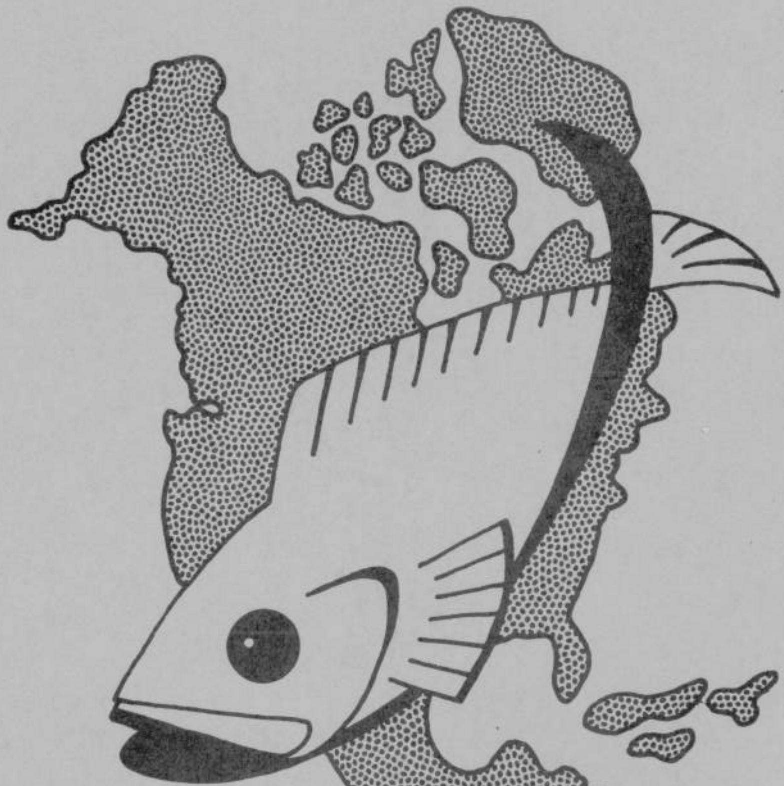
ANNUAL PROCEEDINGS of the TEXAS CHAPTER AMERICAN FISHERIES SOCIETY



SEPTEMBER 29, 1979
COLLEGE STATION, TEXAS

VOLUME 2

KURZAWSKI

ANNUAL PROCEEDINGS
OF THE
TEXAS CHAPTER

September 29, 1979
College Station, Texas

OFFICERS

Dr. Bobby Gene Whitesides, President
Southwest Texas State University

Dr. Rich L. Noble, President-Elect
Texas A & M University

Allen Forshage, Secretary-Elect
Texas Parks and Wildlife Department

Edited by Dr. James T. Davis
Printed at Texas A & M University
College Station, Texas
1980

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LIST OF AMERICAN FISHERIES SOCIETY ATTENDEES

TEXAS CHAPTER, 1979

Andreasen, James K.
U.S. Fish and Wildlife Service
P.O. Box 2087
Victoria, Texas 77901

Arzapalo, Anne Henderson
Texas A&M University
College Station, Texas 77843

Bailey, Madeline
Star Rt. 1 Box 257

Bamberg, Roy
Texas Parks and Wildlife Department
609 Glenhaven
Abilene, Texas

Bivings, Bert
Texas A&M University
Department of Wildlife & Fisheries
College Station, Texas 77843

Bounds, Robert L.
Texas Parks and Wildlife Department
201 Oak Ridge
San Marcos, Texas 78666

Brenner, Blair
Texas A&M University
Department of Wildlife & Fisheries
College Station, Texas 77843

Brick, Robert W.
Texas A&M University
1415 Angelina
College Station, Texas 77801

Broussard, Meryl Jr.
Texas A&M University
Department of Wildlife & Fisheries
College Station, Texas 77843

Campbell, David L.
Texas Parks and Wildlife Department
Rt. 11 Box 311
Tyler, Texas 75709

Campbell, Mike
Texas A&M University
1501 Hwy 30 Apt. 541
College Station, Texas 77840

Carter, Nick
Texas Parks and Wildlife Department
P.O. Box 18662
Austin, Texas 78760

Chandler, Charlie R.
1217 Calhou
Panama City, Florida

Cichra, Charles E.
Texas A&M University
821 Enfield
Bryan, Texas 77801

Cichra
Houston Independent School District
821 Enfield
Bryan, Texas 77801

Davis, James T.
Texas A&M University
202 Nagle Hall
College Station, Texas 77843

Davis, Joe Bill
Southwest Texas State University
Aquatic Station
San Marcos, Texas 78666

Dunn, Linda
Texas A&M University
2213 - 16th Ave. N.
Texas City, Texas

Durocher, Philip P.
Texas Parks and Wildlife Department
13010 Shawnee Drive
Manchaca, Texas 78652

Edwards, Deborah C.
Department of Human Resources
2104 San Gabriel
Austin, Texas

Edwards, Robert J.
University of Texas at Austin
Department of Zoology
Austin, Texas

Farquhar, Bobby
Texas Parks and Wildlife Department
4928 Mobile
Ft. Worth, Texas 76111

Forshage, Allen A.
Texas Parks and Wildlife Department
Rt. 10 Box 532
Tyler, Texas 75707

Gatlin, Del
Texas A&M University
243 Dunn Hall
College Station, Texas 77843

Ceoghegan, Paul
Texas A&M University
303-A Boyett St.
College Station, Texas 77843

Gilliland, Gene
Oklahoma Coop. Fishery Research Unit
Stillwater, Oklahoma

Green, Albert W.
Texas Parks and Wildlife Department
2309 Davis Lane
Austin, Texas 78745

Grobe, Randy
Texas A&M University
204-B 2nd Street
College Station, Texas 77843

Guest, Clell
Texas Parks and Wildlife Department
Junction Star Route, Box 62
Ingram, Texas 78025

Guillen, Chatta A.
Texas A&M University at Galveston
106 Mechanic #89
Galveston, Texas 77550

Guillen, George
Texas A&M University at Galveston
106 Mechanic #89
Galveston, Texas 77550

Hall, Carlton, R.
7448 Aberdeen
Fort Worth, Texas 76116

Hambric, Bob
Professional Lake Service
9129 Chatwood Drive
Houston, Texas 77078

Hart, Janice Lynn
Southwest Texas State University
1725 Toomey #307
Austin, Texas 78704

