysis of the data using a sine curve failed to substantiate this hypothesis.

It is recommended that intensive tagging studies of spotted seatrout should be conducted to determine if fish in other Texas bays are behaving the same way as those in Bastrop Bayou.

INTRODUCTION

Essential to effective management of estuarine fish is an understanding of their movement. Tagging data from Florida have indicated that most spotted seatrout (Cynoscion nebulosus) travel $<$ 48 km from a tagging site (Moffett 1961, Iversen and Tabb 1962, Tabb 1966, Beaumariage 1969, Moe 1972). Tag returns for spotted seatrout tagged in Texas from 1950 through 1970 also indicate little movement (Simmons and Breuer, unpublished data); however, except in three instances, these fish were tagged during infrequent intervals, in low numbers and at many different sites. In addition, Simmons and Breuer reported a low recapture rate (3.09% average). Therefore, interpretation of spotted seatrout movement was very difficult.

This paper presents data on the extent of spotted seatrout movement from Bastrop Bayou, part of the Galveston Bay system. The data indicate that spotted seatrout may be more migratory in Texas than has been previously reported.

We would like to thank Mr. Jack Booth of Bastrop Bayou Marina who allowed us to use his facilities during the tagging project. Thanks go to Lynn Benefield, John Key and the personnel at the Seabrook Marine Laboratory who helped tag fish and to Hal Osburn for his suggestions on evaluating spotted seatrout movement. Thanks also go to Patricia Johansen, Albert Green, Roy Johnson, Tom Heffernan, Hal Osburn and Ed Hegen who reviewed the manuscript and to Dolores Kleypas for typing it.

MATERIALS AND METHODS

During February 1976-April 1978, 736 spotted seatrout (115-450 mm TL) were caught for tagging with hook and line at Bastrop Bayou Marina (18.5 km from Bastrop Bay) in the Galveston Bay system (Fig. 1, Table 1). Each fish was measured (total length to the nearest 5 mm), tagged with a uniquely numbered tag with external streamer (according to the technique described by Moffett 1961) and held for up to 5 d in a 1.2 x 1.2 x 1.2-m cage. Tags were made of semihard, glossy green plastic (25.4 x 6.4 x 0.8 mm) with round corners. From a single hole in the center extended a section of bright yellow flexible plastic hollow tubing (∼50 mm long; O.D. = 2.1 mm· I.D. - 1.0 mm). "TEXAS PWD, SEABROOK" was printed on each tag. During the holding period fish were fed dead shrimp daily; after the holding period the tagged fish were released into the bayou.

Posters were placed at commercial fish houses, fish camps, fishing piers and sporting goods stores to publicize the Texas Parks and Wildlife Department tagging program. In addition, the program was occasionally publicized on radio, television and in newspapers throughout the state. Each individual returning a tag was requested to provide the total length and/or weight, date of catch and location of catch. A reward of $1-$25 was paid by the National Marine Fisheries Service or the Gulf Coast Conservation Association for each returned tag.

Minimum distances traveled were obtained by plotting the tagging and recapture sites and measuring the shortest aquatic distance (to the nearest km) between the two sites on NOAA Nautical Charts dated "August 1975".

Fish were grouped according to when they were tagged (September-November or February-April) and distance traveled was plotted against date of recapture for each group (Figs. 2 and 3). Size of fish at tagging was also plotted against distance traveled (Fig. 4) to determine if there was a relationship between size and distance moved. Distances traveled by recaptured spotted seatrout were grouped into 5-km increments (Table 2) to determine if there were differences in the pattern of movement. Days free were determined by counting all days the fish was in the water excluding the day of tagging and including the day of recapture.

To determine if spotted seatrout might be leaving the tagging site and returning at a later date, each return date was expressed as a Julian date. Fish tagged during September-November were pooled and fish tagged during February-April were pooled. Distance traveled was regressed against $|\sin[(\text{Julian date})(0.986) + 91]|$ for fish tagged during September-November and $|\sin[(\text{Julian date})(0.986) - 73]|$ for fish tagged during February-April according to a least squares analysis (Sokal and Rohlf 1969). Multiplying the Julian date by 0.986 adjusted the year to 360 days. Adding 91 to the Julian date for fish tagged during September-November and subtracting 73 from the Julian date for fish tagged during February-April adjusted the return date to a 360-day year with 10 October as day one for fish tagged during September-November and 15 March as day one for fish tagged during February-April.

RESULTS

Of 736 spotted seatrout tagged in Bastrop Bayou, 9.2% (68 fish) were recaptured (Table 1). No return data were reported for two of these fish so they were eliminated from the analyses (Table 3). Nine fish were eliminated because they were recaptured within 14 days of tagging so that they probably did not have time to disperse. This left 57 recaptured fish with adequate information to be used in the analyses.

Although the total lengths of the spotted seatrout ranged from 115 to 450 mm, most (∼92.0%) of the fish tagged during February-April ranged from 210 to 310 mm and most (∼88%) of those tagged during September-November ranged from 280 to 400 mm (Fig. 5). Although fish tagged during fall were larger than fish tagged during spring, there appeared to be no relationship between the size of fish at tagging and the distance traveled (Fig. 4).

Most (82.1%) of the recaptured fish were returned within 1 yr after tagging; however, fish were recaptured through October 1979 (Table 3). The average number of days free was 230.

Minimum distances traveled by spotted seatrout ranged from 0 to 122 km with 42 fish (75.0%) recaptured within the Galveston Bay system (Table 3). The average distance traveled was 24 km.

Of the 57 recaptured fish, only one moved up the bayou (~3 km) away from Bastrop Bay rather than down the bayou (Table 3). Eleven fish (19.3%) were returned from the Gulf of Mexico—four from the High Island area in summers 1976 and 1977, four from the San Luis Pass area in summers 1976 and 1977, and three from the Freeport area in summers 1976 and 1978 and late spring 1978 (Fig. 1). The four returns from the High Island area were caught by one fisherman in the same locality. Two interbay returns (3.5%) included one from the mouth of the Colorado River and one from the south shoreline of East Matagorda Bay.

Of the 57 recaptured fish most (87.7%) moved ≤ 50 km (Table 2); 32.0% of these fish moved ≤ 5 km. More than half (54.6%) of the spotted seatrout moved ≥ 16 km.

Four spotted seatrout tagged during February-April were recaptured at the tagging site the following September-November and four fish tagged during September-November were recovered near the same tagging site the following March-May (Figs. 2 and 3). The fish tagged during September-November exhibited a progressive movement away from the tagging site while those tagged during February-April did not exhibit this progression. No tagged fish were returned during January-February.

The relationship between distance traveled by spotted seatrout from tagging site and time of year for fish tagged during September-November was expressed in the form:

$$Y = -1.2999 + 44.2564X$$

where Y = distance traveled (km) and $X = \left| \sin [(\text{Julian date})(0.986) + 91] \right|$. The correlation coefficient (r) was 0.440, which was significant (d.f. = 38, $p < 0.01$). The relationship between distance traveled by spotted seatrout from tagging site and time of year of their recapture fish tagged during February-April was expressed in the form:

$$Y = 8.4696 + 18.7495X$$

where Y = distance traveled (km) and $X = \left| \sin [(\text{Julian date})(0.986) - 73)] \right|$. The correlation coefficient (r) was 0.265, which was not significant (d.f. = 15, $p > 0.01$).

DISCUSSION

Moffett (1961) reported that most (95.3%) of the spotted seatrout tagged at Fort Meyers, Cedar Key and Appalachicola (Florida) traveled < 48 km. However, 32.7% of the fish tagged at Cedar Key traveled > 48 km while only 0.4-2.0% of the fish tagged at the other sites traveled > 48 km. Simmons and Breuer (unpublished data) reported that 5-6% of the spotted seatrout tagged during 1950-1970 in Galveston, Matagorda and Aransas Bays (Texas) moved > 32.2 km while a larger percentage of tagged spotted seatrout tagged in San Antonio Bay (16%), Corpus Christi Bay (13%), upper Laguna Madre (50%) and lower Laguna Madre (11%) moved > 32.2 km. Bryan (1971) reported that of the 63 returns from 1134 spotted seatrout tagged in the Arroyo Colorado (lower Laguna Madre) during March 1968-July 1969, 86% moved $\leq$ 14.8 km.