Harvey, Bill
Texas A&M University
1702 Dillon
Bryan, Texas 77801

Hegen, Ed
Texas Parks and Wildlife Service
P.O. Box 1211
Rockport, Texas 78382

Hurd, Sylvia L.
Southwest Texas State University
Aquatic Station
San Marcos, Texas 78666

Inman, Charles R.
Texas Parks and Wildlife Department
2205 Suanne Drive
Tyler, Texas 75701

Klussmann, Wallace G.
Texas A&M University
210 Nagle Hall
College Station, Texas 77843

Johansen, Pat
Texas Parks and Wildlife Department
P.O. Box 552
Rockport, Texas 78383

Landry, Andre M.
Texas A&M University
Department of Marine Biology
1304 Red Bud Lane
LaMarque, Texas

Lock, Joe
Texas A&M University
Box 38
Overton, Texas 75684

Luebke, Dick
Texas Parks and Wildlife Department
Junction Star Route Box 62
Ingram, Texas 78025

Lundbert, Brad
Texas A&M University
301 Ball Street #1100
College Station, Texas 77843

Manns, Ralph
Southwest Texas State University
169 W. Rt. 1
San Marcos, Texas 78666

Matlock, Gary
Texas Parks and Wildlife Department
Rt. 2 Box 300
Austin, Texas

Means, John K.
Texas Parks and Wildlife Department
3323 Brooks Lane
Tyler, Texas 75701

Mulford, Charles J.
Texas Parks and Wildlife Department
6200 Hatchery Road
Fort Worth, Texas 76114

Murphy, Michael D.
Texas A&M University
303A Boyett Street
College Station, Texas 77843

McEachran, John D.
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

McGeachin, Robert B.
Texas A&M University
407 Walton Drive
College Station, Texas 77840

McIntyre, Sherwood
Stephen F. Austin State University
2419 Pearl Street
Nacogdoches, Texas 75961

Nawrocki, Sandra
Texas Electric Service Company
P.O. Box 970
Fort Worth, Texas 76101

Neill, William H.
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

Noble, Richard
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

Osborn, Maury
Texas Parks and Wildlife Department
2221 S. Lakeshore Blvd. #109
Austin, Texas 78744

Osbourn, Hal
Texas Parks and Wildlife Department
Box 1707
Rockport, Texas

Pate, Martin W.
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

Pavela, John S.
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

Phillips, Travis R.
U.S. Fish and Wildlife Service
Rt. 1 Box 159D
San Marcos, Texas 78666

Powell, Gary
Texas Department of Water Resources
2611 Barton Hills Drive
Austin, Texas 78704

Rainwater, Fred L.
Stephen F. Austin State University
Box 13003
Nacogdoches, Texas 75961

Reddell, A.
Texas A&M University
College Station, Texas 77843

Reed, Bobby C.
Stephen F. Austin State University
Box 5817
Nacogdoches, Texas 75961

Rockett, Mark
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

Rutledge, William P.
Texas Parks and Wildlife Department
2604 Harleyhill
Austin, Texas 78745

Sanders, Richard M.
Texas A&M University at Galveston
6713 E. 5th Circle
Panama City, Florida

Seidensticker, Paul
Texas Parks and Wildlife Department
638 E. Crockett
Jasper, Texas 75951

Shlossman, Philip A.
Texas A&M University
309 Ball Street
College Station, Texas 77843

Shult, Milo J.
Texas Agricultural Extension Serv.
110 Nagle Hall
College Station, Texas 77843

Simmons, Ernest G.
Texas Parks and Wildlife Department
3902 Glasgow
Austin, Texas 78749

Smith, Steve
Texas Parks and Wildlife Department
2122 Old Henderson Highway
Tyler, Texas 75702

Spinelli, Tony
Southwest Texas State University
Apt. H-4 Linda La Apt.
San Marcos, Texas 78666

Steinbach, Don
Texas Agricultural Extension Serv.
1504 Foxfire
College Station, Texas 77843

Stickney, Robert T.
Texas A&M University
1812 Hondo
College Station, Texas 77843

Strawn, Kirk
Texas A&M University
Department of Wildlife and Fisheries
College Station, Texas 77843

Valentine, Gary
Soil Conservation Service
209 Timberline Road
Temple, Texas 76501

Wekenthin, Fred Jr.
Southwest Texas State University
Aquatic Station
San Marcos, Texas 78666

Whiteside, Bobby G.
Southwest Texas State University
Aquatic Station
San Marcos, Texas 78666

Williamson, Julien Holt
U.S. Fish and Wildlife Service
1109 Porter
San Marcos, Texas 78666

PROGRAM

Saturday Morning	September 29, 1979
8:00-8:30	Registration - Rudder Tower, Floor 7
8:30-8:45	Welcome Charles Cichra, President Texas A & M Chapter Wallace G. Klussmann, Head Department of Wildlife and Fisheries Texas A & M University Perry L. Adkisson, Vice President for Agriculture and Renewable Natural Resources, Texas A & M University
8:45-9:30	Business Meeting
9:30-10:15	<u>Session I</u>
9:30-9:45	H.R. Osburn, G.C. Matlock, and H.E. Hegen, Texas Parks and Wildlife Department "Description of a Multiple Census Tagging Program for Marine Fisheries Management"
9:45-10:00	A.W. Green, G.C. Matlock, and J.E. Weaver, Texas Parks and Wildlife Department "Effect of Fish Size on Recovery of Tagged Fishes in Areas Treated with Rotenone"
10:00-10:15	R.R. Stickney, S. Wernsing, J.H. Williamson, D.B. Redner, and R.B. McGeachin Texas A & M University "Recovery and Population Dynamics of Benthic Infauna Associated with Intertidal Dredge Material"
10:15-10:30	Coffee Break
10:30-10:45	<u>Session II</u>
10:30-10:45	D.L. Campbell Texas Parks and Wildlife Department "Hybrid Striped Bass Feeding Study"
10:45-11:00	C.J. Mulford Texas Parks and Wildlife Department "Location and Description of Striped Bass Spawning Grounds, Brazos River, Texas"

11:00-11:15	S.F. Smith Texas Parks and Wildlife Department "Pre-impoundment Management of Lake Fork Reservoir"
11:15-11:30	C.E. Cichra Texas A & M University "Factors Affecting Stunting of White Crappie in Flood Prevention Lakes"
11:30-11:45	C. Guest Texas Parks and Wildlife Department "Preliminary Results of Florida and Northern Largemouth Bass Temperature Tolerance Tests"
11:45-1:30	Lunch Break
1:30-3:00	<u>Session III</u>
1:30-1:45	C.R. Chandler and R.M. Sanders Texas A & M University "Use of midwater Artificial Reefs as a Fisheries Management Tool"
1:45-2:00	E.F. Klima National Marine Fisheries Service "Shrimp Research in the Gulf of Mexico"
2:00-2:15	M. Shult Texas A & M University "Fisheries Program of the Texas Agriculture Extension Service"
2:15-2:30	R.J. Edwards University of Texas at Austin "Fish Community Structure and Ecological Diversity in Edwards Plateau Streams"
2:30-2:45	P.S. Crandall and P.P. Durocher Texas Parks and Wildlife Department "Comparison of Growth Rates, Sex Ratios, Reproductive Success and Catchability of Three Sunfish Hybrids"
2:45-3:00	Break
3:00-5:00	Open Discussion Period

1979 OUTSTANDING FISHERY WORKER AWARDS

Fisheries Management

Gary Valentine
U.S. Soil Conservation Service
Temple, Texas

The award was given to Gary Valentine by the Texas Chapter of the American Fishery Society during its annual meeting in College Station.

As a biologist, Valentine is responsible for helping the Soil Conservation Service field personnel give technical assistance to landowners and operators in wildlife and fishery management in privately-owned land.

Outstanding Achievement

Charles Inman
Tyler, Texas

Fisheries Research

Phil Durocher
Austin, Texas

Two employees of the Texas Parks and Wildlife Department's Fisheries Division have received awards from the Texas Chapter of the American Fisheries Society.

Biologist Charles Inman of Tyler received an "Outstanding Fisheries Worker for 1979" award in the field of management in recognition of his 25 years of work in such projects as pond management, fish parasites and diseases, Florida largemouth bass research and management and protection of the public waters of the state.

Phil Durocher of Austin received a similar award in the field of research for his role in development of date processing systems for use in analyzing data from creel surveys, scale analysis for fish growth, hatchery operations, bass tournament reports and a variety of other inland fisheries projects.

Fisheries Education

Richard L. Noble, Ph.D.
Texas A&M University
College Station, Texas

Fish Culture

Robert R. Stickney, Ph.D.
Texas A&M University
College Station, Texas

Drs. Richard L. Noble and Robert R. Stickney of Texas A&M's Department of Wildlife and Fisheries Sciences have been named "Texas' Outstanding Fishery Workers" by membership of the Texas Chapter of the American Fisheries Society.

Noble was honored for his efforts in teaching and research programs in the field of fisheries management. Noble has authored over 20 publications, including a contribution to the International Encyclopedia of Higher Education and a chapter on management of lakes and ponds in the new textbook, "Fisheries Management."

Stickney was recognized for his contributions in the area of fish culture, a career he began in 1970 at Georgia's Skidaway Institute of Oceanography and continued upon his arrival at Texas A&M University in 1975. His research has focused on culture of catfish and tilapia, fish nutrition, recycling of poultry and swine waste through fish ponds, and polyculture of fish and shrimp. He is the author of some 70 scientific and popular articles.

DESCRIPTION OF A MULTIPLE CENSUS TAGGING PROGRAM FOR MARINE FISHERIES MANAGEMENT

By

Hal R. Osburn, Gary C. Matlock and H. E. Hegen
Texas Parks and Wildlife Department
Rockport, Texas 78382

ABSTRACT

A multiple census tagging program is being conducted on the Texas coast utilizing internal abdominal anchor tags. Features of this study include a simultaneous standardized random sampling scheme in eight bay systems and rewards for tag returns. Comparable data are obtained between bay systems for deriving estimates of fish growth, movement, fishing mortality and population size. Eleven major assumptions are attendant to the analyses of these data.

INTRODUCTION

Fish tagging has been utilized to derive information on growth, movement, mortality and population size. Growth data are necessary in fisheries management to predict fish size and to detect differences in the stability of populations. Movement data (immigration, emigration, distance) are required to determine at which geographic level management regulations should be imposed. Controlled allocation of the resource among fishing interests is dependent upon accurate mortality estimates. Abundance estimates are used to estimate exploitation and recruitment of a fish stock and to evaluate the effects of management regulations (Lackey and Hubert 1977).

Extensive fish tagging in Texas coastal waters began in 1950. During the following two decades over 76,000 fish (principally black drum, Pogonias cromis, spotted seatrout, Cynoscion nebulosus and red drum, Sciaenops ocellata) were tagged and released (Simmons and Breuer, unpublished data). Insights into the life histories of tagged fish were gained, but specific conclusions on population dynamics were seldom quantified. In addition, the assumptions of the tagging programs were not clearly defined (Schultz 1962). Comparable sets of data between bay systems as well as detailed statistical analyses of the data sets were lacking. Research was also not conducted to determine tag reporting rates and tag shedding rates.

The multiple census approach to fish tagging is employed by Texas Parks and Wildlife Department (TPWD) personnel primarily because it can be done during a coastwide finfish monitoring program conducted on a monthly basis. The purpose of this paper is to describe this multiple census tagging program and to explain how estimates of growth, movement, mortality and population size for selected estuarine fishes (principally red drum and black drum) may be calculated from the tagging data. In addition, it is the intent of this paper to qualify the attendant assumptions of the TPWD tagging program and to discuss the validity and/or violations of each assumption.

Acknowledgement is due Pat Johansen for her review of this manuscript and to all members of the finfish and creel projects for their efforts in collecting these data.

Between November 1975 and September 1978, 13,167 fish of recreational and commercial value were tagged by TPWD personnel (Table 1). During this same period 1386 tags were returned to TPWD (Table 2). The numbered internal abdominal anchor tags were made of semi-hard glossy blue or 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 plastic hollow tubing (about 50 mm long; O. D. = 2.1 mm; I. D. = 1.0 mm). "TEXAS PWD, ROCKPORT" or "TEXAS PWD, SEABROOK" was printed on each tag (Matlock and Weaver 1979). The numbered portion of the tag was inserted in an incision in the fish's abdomen using the technique described by Moffett (1961).

Fish for tagging were captured at gill net and trammel net stations selected randomly each month in the Galveston, East Matagorda, Matagorda, San Antonio, Aransas, Corpus Christi, upper Laguna Madre and lower Laguna Madre Bay systems (Figure 1). Monofilament gill nets of 7.6-, 10.2-, 12.7- and 15.2-cm stretched mesh and multifilament trammel nets of 7.6-cm stretched mesh in the inner wall were used. Tagging materials and methods were standardized between every bay system. Only apparently healthy fish were tagged and released at the site of capture; released fish were measured to the nearest 1 mm (total length) and weighed when possible to the nearest 5 g. Tagged fish captured in TPWD sampling were retained for the tag return information.