Part of Simmons and Breuer's data, Moffett's Cedar Key data and data from the present study support the hypothesis that spotted seatrout travel long distances. However, Simmons and Breuer's data in Galveston Bay and Bryan's data in the Arroyo Colorado indicated little movement. Such discrepancies may be due perhaps to differences in tagging procedures or differences in data analyses. For example, Simmons and Breuer used Monel jaw tags which are more easily lost from fish than abdominal anchor tags. Such tag loss could result in a shorter average distance traveled due to an apparent shorter average time free. In addition, neither Simmons and Breuer nor Bryan eliminated those fish caught within a short time after tagging. If Bryan had eliminated those fish caught within 30 days of tagging, then ∼ 22% of the spotted seatrout would have moved > 22 km and only ∼ 27% would have moved < 7 km.

Data from the present study indicate some movement from Bastrop Bayou to the shallow Gulf areas (particularly during summer) of spotted seatrout. Simmons (1951) noted the movement of spotted seatrout to and from the Gulf through Cedar Bayou, Texas. Simmons and Breuer (unpublished data) reported one tag return from the shallow Gulf off Port Aransas, Texas.

The reasons for such bay-to-Gulf movements are unclear. The fact that 10 of the 11 spotted seatrout returned from the Gulf during the present study were returned during summer (one during late spring) suggests that movement may be temperature induced. Mahood (1974) noted increased gill net catches of spotted seatrout along Georgia beaches during summer and suggested that some fish move from creeks, bayous and sounds to beaches during periods of warm water. In addition to the present study, other investigators both in Texas (Pearson 1929, Simmons 1951, Guest and Gunter 1958) and in Georgia (Mahood 1974) have noted movement of spotted seatrout from bayous to deeper waters of estuaries during periods of cold water. Salinity or salinity in combination with temperature might also affect spotted seatrout movement. Mahood also suggested that higher salinities off Georgia beaches during summer may attract spotted seatrout.

Worth noting is the fact that the four spotted seatrout recaptured in the surf off High Island were caught in one day by one fisherman in the same locality. Of these four fish one had been tagged on a different day from the rest. Therefore, it appears that spotted seatrout will stay together as they travel long distances. It is entirely possible that these fish were in one "school" and remained so while they were moving.

Although the September-November relationship between distance traveled and time was significant it only explained 19% of the variation. Therefore, it, as well as the non-significant February-April relationship, did not substantiate the seasonal movement of spotted seatrout to and from Bastrop Bayou. Circumstantial evidence, however, exists that indicates that the fish move out of the bayou in late fall, return in early spring, move out in late spring and return in early fall. For example, some spotted seatrout tagged during September-November were recaptured at the same tagging site (Bastrop Bayou) during March-April of the following year. Also, some fish tagged during February-April were recaptured at the same site during September-November. One fish tagged on 20 October 1976 was recaptured at the same site over 1 year later (27 October 1977). With few exceptions no recaptures occurred near the tagging site between late fall and early spring, although this may be a result of reduced fishing pressure. On the other hand, few recoveries of fish near the tagging site occurred during summer when fishing pressure was high (McEachron, personal communication).

It is also indicated that the majority of spotted seatrout do not leave the bays at all. For example 11 of 17 spotted seatrout tagged in the Arroyo Colorado and free for > 150 days were recaptured within 7 km of the tagging site (Bryan 1971). In the present study 75% of the recaptured fish were returned from the Galveston Bay system. More extensive tagging will be required to determine the extent spotted seatrout remain in a particular bay, move to and from adjacent bays, and move to and from Gulf of Mexico waters.

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Table 1. Number of spotted seatrout (Cynoscion nebulosus) tagged at Bastrop Bayou Marina on each day of tagging during 27 February 1976-19 April 1978.

Date	Total length range (mm)	Number tagged	Number returned	% returned
2-27-76	210-415	80	6	7.5
3-5-76	215-310	91	4	4.4
9-21-76	220-420	98	12	12.2
10-6-76	220-440	178	19	10.6
10-20-76	245-450	122	16	13.1
11-4-77	210-355	65	3	4.6
4-9-78	190-335	74	6	8.1
4-19-78	115-335	28	2	7.1
Total	115-450	736	68	9.2

Table 2 . Distance traveled (5-km increments) by spotted seatrout (*Cynoscion nebulosus*) tagged in Bastrop Bayou, Texas during 27 February 1976-19 April 1978.

Date tagged	Km traveled										
	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	≥51
2-27-76	0	0	0	3	0	0	1	1	1	0	0
3-5-76	2	0	0	0	0	0	0	1	0	0	0
9-21-76	6	1	2	1	1	0	0	0	0	0	0
10-6-76	3	0	0	2	1	0	1	1	0	0	3
10-20-76	4	1	2	3	1	0	2	0	0	0	3
11-4-76	0	0	1	0	0	0	1	0	0	0	0
4-9-78	3	0	0	1	0	0	1	0	0	0	1
4-19-78	0	0	1	1	0	0	0	0	0	0	0
Total No.	18	2	6	11	3	0	6	3	1	0	7
Total %	31.6	3.5	10.5	19.3	5.3	0.0	10.5	5.4	1.8	0.0	12.3

Table 3. Date tagged, date and location of return, days free and distance traveled (km) by spotted seatrout (<u>Cynoscion</u> <u>nebulosus</u>) tagged in Bastrop Bayou, Texas during 27 February-19 April 1978.

Date tagged	Date Returned	Location of return	Days free	km traveled
2-27-76	6-6-76	West Bay - N. Deer Island	100	44
2-27-76	6-22-76	S. W. West Bay	846	20
2-27-76	8-10-76	Surfside Fishing pier - Gulf	165	36
2-27-76	8-28-76	West Bay - San Luis Pass	183	17
2-27-76	8-10-76	San Luis Pass	165	17
2-27-76	12-18-76	West Bay Carancahua Reef	295	33
3-5-76	Unknown	Never turned in	ND	ND
3-5-76	10-5-76	Jack Booth's Marina	214	0
3-5-76	9-8-76	Jack Booth's Marina	187	0
3-5-76	5-8-77	West Bay - Green's Cut	429	39
9-21-76	9-26-76	Down the Bayou, 3/4 mile	5	1
9-21-76	10-7-76	Jack Booth's Marina	16	0
9-21-76	10-8-76	Jack Booth's Marina	17	0
9-21-76	10-10-76	Jack Booth's Marina	19	0
9-21-76	10-10-76	Down the Bayou, 3/4 mile	19	1
9-21-76	10-10-76	Jack Booth's Marina	19	0
9-21-76	10-15-76	Jack Booth's Marina	24	0
9-21-76	10-23-76	N. Shore of Bastrop Bay	32	11
9-21-76	10-23-76	GIWW and Bastrop Bay	32	9
9-21-76	5-13-77	Intersection of Cold Pass & Christmas Bay	234	14
9-21-76	7-25-77	Parker's Cut off Oyster Creel^{k} Near Freeport	307	25
9-21-76	11-17-77	Christmas Bay and Churchill Bayou Junction	422	16
10-6-76	10-11-76	Jack Booth's Marina	5	0
10-6-76	10-16-76	1 Mile from Jack Booth's Marina	10	2
10-6-76	10-16-76	100 yds. North of Bayou Bridge	10	1
10-6-76	10-19-76	Jack Booth's Marina	13	0
10-6-76	10-25-76	Jack Booth's Marina	19	0
10-6-76	11-3-76	Chocolate Bay - Marker 14	28	22
10-6-76	11-23-76	Green's Cut - West Bay	48	39
10-6-76	3-25-77	Jack Booth's Marina	170	0
10-6-76	5-28-78	N. Jetty - Freeport	599	32
10-6-76	6-10-77	Campbell Bayou - near Swan Lake	247	52
10-6-76	6-27-77	Colorado River, 3/4 mile from mouth	264	113
10-6-76	6-30-77	Cold Pass	267	17
10-6-76	8-2-77	Cold Pass	300	17
10-6-76	8-15-77	Black's Pier at High Island (5 mi. East of pier	313	100
10-6-76	8-26-77	Cox's Lake - Bastrop Bayou	324	5
10-6-76	10- ? -77	Hoskins Mound	ND	ND

Table 3. (Cont'd).

Date tagged	Date Returned	Location of return	Days free	km traveled
10-20-76	10-23-76	Mid-Bastrop Bay	3	11
10-20-76	10-23-76	Cox's Lake - Bastrop Bayou	3	5
10-20-76	10-25-76	Jack Booth's Marina	5	0
10-20-76	11-4-76	Wharton Camp Reef - Chocolate Bay	15	19
10-20-76	11-6-76	Bastrop Buoy #3[3]	17	9
10-20-76	12-16-76	West of Carancahua Cut - West Bay	57	33
10-20-76	3-25-77	Jack Booth's Marina	156	0
10-20-76	3-28-77	Jack Booth's Marina	159	0
10-20-76	5-28-77	Jack Booth's Marina	220	0
10-20-76	6-12-77	Texaco Oil Cut - Bastrop Bay	235	12
10-20-76	7-8-77	San Luis Pass Pier	261	19
10-20-76	7-19-77	3 miles from San Luis pass in Surf - Freeport side	272	25
10-20-76	8-15-77	Black's Pier at High Island (5 mi. East of pier)	299	100
10-20-76	8-15-77	Black's Pier at High Island (5 mi. East of pier)	299	100
10-20-76	8-15-77	Black's Pier at High Island (5 mi. East of pier)	299	100
10-20-76	9-18-77	West Bay - Carancahua Reef	333	33
10-20-76	10-27-77	Jack Booth's Marina	372	0
10-20-76	6-12-78	Cold Pass off San Luis Pass	600	17
10-20-76	7-16-78	Christmas Bay	634	14
11-4-77	11-9-77	1/2 mi. down Bayou from marina	5	1
11-4-77	10-11-78	Bastrop Bay	341	11
11-4-77	12-1-78	Marker 45 (Old ICWW) in West Bay	392	33
4-9-78	5-22-78	Austin & Bastrop Bayou Intersection	43	3
4-9-78	6-22-78	Tire Reef - West Bay	74	20
4-9-78	7-16-78	North Jetty - Freeport	98	32
4-9-78	10-26-78	Jack Booth's Marina	200	0
4-9-78	11-23-78	Bastrop Bayou	228	1
4-9-78	10-23-79	South shoreline - East Matagorda Bay	562	75
4-19-78	7-24-78	Nick's Cut & GIWW	96	17
4-19-78	10-6-79	North side Bastrop Bay	535	11

ND = No data

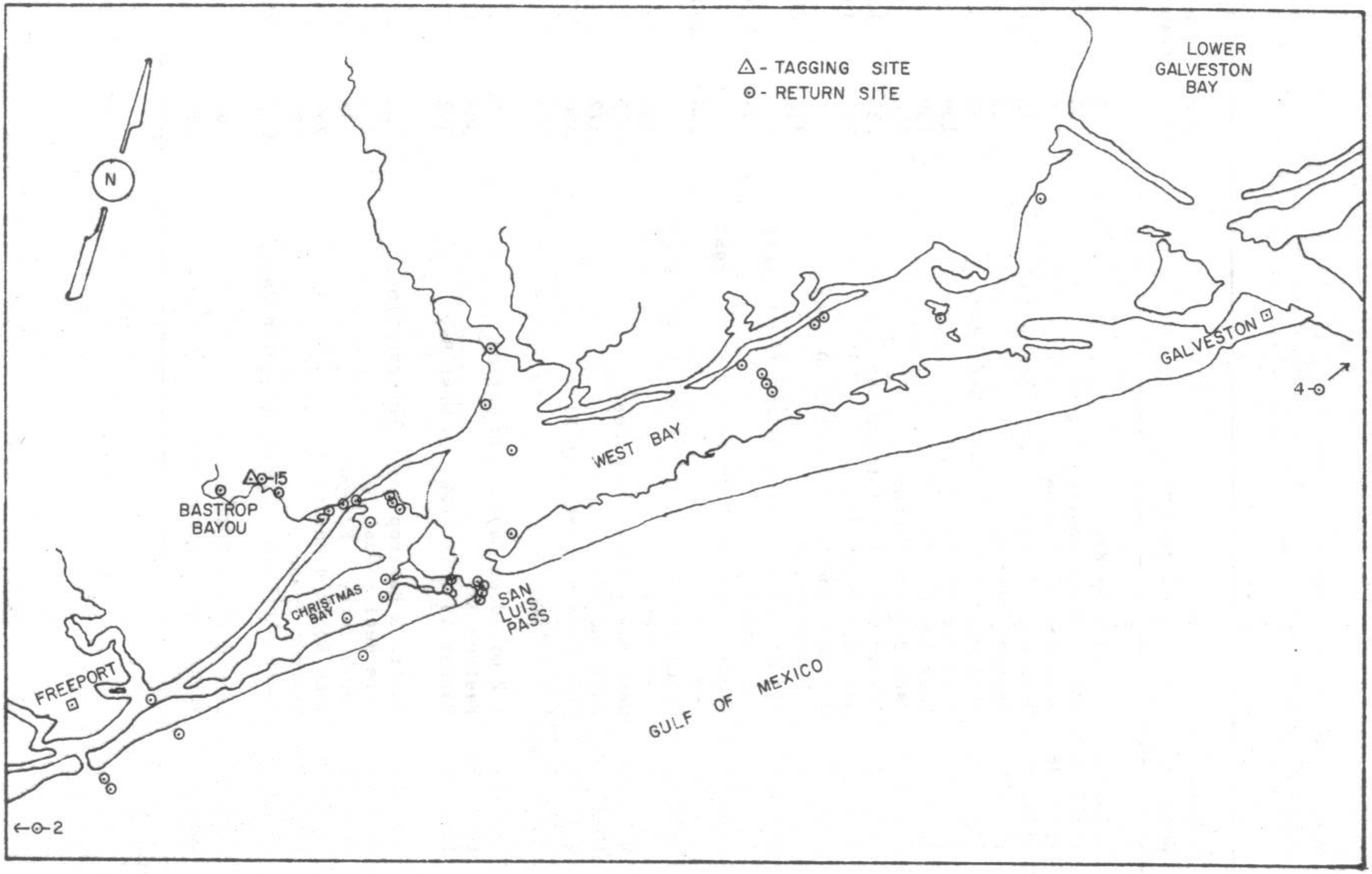

Figure 1. Recapture sites of spotted seatrout (Cynoscion nebulosus) tagged in Bastrop Bayou, Texas (Feb. 1976-Apr. 1978).