Mean size (mm TL 1SE) of red drum and black drum tagged during the first three years of the program were 439 ± 11 mm and 373 ± 12 mm, respectively (Osburn and Hammerschmidt, unpublished data). Gear types used did not effectively sample red drum less than about 335 mm or black drum less than about 250 mm (Matlock et al. 1978).

The tagging program was publicized on radio and television stations in cities adjacent to each bay system as well as in newspapers and the Texas Parks and Wildlife Magazine throughout Texas. In addition, posters were placed at commercial fish houses, fish camps, fishing piers and sporting goods stores. Each individual returning a tag was requested to provide the total length, weight, date and location of catch and whether the individual was a sport or commercial fisherman. A monetary reward was paid by the

National Marine Fisheries Service or the Gulf Coast Conservation Association regardless of the amount of information returned with the tag. For every 100 tags released there were two $25 rewards, five $10 rewards, five $5 rewards and eighty-eight $1 rewards randomly preselected before tagging (Matlock and Weaver 1979).

ASSUMPTIONS

The accuracy of growth, movement, mortality and population size estimates are dependent on the attendant assumptions. The major assumptions applicable to the TPWD tagging program and data analyses include: 1) valid return data; 2) no behavioral differences between tagged and untagged fish; 3) equal fishing pressure and/or success in all areas where the target species may move; 4) random sampling effort or distribution of tags; 5) no tag shedding, handling mortality or natural mortality of the tagged population; 6) no recruitment; 7) all tagged fish are available for recapture the same length of time; i.e., instantaneous tagging; 8) no immigration or emigration; 9) known tag reporting rates of fishermen (this assumption is not necessary to calculate total mortality using the procedures of Brownie et al. 1978); 10) no differential catch rates between tagged and untagged fish and 11) minimal variances of the estimates; i.e., adequate tag return sample size.

GROWTH

Growth, as a change in total length between release and recapture, is obtainable for non-approximated return lengths. Growth rates are calculated as the change in total length divided by the number of days free (for non-approximated return dates). Summing the appropriate growth rates and dividing by the total number of growth rates summed provides mean total length growth rates for each fishing interest (sport, commercial, TPWD, other) in every bay system. Analysis of variance techniques (Freund 1962, Draper and Smith 1966, Sokal and Rohlf 1969) can be used for comparisons of mean growth rates in different bay systems and for data obtained from different fishing interests.

The influence of water temperature and fish size at tagging on length growth rates can be investigated using multiple regression analysis techniques (Draper and Smith 1966). Total days free for each return can be broken into cold-water periods (December-February) and warm-water periods (March-November). Since weight data are more sensitive to such factors as environment, sex and the measurement instrument used by fishing interests (Matlock and Weaver 1979), accurate growth rates in weight may not be obtainable.

The growth data analyses assume 1) that the return information from all fishermen is valid and 2) that there are no behavioral differences between tagged and untagged fish. Substantial violation of either assumption would have an unpredictable influence on growth calculations.

A telephone survey conducted during November 1978-January 1979 determined that 96 out of 100 sport fishermen measured the total length of their returned fish and 89 out of 100 used some sort of graduated measuring device. Similar data is not available for commercial fishermen although the accuracy of their return lengths may be judged by a comparison of fish mean growth rates measured by commercial fishermen with those measured by sport fishermen and TPWD. Annual means, however, may mask differences in seasons free and sizes of returned fish of the various fishing interests.

Tag retention and mortality studies for up to 424 days by Elam (1971) indicated that the 6-mm slit in the fish's abdomen did not cause substantial violation of the second assumption.

MOVEMENT

The minimum distance traveled by each returned fish is obtainable by measuring the shortest aquatic distance (to the nearest km) between the release and recapture sites. During the first 3 yrs of the project, fishermen generally cited specific landmarks when reporting recapture locations indicating an accuracy on the order of ± 2 km. Movement between bay systems can be quantified by grouping the returned fish according to whether they are recaptured in the same or a different bay system as that of initial release. The relative movement of a species can be determined for each bay system by grouping the distance traveled by each fish into 5 km increments from the site of tagging. Fish movement between bay systems is comparable for both of the above tabulations by using a test of independence (Sokal and Rohlf 1969). The influence of the time of year and fish size on movement can be detected from plots of the number of km traveled vs. the date of recapture and the number of km traveled vs. the size at recapture, respectively.

Assumptions requisite to the movement data analyses include those associated with growth as well as the assumption that there is approximately equal fishing pressure and/or success in all areas where the target species may have moved, including bays, rivers and Gulf. Gross violations of any of these assumptions could make conclusions drawn from the movement data tenuous. Other factors being equal, a propotionally higher number of tags will be returned from areas with greater or more successful fishing pressure.

Creel survey studies (Heffernan et al. 1976, Breuer et al. 1977) have shown that successful, although not necessarily equal, fishing pressure has been distributed throughout all bay systems on the Texas coast. Fishing pressure in coastal rivers and the Gulf of Mexico is unknown although creel survey programs are being expanded to include a number of Gulf sites.

MORTALITY

Fishing mortalities during a selected tagging period are obtainable for every fishing interest in each bay system for the target species according to the empirical formulae:

$$\text{Fishing mortality} = \frac{\text{Number of tagged fish reported}}{\text{Number of tagged fish available x Reporting rate}}$$

$$\text{where Reporting rate} = \frac{\text{Number of recaptured tagged fish reported}}{\text{Number of tagged fish recaptured}}$$

Survivorship and recovery rate (recapture rate x reporting rate where recapture rate equals number of tags recaptured/number of tags available) estimates from one tagging period to the next can be obtained using a procedure and written computer programs developed by Brownie et al. (1978) based on the principle of Maximum Likelihood (Matlock and Weaver 1979). These estimations are made using tag returns in the release year and each year thereafter. A survivorship estimate yields total mortality of the target species from which the number of tagged fish available may be calculated for use in the fishing mortality equation. A number of computer models are listed by Brownie et al. (1978) based on assumptions concerning the constancy of recovery and survival rates with approximate confidence intervals and goodness-of-fit tests for each model.

A mean fishing mortality for the designated tagging periods is estimated by summing the calculated fishing mortalities and dividing by the number of tagging periods in the year. Multiplying this mean value by the number of tagging periods in the year provides an annual fishing mortality estimate. Comparable fishing mortality estimates are thus obtainable for each tagging year of the study.