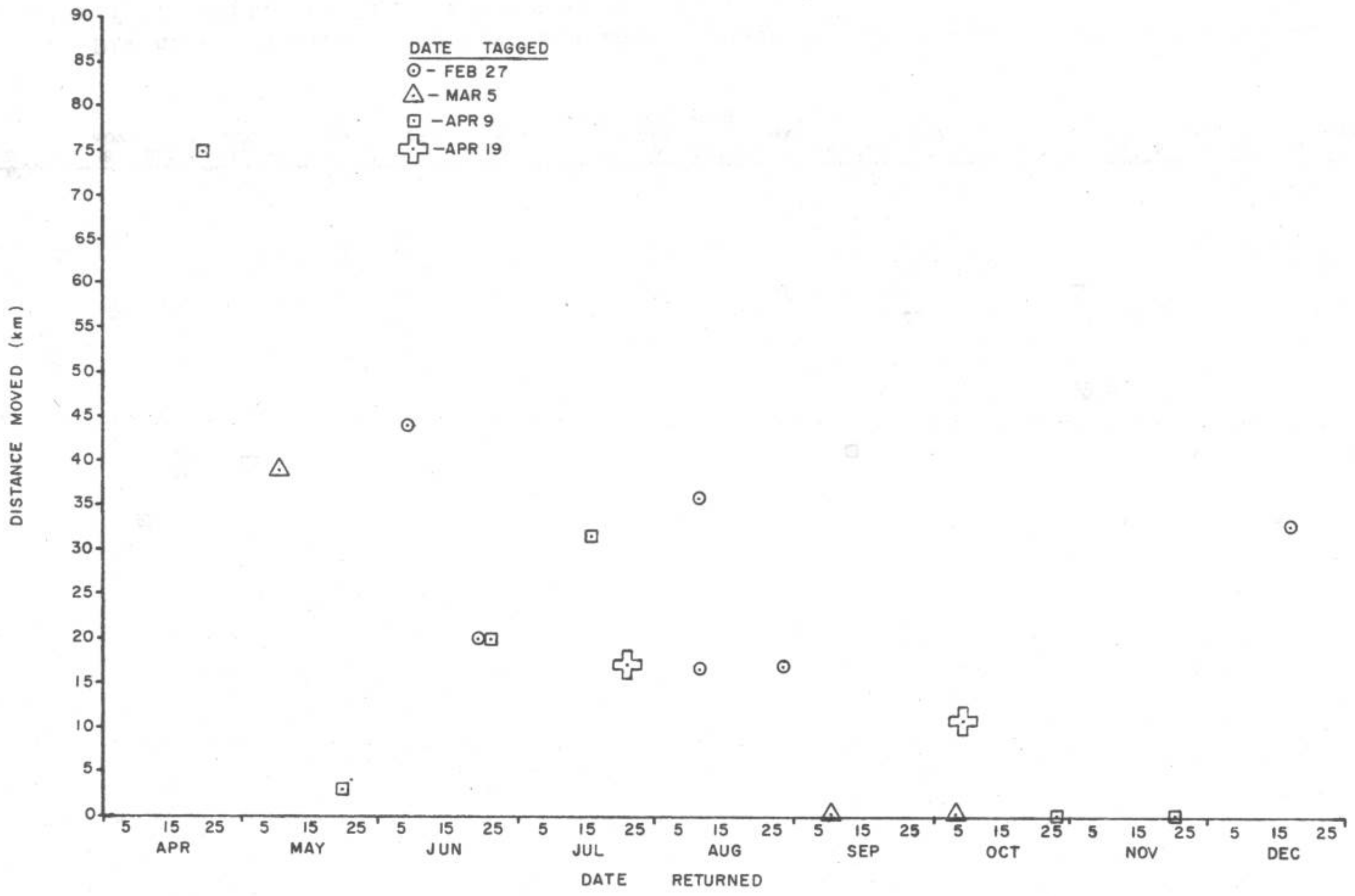

Figure 2. Distance traveled by spotted seatrout (Cynoscion nebulosus) tagged in Bastrop Bayou, Texas during spring (Feb.-Mar. 1976 and Apr. 1978).

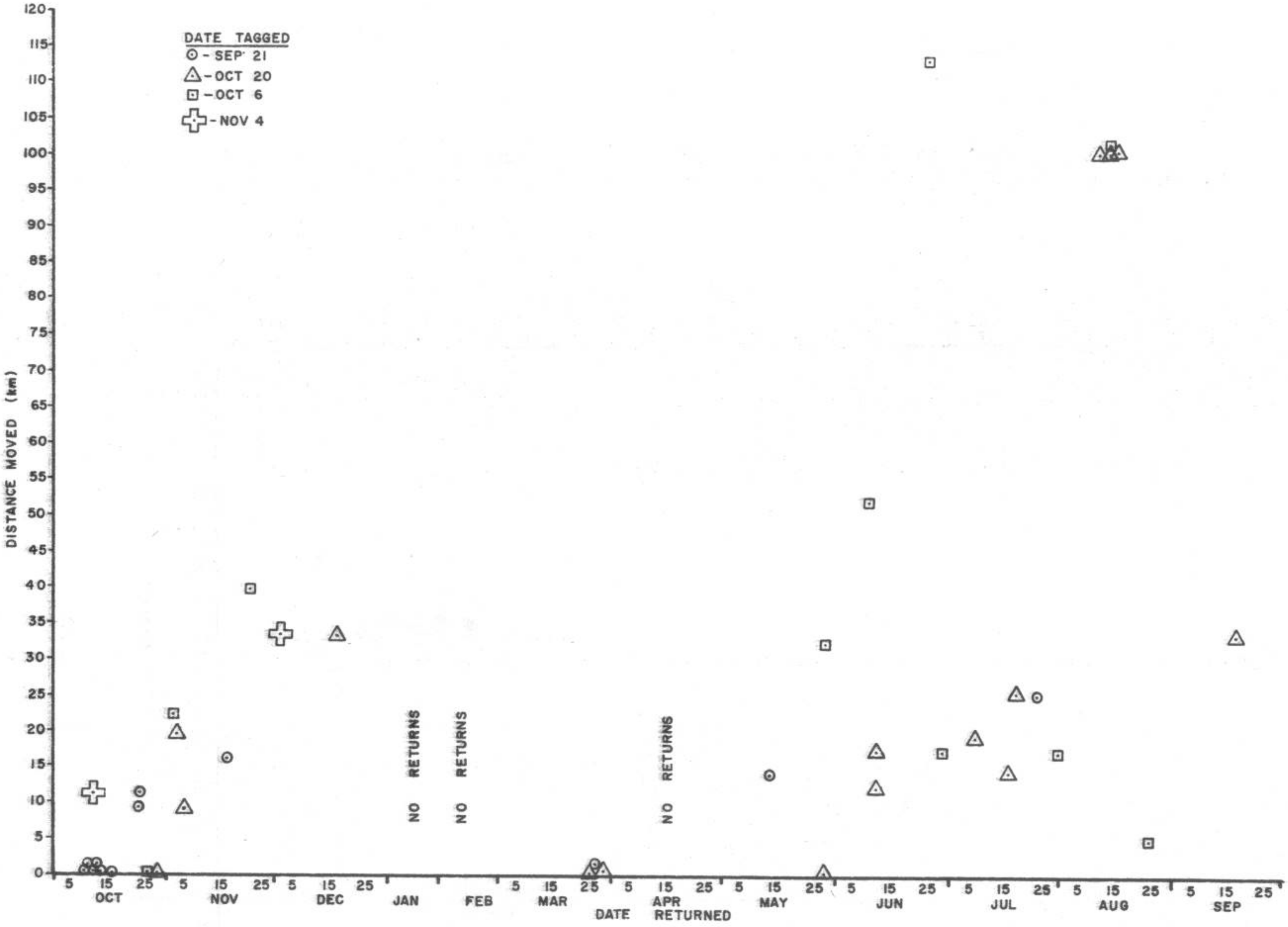

Figure 3. Distance traveled by spotted seatrout (<u>Cynoscion nebulosus</u>) tagged in Bastrop Bayou, Texas during fall (Sept.-Oct. 1976 and November 1977).