If either the first, second or fourth assumptions are violated, the fishing mortality estimates would be biased unpredictably. Underestimates of fishing mortality would occur if the assumptions concerning tag loss and tagged fish mortality, recruitment, instantaneous tagging or immigration to the target population are violated. Overestimates of fishing mortality would result if emigration occurs, if reporting rates are underestimated or if the catch rate of tagged fish is greater than that of untagged fish. Fishing mortality estimates have less precise confidence intervals as the sample size is reduced.

The first two assumptions have been partially addressed under GROWTH. Replication and expansion of both of the cited studies to include all fishing interests and target species would be desirable.

Since fish for tagging are obtained from and released at randomly selected sites throughout each bay system it is reasonable to assume that random mixing of tagged and untagged fish occurs, relative to each species' population structure (Ricker 1975). This satisfies the fourth assumption.

Further work is needed to confirm the fifth assumption for all target species; however, Elam (1971) reported a mean tagging mortality of only 6.8% for tagged red drum held in 0.4- and 1.5-ha ponds for 35-424 days. Natural mortality (2-6%) of tagged fish held < 200 days did not differ substantially from that of control fish (0-5%). Internal abdominal tag retention for both red drum and black drum was 87%. Although differences may exist between fish held in ponds and fish in the natural environment, the calculated tag shedding rate (13%) can be used to adjust the number of tagged fish available for a closer approximation of fishing mortality.

In Texas, adult red drum (generally > 750 mm) spawn in late summer and early fall (Pearson 1928). The young fish reach ~ 325 mm at the end of 1 yr (Simmons and Breuer 1962). Black drum spawning occurs from February through April; young fish reach ~ 210-250 mm in 1.5 yr (Simmons and Breuer 1962). Each tagging year of the present study begins in late fall and extends through early fall; red drum and black drum spawned just prior to or during the tagging year do not reach the taggable size range until near completion of the tagging year so that the sixth assumption is satisfied. Requisite to the above conclusions is that the project encompasses "normal" years of red drum and black drum spawnings and growth.

Since Maximum Likelihood estimates assume instantaneous tagging, the multiple release procedures of the present study will introduce a bias into the fishing mortality calculations. Grouping the tag release data into two or three month periods may reduce this bias while still satisfying the sample size requirements. Future tagging efforts should concentrate on releasing greater numbers of tagged fish over shorter periods of time.

Red drum and black drum tagged in Florida exhibited little movement, the majority ($>$ 85%) of the recaptured fish traveling $<$ 9.3 km from the tagging site (Beaumariage 1969). Returned data from the present study also indicates no substantial emigration or immigration of these species for the size tagged. Generalizations regarding fish movement could be verified using sonic tags. Such short term tracking could detect diel and climate induced movement patterns.

Reporting rates of recaptured tagged fish for each fishing interest may vary considerably over the study period. Rawstron (1971) estimated that 36-69% of the tagged fish caught by anglers at Folsum Lake, California were not reported. A study on the Texas coast during a portion of the present tagging program indicated that approximately 30% of the sport fishermen returned recaptured tags (Matlock, unpublished data). The determination of this estimate involved interviewing anglers at boat ramps and implanting tags in their uncleaned fish without their knowledge. Similar attempts to obtain estimates of reporting rates for commercial fishermen have yielded little data as yet. A range of possible reporting rates may be determined, however, and used to calculate a range of fishing mortalities for any fishing interest (Matlock and Weaver 1979).

Differential catch rates between tagged and untagged fish are not suspected since the only external feature of the tag is a thin smooth plastic tube.

Neither the number of taggable fish available from a maximum TPWD sampling effort under a finfish monitoring scheme nor the expected return rate of tags was known prior to the present study. The projected sample size required to minimize variance of the estimates is limited by these restrictions. From the data collected to date, the sample size requirements for a minimum estimate variance may be determined (Robson and Regier 1964).

POPULATION SIZE

When reliable harvest data and reporting rates for a fishing interest are available, the population size of the target species' stock in each bay system may be estimated for each selected tagging period, according to the empirical formula:

$$\begin{array}{l}\text{Number of individuals}\\ \text{in fish stock at}\\ \text{time of tagging}\end{array} = \frac{\text{Number tagged}}{\begin{array}{l}\text{Number returned by}\\ \text{fishing interest}\end{array}} \times \begin{array}{l}\text{Fishing}\\ \text{interest}\\ \text{harvest}\end{array} \times \begin{array}{l}\text{Fishing}\\ \text{interest}\\ \text{reporting rate}\end{array}$$

Population sizes for each tagging period in the year can be summed and divided by the total number of tagging periods to develop an annual mean population size.

The assumptions relevant to estimating fish population size are the same as those listed under MORTALITY. The consequences of violated assumptions will be the opposite of those detailed under MORTALITY so that if fishing mortality is underestimated then population size will be overestimated or vice versa.

CONCLUSION

The multiple census tagging program described herein either directly satisfies or, through quantification of the violations, can account for the assumptions necessary for providing estimates of fish growth, movement, mortality and population size. In addition, such a program makes the public aware of fisheries resources and the necessity for managing them.