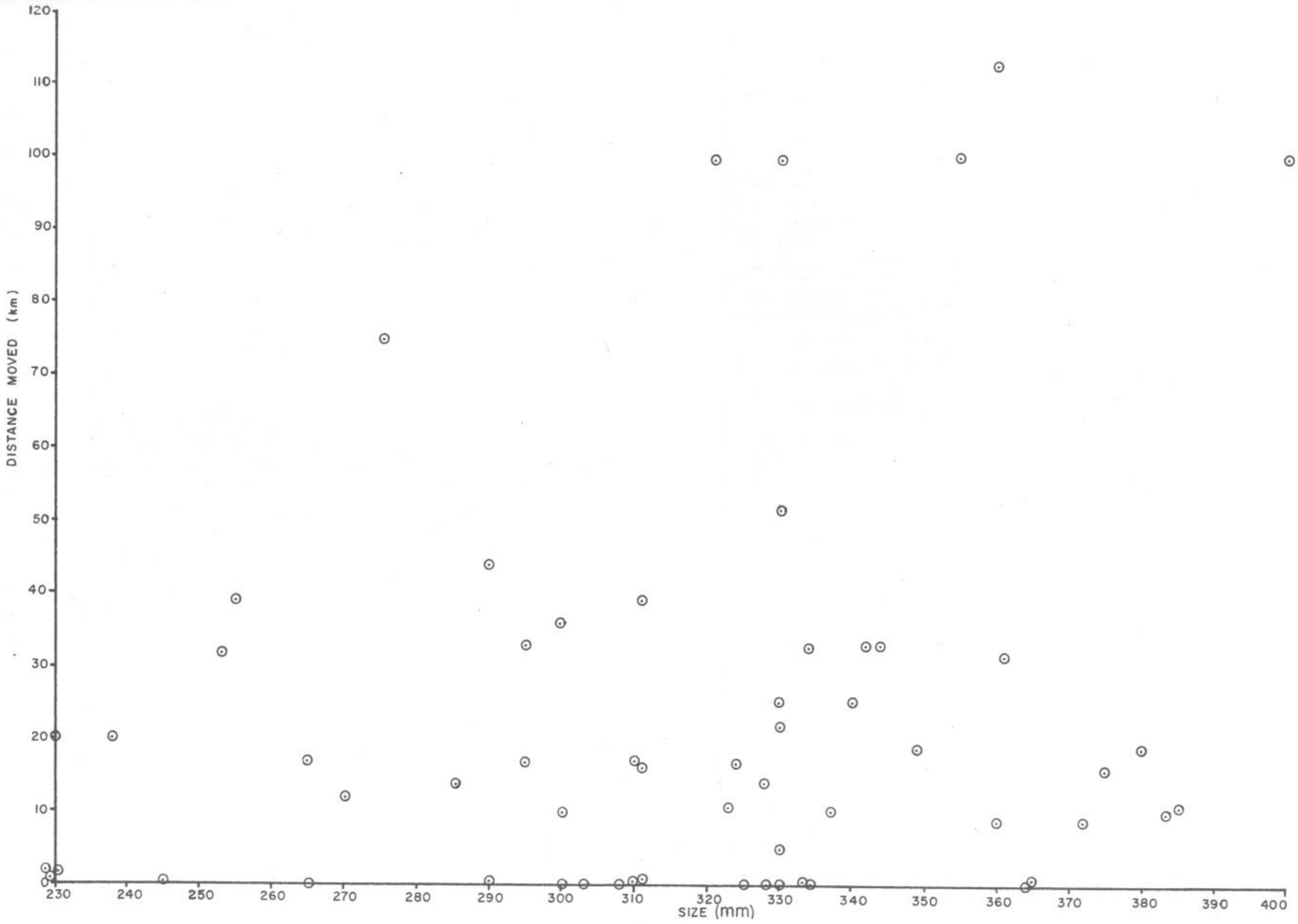

Figure 4. Distance traveled (km) vs. size of spotted seatrout (Cynoscion nebulosus) tagged in Bastrop Bayou, Texas during 1976-1978.

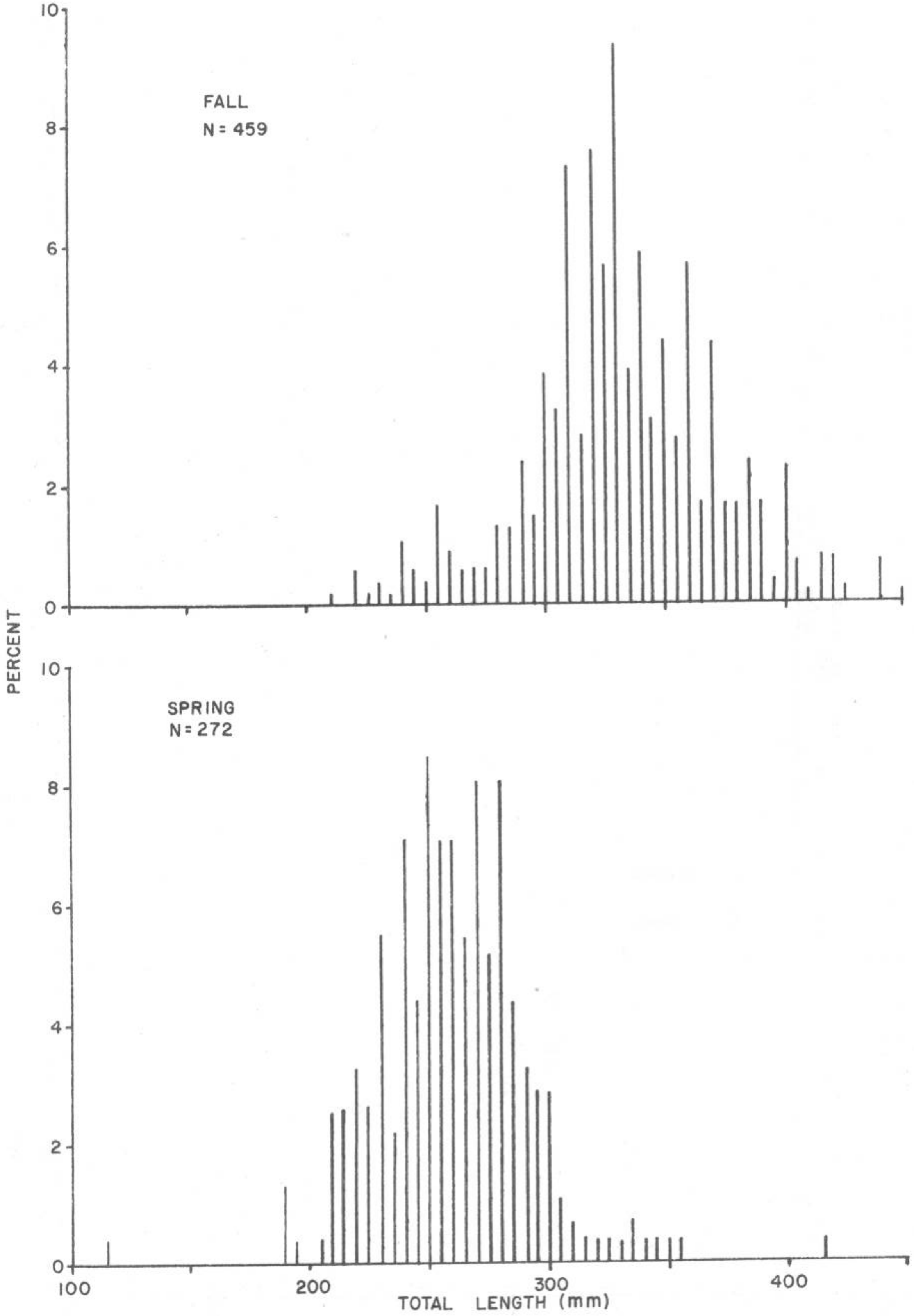

Figure 5. Length frequency of spotted seatrout (Cynoscion nebulosus) tagged in Bastrop Bayou, Texas during fall (Sept.-Oct. 1976 and Nov. 1977) and spring (Feb.-Mar. 1976 and Apr. 1978).

Variation in First Year Growth of Largemouth Bass in a North Texas Farm Pond

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ABSTRACT

Young-of-the-year bass were sampled in a north Texas farm pond over five successive years. Samples taken in the fall showed strongly bimodal length-frequency distributions accentuated by an abundance of bass less than 150 mm. Most spring samples showed a single mode of bass greater than 200 mm and few if any bass less than 150 mm. It was postulated that abundance of forage was the major cause of the bimodal fall samples and that predation was the major factor in the low over-winter survival of bass less than 150 mm producing a single mode in the spring samples.

INTRODUCTION

Many studies have shown highly variable growth rates of largemouth bass (Micropterus salmoides) and have attributed these variations to numerous factors, most of which impinge on availability and abundance of prey. Growth rates of young-of-the-year bass have been reported in Texas for large bodies of water by Carlander (1977) and Prentice and Durocher (1978) as well as for small bodies of water by Bivings et al. (1978), Prentice and Whiteside (1974), and others. Additionally, Shelton et al. (1979) discussed factors influencing growth of young-of-the-year bass in an expanding population which resulted in a bimodal length-frequency distribution of that year class. Bivings (1976) reported low over-winter survivorship of young-of-the-year bass which he postulated was due to heavy predation. This paper reports data on growth rate and length-frequency distribution of young-of-the-year bass in a stable farm pond which was sampled over several years.

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METHODS

This study was conducted on a 15-hectare pond located on a private farm approximately 6 km southeast of Grand Saline, Van Zandt County, Texas. The pond received runoff from fertilized pastures and filled to maximum and mean depths of 7 and 3 m, respectively. A fish survey in 1975 indicated a diverse forage community including six species of minnows, seven species of sunfishes, and established populations of both threadfin shad (Dorosoma petenense) and gizzard shad (D. cepedianum) (Bivings 1976).

Samples of each new year class of young-of-the-year bass from 1975-1979 were collected in both the late fall and early spring of the following year when possible. Samples were taken by both electrofishing and hook-and-line. Total length to the nearest 1 mm and weight to the nearest 1 g were recorded for each fish. Scales were taken for age determination from each fish from below the lateral line near the tip of the pectoral fin. Examination of magnified scale impressions made in cellulose acetate was used as a check for assignment of fish to proper year classes utilizing accepted criteria for annulus identification as described by Bivings (1976). Mean total first year lengths and 95% confidence intervals were computed for each year class. Differences between mean total first year lengths of year classes were tested using analysis of variance and Tukey's multiple range test (Steel and Torrie 1960).

RESULTS

A total of 239 young-of-the-year largemouth bass representing five year classes from 1975-1979 was collected during this study. Estimates of mean first year total lengths ranged from 184 mm in 1979 to 216 mm in 1977 (Table 1). Mean first year total lengths in both 1978 and 1979 were significantly lower than in 1977. No other significant differences between mean first year total lengths for other years were observed. Confidence intervals were calculated for the estimates of mean total first year lengths to illustrate the range in which the means might be expected to vary (Table 1).

Most fall electrofishing samples of the year classes exhibited strongly bimodal length-frequency distributions (Fig. 1). Samples from the 1975 and 1976 were dominated by bass less than 100 mm with few fish greater than 150 mm. The 1978 and 1979 samples were dominated by bass in the range from 100-150 mm. The 1977 sample was the only fall sample in which bass greater than 150 mm were dominant.

Most spring electrofishing samples of the previous year class exhibited length-frequency distributions with a single mode (Fig. 2). Bass less than 150 mm were rare in the 1975, 1977, and 1979 samples and were absent in the 1976 sample. No bass were observed in any spring sample which were less than 100 mm. The 1978 sample was the only spring sample dominated by bass in the 100-200 mm range.

DISCUSSION

Much of the variation in mean first year total length can be accounted for by the changing abundance of bass less than 150 mm between the fall and spring samples. While these bass were relatively abundant in most fall samples, they were nearly absent from most spring samples. Although the reasons for this phenomenon are not clear, the slower growing bass appeared to have a dramatically lower over-winter survivorship than the bass greater than 150 mm. Since the water was clear and adult bass were abundant, it is likely that predation was a major factor. However, it is not clear why this was not as strong a factor for the 1978 year class. This is possibly due to buffering by increased abundance of other forage species but no data are available to support this hypothesis. The low relative frequency of bass less than 150 mm in the fall sample of the 1977 year class is probably due to excellent growth. Casual observations over the growing season indicated that large schools of small shad were common and that the bass were voraciously feeding on them. The net effect of low over-winter survival of bass less than 150 mm is to increase the estimated first year total length, when at least part of the sampling is done in the spring, over estimates taken exclusively from fall samples. This would be especially true when comparing estimates back-calculated from scales with estimates from fall samples.

The bimodal distribution of young-of-the-year bass in the fall samples was similar to the distribution reported by Shelton et al. (1979). These results support their hypothesis that the abundance of forage was the major factor in the formation of a bimodal year class. This bimodal tendency was least pronounced in 1977 when forage was very abundant which produced a strong year class of fast growing bass. The bimodal distribution was most apparent in the 1978 sample. However, this was the only sample which was taken in August and thus, my not have been representative.

Several genetic factors may also have contributed to the maintenance of bimodal distributions in the fall samples. There are genetic differences in the population due to the Florida strain bass that were stocked as fingerlings in the fall of 1975. Casual observation of lateral line scale counts indicated that these bass first spawned in 1977 and that both the 1978 and 1979 year classes had approximately 5% Florida and 10% hybrid bass. Since Inman et al. (1977) reported significantly slower first year growth by Florida bass than by either native or hybrid bass, the Florida bass would be expected to make a greater contribution to the slower growing group. Additionally, the strong selective pressure of low survival of slower growing bass may have reinforced genetic differences by selecting for fast growing genetic characteristics, i.e. overwinter losses may have been mostly fish of the Florida strain.

In conclusion, it appeared that in spite of apparent overwinter mortality, the bass population was surviving and growth satisfactory. A high percentage of bass was exceeding 200 mm total length during the first growing season. While few of these fish were being harvested, they were large enough to be caught on hook-and-line, which was desirable since the primary use of the lake was sport fishing. Fishing for bass of this size and larger was reported to be excellent and the land owners indicated continual successful fishing trips.

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Table 1. Mean total length and 95% confidence interval of young-of-the-year largemouth bass from Grand Saline, Texas, 1975-1979.

Year class	N	Mean total length	[Confidence interval]
1979	53	184	[169, 199]
1978	42	188	[172, 204]
1977	93	216	[205, 226]
1976	27	203	[188, 218]
1975	24	214	[198, 231]

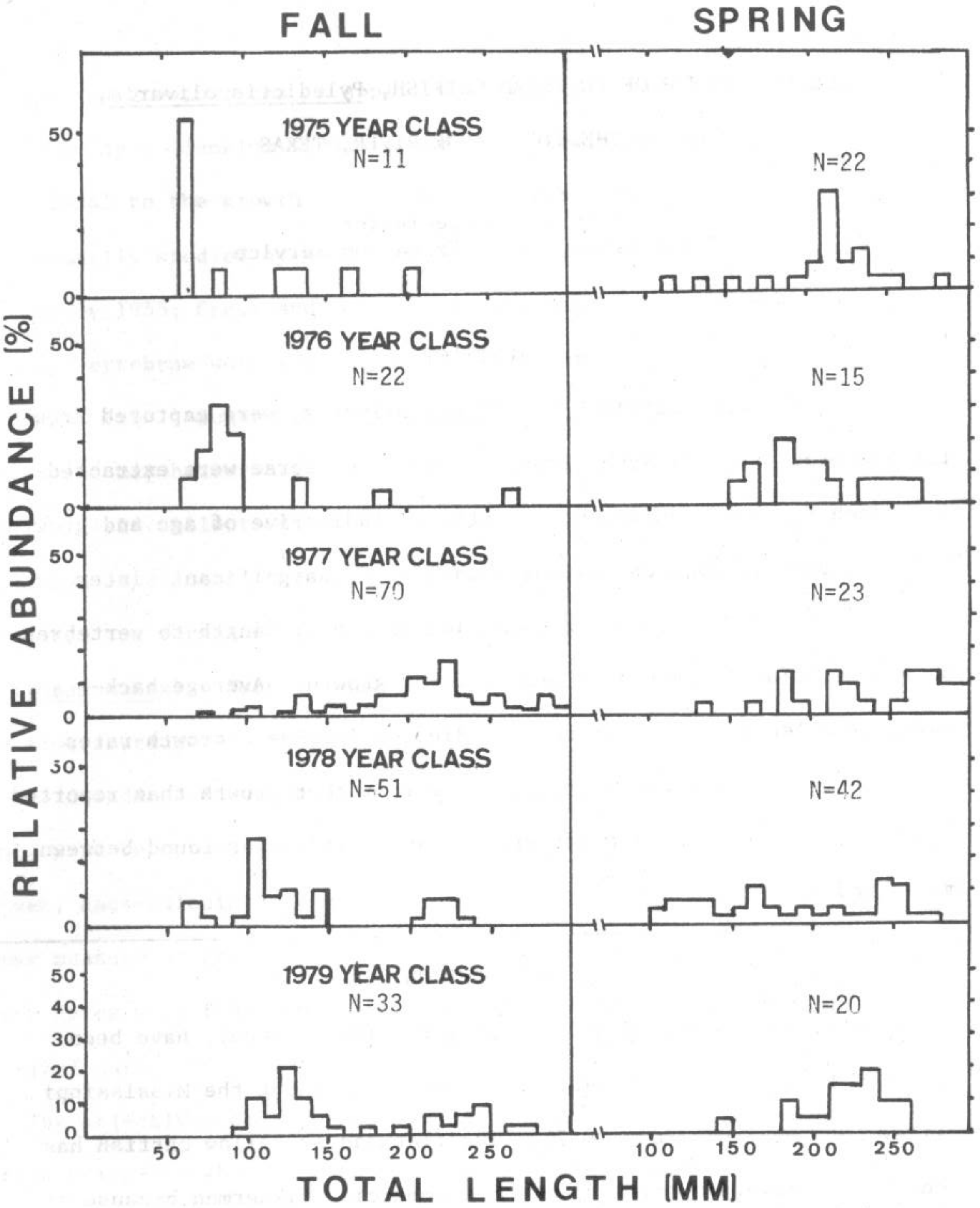

Figure 1. Length-frequency distribution (10 mm groups) by year class of young-of-the-year largemouth bass collected in the fall and yearlings collected the following spring from Grand Saline, Texas.

AGE AND GROWTH OF FLATHEAD CATFISH, Pylodictis olivaris, IN THE RIO GRANDE RIVER, TEXAS

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ABSTRACT

Forty flathead catfish, Pylodictis olivaris, were captured from the Rio Grande River, Webb County, Texas. Vertebrae were extracted from each fish and evaluated for patterns indicative of age and growth. Multiple observations of vertebrae indicated insignificant winter mark variance within fish. Formulation of a body length to vertebrae radius relationship revealed proportional growth. Average back-calculated lengths from vertebrae indicated increased growth rates after the second year of life resulting in higher growth than reported elsewhere. No significant difference in condition was found between males and females.

INTRODUCTION

Flathead catfish, Pylodictis olivaris (Rafinesque), have been reported from large North American rivers throughout the Mississippi valley into Mexico (Eddy 1957). The flathead or yellow catfish has long been a favorite among sport and commercial fishermen because of its ability to attain large sizes and its desirable taste. However, the flathead has not been studied as thoroughly as most of the other principal sportfish.