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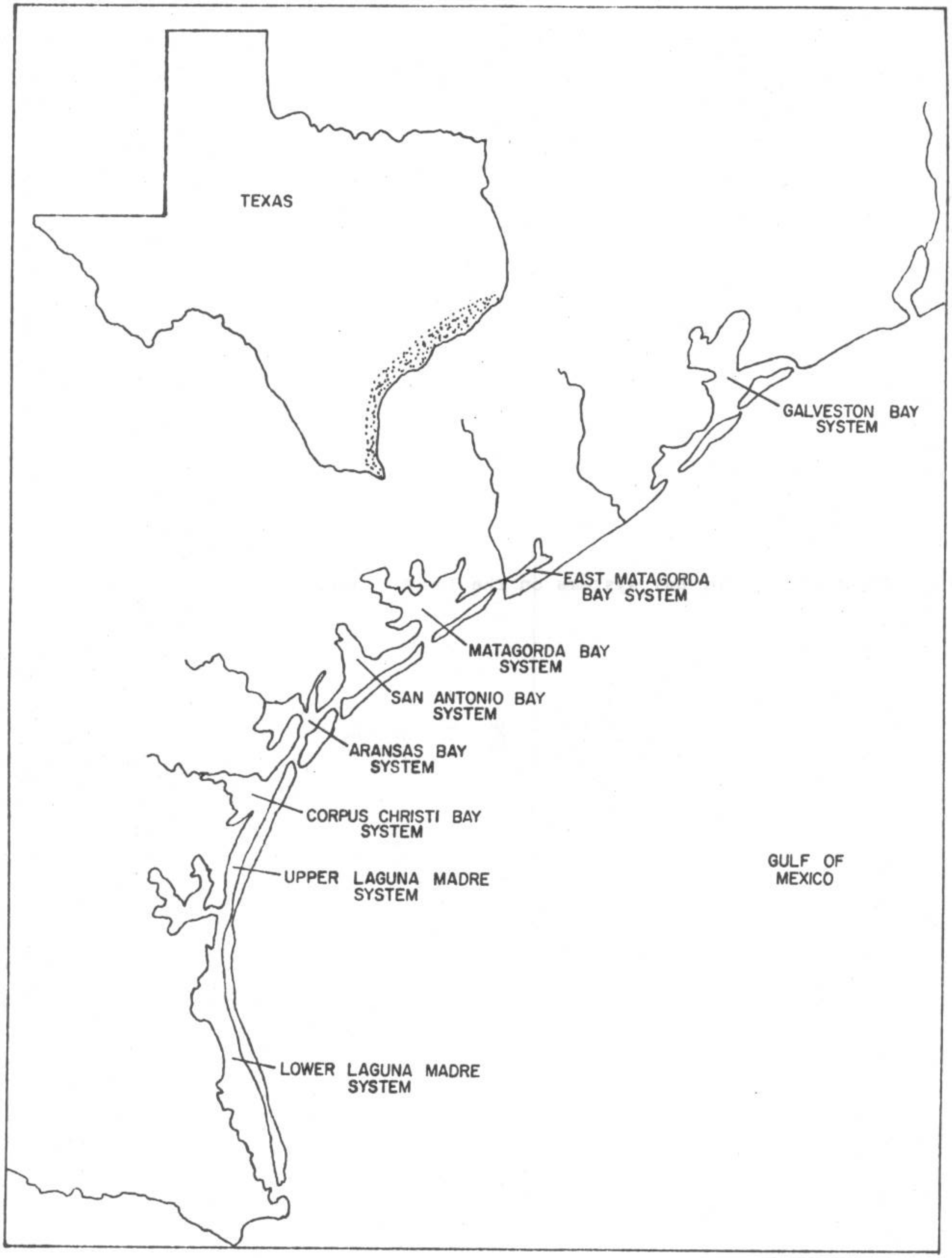
Table 1. Number of fishes tagged with internal abdominal anchor tags during November 1975-September 1978 on the Texas coast.

Species	Nov. 1975-Sept. 1976	Oct. 1975-Sept. 1977	Oct. 1977-Sept. 1978	Nov. 1975-Sept. 1978
Red drum (*Sciaenops ocellata*)	1341	1935	2104	5380
Black drum (*Pogonias cromis*)	1572	1585	1458	4615
Southern flounder (*Paralichthys lethostigma*)	199	231	244	674
Sheepshead (*Archosargus probatocephalus*)	205	595	596	1396
Spotted seatrout (*Cynoscion nebulosus*)	303	353	349	1005
Gulf flounder (*Paralichthys albigutta*)	43	27	27	97
Total	3663	4726	4778	13167

Table 2. Total number of tagged fishes returned on the Texas coast during November 1975-September 1978.

Species	Nov. 1975-Sept. 1976		Oct. 1976-Sept. 1977		Oct. 1977-Sept. 1978		Nov. 1975-Sept. 1978	
	Number	% Returned	Number	% Returned	Number	% Returned	Number	% Returned
Red drum	159	11.9	362	18.7	413	19.6	934	17.4
Black drum	53	3.4	125	7.9	136	9.3	314	6.8
Southern flounder	9	4.5	13	5.6	16	6.6	38	5.6
Sheepshead	6	2.9	15	2.5	9	1.5	30	2.1
Spotted seatrout	7	2.3	41	11.6	20	5.7	68	6.8
Gulf flounder	4	9.3	0	0	1	3.7	5	5.2
Total	238	6.5	556	11.8	595	12.5	1389	10.5

Figure 1. Major bay systems on the Texas coast.


TEXAS
GALVESTON BAY SYSTEM
EAST MATAGORDA BAY SYSTEM
MATAGORDA BAY SYSTEM
SAN ANTONIO BAY SYSTEM
ARANSAS BAY SYSTEM
CORPUS CHRISTI BAY SYSTEM
UPPER LAGUNA MADRE SYSTEM
GULF OF MEXICO
LOWER LAGUNA MADRE SYSTEM

EFFECT OF FISH SIZE ON RECOVERY OF TAGGED FISHES IN AREAS TREATED WITH ROTENONE

by

Albert W. Green, Gary C. Matlock and James E. Weaver

Coastal Fisheries Branch
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744

ABSTRACT

Three randomly selected shorline areas (1.67 ha) in each of seven Texas bay systems were treated with rotenone (2.0 ppm) during 1 July 1978 - 30 September 1978. Each sample area was enclosed with a 2-m deep net (35-mm stretched mesh). Twenty-seven different groups of 7-41 tagged fish each, having mean total lengths ranging from 84 to 447 mm were released into the area prior to rotenoning to obtain recovery rates. Each group of tagged fish was assigned to a species group and assigned an expected recovery value based on previous experience. Recovery rates were regressed on mean length, mean length squared, mean length cubed and expected recovery value. A significant regression ($R^2 = 0.778$; $P<0.001$) of the form $Y = -134.5502 + 0.6180X - (2.1028x10^{-6})X_1^3 + 1.2597X_2$ was found, where Y was the recovery rate, X_1 was the mean length and X_2 was the expected recovery value. The expected recovery value explained only 9% of the observed variation whereas mean length explained 69%, indicating that the estimation of recovery rates for different sizes of fish is more important than estimating recovery rates for different species or species group.

INTRODUCTION

Fisheries biologists have realized for some time that sampling with rotenone does not result in the recovery of all fish within the sampled area (Krumholz 1950). Henley (1967) documented by direct observation (using scuba gear) that only 74% by number and 95% by weight of all fishes present were recovered within 52 h after a rotenone application. He concluded that species composition and size distribution (small fishes sank more often than did large fish) affected the recovery of fish more than any other factor (temperature, cover, etc.). Recently, studies have attempted to account for some of the variability observed in the recovery of fish by estimating recovery rates for each species (Matlock et al. 1978, Grinstead et al. 1978) but they have ignored size relationships. This study reports the relationship observed between fish size and recovery rate in 21 rotenone samples collected in Texas bays.

We would like to thank each member of the Bay Finfish Monitoring Program who completed all of the scheduled samples. Their diligence and perseverance was commendable as anyone who has picked up 2-day old fish from 36 C water knows. A special thanks goes to each responsible team leader: Bill Harshaney, Jim Dailey, Paul Hammerschmidt, Ed Hegen, Hal Osburn, Dick Harrington and Gary Stokes. We also extend a warm thanks to Patricia Johansen, Tom Hefferman and Roy Johnson for reviewing the manuscript.

MATERIALS AND METHODS

During July, August and September 1978, three different sites in each of the following bay systems were sampled with rotenone: Galveston, Matagorda, San Antonio, Aransas, Corpus Christi Bays and upper and lower Laguna Madre (Fig. 1). Sample sites within each bay system were randomly selected from a list of sites where the water depth was 1.2 m at a distance of 91.4 m from the shore.

The sample site was enclosed with a 2.1-m block-off net (made of 35-mm stretched mesh) set in the shape of a rectangle. The top of the net was extended 200-300 mm above the water surface. Chem-fish Regular (0.5% rotenone emulsified in methylated naphthalene and diluted in water (1:10 ratio)) was then applied to the area within 0.5 h of sunset in a sufficient quantity to achieve a 2.0-ppm concentration (Hegen 1978). The rotenone was dispersed from an outboard-powered skiff driven throughout the area. Rotenone drifting out of the sampled area was detoxified by simultaneously dispensing potassium permenganate just outside of the block-off net.

Recovery rates were estimated using fish obtained from areas adjacent to the sampling site. These fish were arranged into groups, tagged and released into the sample area prior to rotenoning. Each group contained approximately 20 individuals belonging to the same species and having as narrow a total length range as possible. The fish were tagged with individually numbered tags having an internal abdominal anchor (25.4 x 6.4 x 0.8 mm plastic button) and an external yellow plastic streamer (approximately 75 mm long and 2 mm in diameter). All tagged fish were measured to the nearest 1 mm (total length) and placed inside the sample site after the block-off net was in place and prior to the application of rotenone.

Collection of all fish> 75mm began within 2 h after sunrise on the morning after rotenone application and continued until sunset. All fish found floating along the shoreline or block-off net were collected. The next day, fish collection began within 2 h after sunrise and continued until 1200 (CST).

Recovery rates were calculated for each group of fish by dividing the number of tags recovered by the number of tags introduced. Mean total lengths and standard deviations were calculated for each group of fish that was released. Each species was given an expected recovery value (48-88%) based on work presented by Matlock et al. (1978). The recovery value for a given species was the recovery rate reported by that study.

It was suspected that a size-recovery rate relationship might be curvilinear; therefore, the observed recovery rates were regressed on size using a third-order polynomial. A linear relationship between recovery rate and species group was assumed:

$$Y = B_0+B_1X_1B_2X_1^2+B_3X_1^3+B_4X_2$$

The regression coefficients (B_0,B_1,B_2,B_3, and B_4) were estimated using the observed recovery rate for each group (Y), the mean length (mm) of each group (X_1) and the recovery value for each group (X_2). The regressions were accomplished with the BMDP2R program in the BIOMED statistical package and details of this analysis can be found in Draper and Smith (1966).

RESULTS

Twenty-seven groups of tagged fish were released in 21 different rotenone samples. Two groups were omitted before an attempt to fit the data to an equation was made. A group of 28 red drum having a mean length of 354 ± 58 mm was omitted because the biologist found the lead line of the block-off net off the bottom. Another group of 20 sea catfish having a mean length of 291 ± 40 mm was omitted because high winds blew a large number of fish over an unstaked portion of the block-off net during the first night. These incidents were not normal and would probably result in atypical recovery rates. Sample sizes for each of the remaining groups ranged from 19 to 28 fish in all but four groups (Table 1). Two groups had sample sizes < 19 (7 and 13) and two groups had samples sizes > 28 (40 and 41). Mean total lengths for each group ranged from 84 to 447 mm and standard deviations ranged from 4 to 84. Recovery rates ranged from 0 to 100%. A total of 595 fish was tagged; 360 fish were recovered.

Three of the 25 remaining groups of fishes were made up of species having high expected recovery values (84-88%). One group was made up of red drum (*Sciaenops ocellata*), two of black drum (*Pogonia cromis*) and one of spotted seatrout (*Cynoscion nebulosus*). Three other groups were made up of species having low expected recovery values (36-48%). Spot (*Leiostomus xanthurus*) was the only species represented in these groups. The remaining 19 groups had intermediate expected recovery values (68-74%) and were distributed as follows: 10 groups of striped mullet (*Mugil cephalus*), 5 groups of sea catfish (*Arius felis*), 2 groups of Atlantic croaker (*Micropogon undulatus*), and 1 group of white mullet (*M. curema*) and gizzard shad (*Dorosoma cepedianum*).

The regression analysis showed that 69% ($F = 24.922$; $df = 2,22$; $p < 0.01$) of the total variation observed in the recovery rates was explained as a function of mean length and mean length cubed (Table 2). The entry of the expected recovery value into the regression explained an additional 9% of the total variation ($F = 24.558$; $df = 3,21$; $p < 0.01$). The final form of the regression equation ($Y = -134.5500 + 0.6180X_1 - (2.1028x10^{-6}) X_1^3 + 1.2597X_2$) showed a maximum recovery rate occurring at 320 mm. Groups having mean lengths < or > 320 mm had lower recovery rates. Mean length squared did not enter the regression equation as a significant predictor for recovery rates. The standard error for the estimate was ± 17%.

DISCUSSION

This study indicates that fish size was more important than species identity in predicting whether a fish would be retrieved from an area treated with rotenone. The fact that the recovery value was significant in improving the recovery. Certainly some species would always have low recovery rates because they never get very large. Other factors associated with the species identity which may affect recovery may be differences in body shape (round or flat) or density (relative size of air bladder and composition of flesh).

The probability of recovering a fish in a rotenoned area may also be a function of the fish's susceptability to predation or its ability to escape the area. Sea gulls and egrets preyed on fish affected by rotenone in the sample area. Krumholz (1950) found that small fish were also preyed upon by large fish during the early stages of rotenone application to an area. Predation was not limited to small fish. Mammal tracks (raccoon, coyote and bobcat) on the beaches adjacent to the area the morning after rotenone application indicated that night feeding had occurred. These mammals were large enough to eat or carry off large fish. Since rotenone affects small fish sooner than it affects large fish (Henley 1967), large fish had a longer time in which to escape.