Age and growth studies of flathead catfish have been conducted throughout the midwest and south. The use of hard parts to determine fish age and growth rates is applicable when working with populations of unknown age. Jenkins (1954) found that growth of the hard parts was proportional to the growth of fish. Age determinations of flatheads have been primarily studied by dorsal or pectoral spine sectioning (Jenkins 1954; McCoy 1955; Greer and Cross 1956; and Minckley and Deacon 1959). However, vertebrae were rarely used for age determination.

Sneed (1961) suggested that measurements from vertebrae are more regular and may better correlate body length than is the case with spines. However, field collections of vertebrae are less practical than the collection of spines. Forney (1955) compared the use of opercles, vertebrae, and dorsal spines in determining the age of black bullhead (Ictalurus melas). Forney found a somewhat consistent arrangement of size distributions within year classes suggesting that centrum markings are valid indices in age determination of bullhead catfish. False annuli were reportedly more frequent on vertebrae than on spines; however, back-calculated lengths from vertebral measurements offered a better measure of growth history than did spine measurements. Calculated growth rates were found to be more uniform and in better agreement with empirical data.

The objectives of this study were to determine the ages of flathead catfish using vertebrae and to evaluate the use of back-calculation techniques in determination of annual growth rates. A length-weight relationship was also developed between consecutive samples to compare differences in condition between years.

MATERIALS AND METHODS

Twenty-four flathead catfish were captured from the Rio Grande in Webb County Texas, in March 1979. An additional 16 fish were collected from approximately the same location in March 1980. Common throw lines, approximately 3.5 to 4.0 in length were baited with live green sunfish (Lepomis cyanellus), black bullhead (Ictalurus melas) or carp (Cyprinis carpio). Number eight hooks were used on each line with two hooks per line. Lines were deployed for three consecutive days and checked in the morning and evening of each day. Bait which was absent or dead upon each check was immediately replaced with live fish. All captured flatheads were placed into holding baskets and transferred to a small irrigation tank approximately 0.5 km from the river.

All flatheads were removed for processing following the third day of collection. Total length (mm), weight (kg), sex and state of maturity, and stomach contents were obtained from each fish. Vertebrae were obtained by dorsal sectioning and subsequent removal of the sixth through ninth trunk vertebrae. Vertebrae were placed into labelled containers and allowed to dry for 2 weeks.

Vertebrae were separated and cleaned to allow full vision of the posterior end of the centrum. A binocular dissecting microscope aided by relected light was used to determine annual marks following the criteria of Lewis (1949) and Marzolf (1955). A minimum of two vertebrae per fish were separately examined. An additional observation was conducted if the first two differed in the number of annuli present.

An ocular micrometer inserted into one eyepiece was used to measure the distance from the focus to the edge of each annual mark along a dorsal radius across the vertebrae. This distance represented the growth of the fish through consecutive years. All measurements were to the nearest 0.1 mm. Total vertebra radius, measured from the focus to the anterior edge, was taken to develop a body length to vertebra radius relationship. Focus to annulus measurements were used to back-calculate individual growth at the end of each growing season following the procedure of Everhart, et al. (1975).

A length-weight relationship was developed for 23 flatheads for the March 1979 sample and for 16 flatheads in the March 1980 sample following Ott (1977). Length-weight relationships were developed for males and females and compared following the analysis of covariance procedure (Ott 1977).

RESULTS AND DISCUSSION

All 40 fish had vertebrae which were readable. Winter marks on the vertebrae were in the form of dark, heavy translucent bands of crowded circuli, whereas summer growth was represented by broad, white opaque bands. Most vertebrae had accessory marks which were usually faint and easily distinguishable. The first annual mark was located near the center of the centrum and was the most difficult to discern. The second annual mark lay relatively close to the first indicating slow growth during the first two years. The age of the fish was assigned by the number of winter marks located on the vertebra. Multiple observations of vertebrae from each fish indicated little variance in the number of winter marks.

After the second reading, 75% of the aged vertebrae were in agreement with the first reading. A subsequent third observation of the remaining six vertebrae showed two in agreement with the first reading and four with the second. There was some degree of overlap in length ranges between age groups from the first sample (Figure 1). A considerably greater overlap of age classes occurred in the second sample; however, most age groups compared favorably between samples. McCoy (1955) reported overlap between age groups particularly in ages XI and older, however, my data contained overlap in ages V, VI, VII and VIII.

A body length to vertebra radius relationship was calculated by linear regression to determine if body length was directly proportional to vertebral growth. Appleget and Smith (1951) suggested that ossification of the vertebrae may not take place until the fish grew to approximately 15 mm. The body length to vertebra radius relationship from my data can be expressed by: $\text{VERT(RAD)} = -1.5285 + 0.0132\ \text{BODY LEN}$ ($r = 0.958$). Since the intercept of -1.5285 mm would be negligible in the back-calculation of annual growth, back-calculation of annual growth was determined by direct proportion:

$$\text{LEN X} = \frac{\text{LEN(vert rad) to annulus X}}{\text{LEN(total vertebra radius)}}\ \text{(LEN(cap))},$$

where LEN X is length of the fish at the end of a growing season and LEN(cap) is the length at the time of capture.

Average back-calculated lengths to each year of life show that during the third year, flathead growth rate (Table 1) tended to increase. Data sets were combined and calculated on a weighted sample basis between year classes to show average growth over time. One flathead was omitted from back-calculation because of difficulty in obtaining an accurate reading. Figure 2 shows comparative growth curves calculated from empirical and back-calculated data. Jenkins (1954) found that age groups grew at a fairly uniform rate throughout the first 8 years of life in Oklahoma lakes. Flathead catfish, ages IV through VII, displayed a decreased rate of growth from 21 Oklahoma lakes (McCoy 1955).

Linear regression analysis of length-weight relationships was performed for males and females of the 1979 sample and examined by analysis of covariance. The 1980 sample revealed that 80% of the fish were males. No significant difference ($p<0.01$) was found in the condition between sexes. Although not significant, females were 2.3% heavier at any given length than males. The development of gonads and small sample sizes are probably responsible for the slight difference.

A length-weight relationship was developed for the thirty-nine flatheads. This relationship is best described by:

$$\mathrm{LOG_e WT} = -13.4034 + 3.3187\mathrm{LOG_e LEN} \quad (r = 0.990)$$

Length-weight comparisons between the 1979 and 1980 samples indicated no significant differences in condition between years.

CONCLUSION

The use of vertebrae in age determination and back-calculation of annual growth of flathead catfish appears to be fairly accurate upon comparison with the literature. Although field extraction of vertebrae is somewhat difficult, they may be used in conjunction with dorsal or pectoral spines for age confirmation. Laboratory preparation of vertebrae and low powered magnification make age determination and annuli measurements simple.

Growth rates for flathead catfish in south Texas appear to be quite comparable to other studies for the first two years, however, the substantial increase in growth rate during the third year far exceeds data from the literature. Differences in growth curves from empirical and back-calculated data suggest several hypotheses. First, flatheads, by time of capture, had grown substantially since the time of laying down the preceeding winter annulus. Second, fish from recent year classes are exhibiting increased growth rates over previous year classes. Because no fish younger than age IV were collected, growth rates from early year classes could only be obtained by the back-calculation method. Growth rates of initial year classes which were back-calculated from older fish indicate that Lee's phenomenon may be occurring, i.e., slow growing fish live longer, therefore, the older fish sampled probably had lower annual growth rates.

The higher number of age VI fish from the 1979 sample should have been well represented as age VII in the 1980 sample. However, few were collected in that year class suggesting that age VI fish may be more vulnerable to capture by this sampling technique.

ACKNOWLEDGEMENTS

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Table 1. Average total lengths (weighted) at capture and back-calculated lengths to the end of each year of life for thirty-nine flathead catfish, Rio Grande River, Webb County, Texas.

Year Class	No.	$\overline{\text{TL}}$(cap)	Range(mm)	Avg. $\overline{\text{TL}}$ (mm) at end of year of life								
				I	II	III	IV	V	VI	VII	VIII	IX
1975	7	482.1	410-580	68.3	134.7	219.6	342.0	521.4				
1974	13	624.2	490-710	63.3	123.8	239.1	373.6	489.2	629.8			
1973	13	670.7	560-785	70.5	128.8	256.7	397.7	513.0	610.1	670.3		
1972	4	815.0	730-925	55.3	110.7	201.5	281.9	420.9	538.3	648.4	687.9	
1971	2	942.5	860-1025	48.6	120.6	241.9	348.8	479.8	581.6	699.0	826.0	913.9
Average				61.2	123.7	231.8	350.2	484.9	590.0	672.6	756.6	913.9
Increment				61.2	62.5	108.1	118.4	134.7	105.1	82.6	84.0	157.3

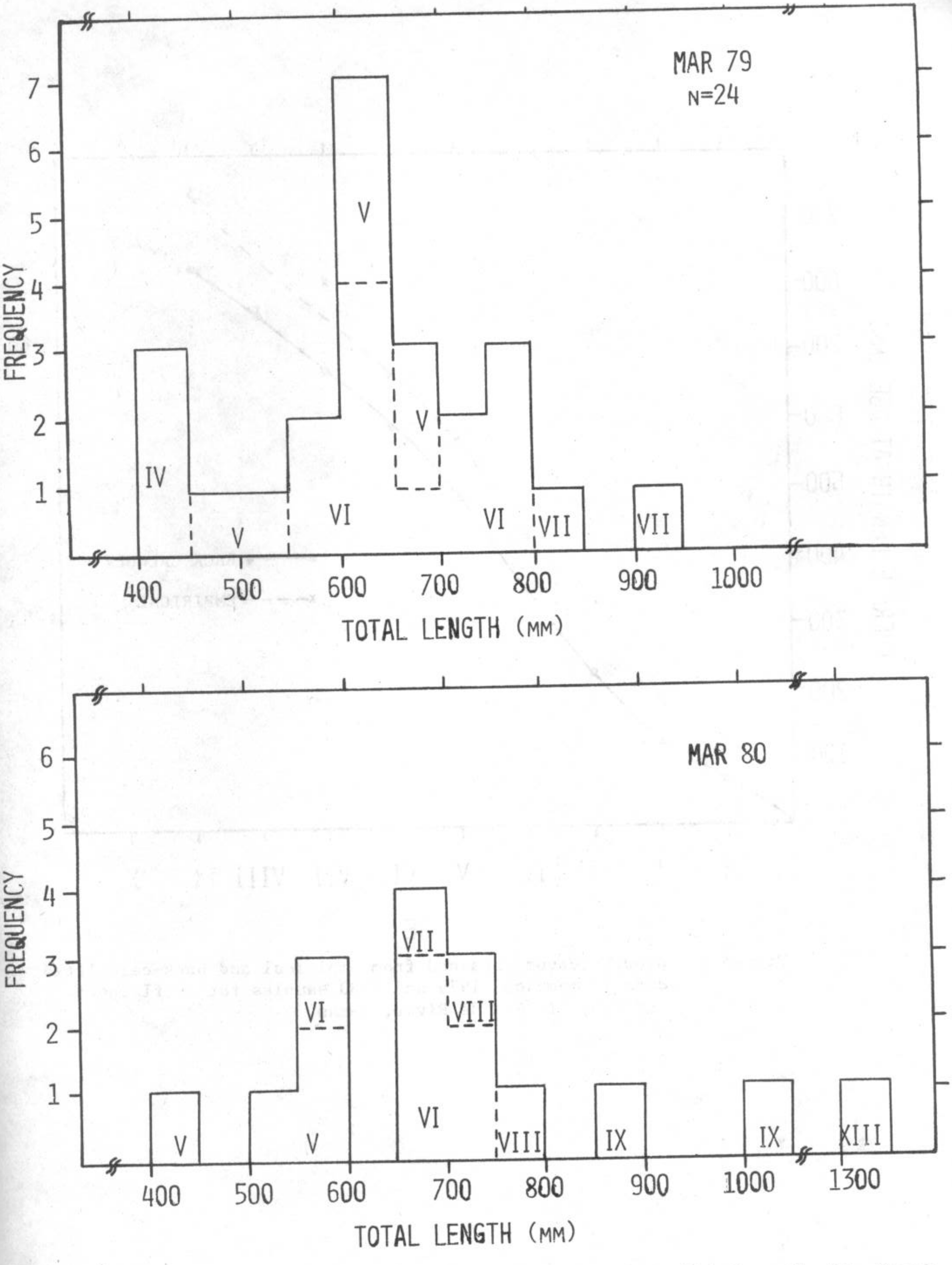

Figure 1. Length-frequency histograms of flathead catfish from the Rio Grande River, Texas. Ages are shown for each fish in the histogram.

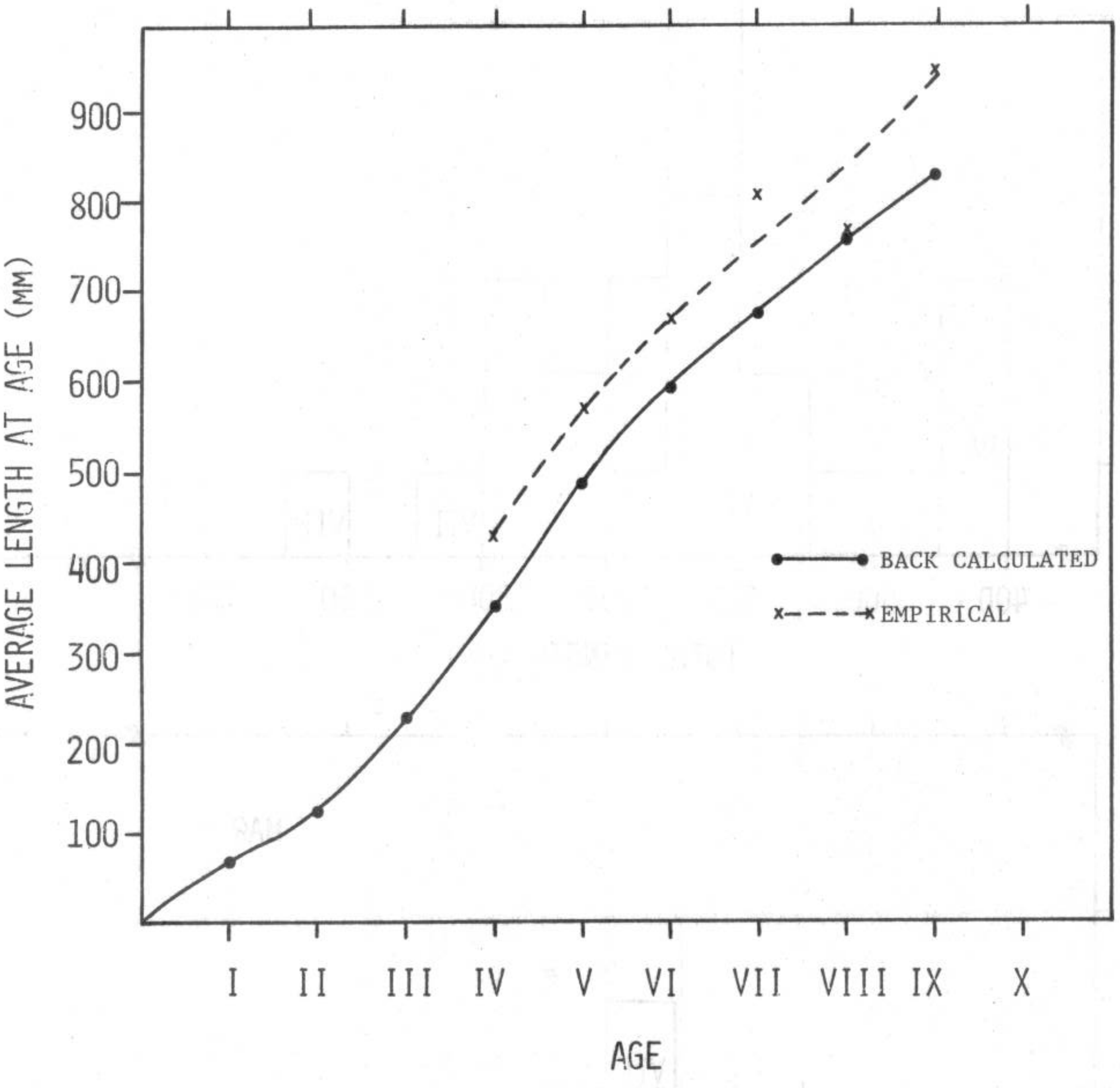

Figure 2. Growth curves obtained from empirical and back-calculated data in combined 1979 and 1980 samples for 39 flathead catfish, Rio Grande River, Texas.