Large fish are more likely to have the physical strength to jump over block-off nets or swim under the lead line than small fish; hence, large fish probably have a better chance of escaping a rotenoned area than small fish. Even though block-off nets were raised 200-300 mm above the surface of the water, fish were seen jumping over the net; both into and out of the area. Unfortunately, this phenomenon could bias recovery rate estimates. If the number of fish jumping into the area equalled the number jumping out, recovery estimates would be biased low since the probability that a tagged fish jumping out is greater than that of a tagged fish jumping in.

The maximum recovery rate would be for that size of fish for which predation and escapement is least and for species or species groups for which the chances of floating and not decomposing are greatest. The mechanisms which cause the recovery rates to decline on either side of the maximum are probably different. Small fish are eaten, sink to the bottom (Henley 1976) and probably decompose more rapidly than large fish. Fish greater than the size of maximum recovery probably have a better chance of escaping the area. Finding relationships between recovery rates and physical factors such as fish form, fish density, water depth and the density of vegetation in the sampled area may be a more practical and general way to reduce the high variability observed in recovery rate estimates (Barr and McDonough 1978) than making estimates for each species.

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Figure 1. The seven Texas Bay systems in which the 21 rotenone experiments were conducted.

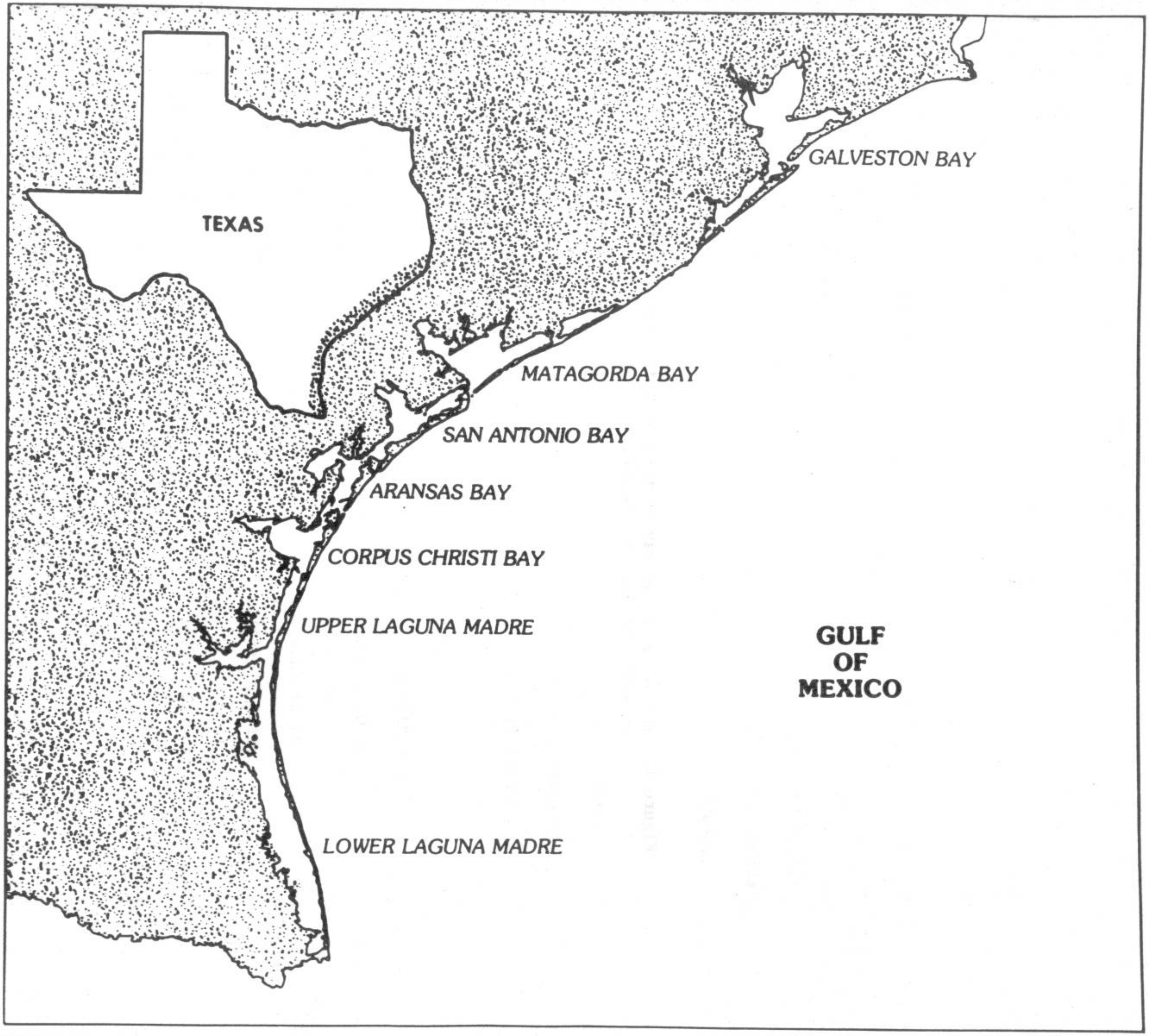
TEXAS
GALVESTON BAY
MATAGORDA BAY
SAN ANTONIO BAY
ARANSAS BAY
CORPUS CHRISTI BAY
UPPER LAGUNA MADRE
LOWER LAGUNA MADRE
GULF
OF
MEXICO

Table 1. Recovery rates of tagged fishes obtained from rotenoning 21 different sites (1.67 ha each) in Texas bays (July-September 1978).

Bay system[a]	Species	Number tagged	Mean total length (mm)+1sd	Expected recovery value[b] (%)	% recovered
Aransas[1]	White mullet	13	84± 4	68	0.0
Aransas[1]	Striped mullet	7	101±24	68	42.9
Corpus Christi[2]	Spot	20	112± 4	48	0.0
Lower Laguna Madre[3]	Striped mullet	27	119±26	68	7.4
Matagorda	Atlantic croaker	20	127±45	69	5.0
Upper Laguna Madre	Striped mullet	26	144±15	68	23.1
Corpus Christi[2]	Spot	22	227±14	48	4.5
Aransas[4]	Spot	25	234±10	48	68.0
Corpus Christi	Atlantic croaker	24	250±10	69	75.0
Matagorda	Sea catfish	21	254±64	73	71.4
Upper Laguna Madre	Striped mullet	22	260±84	68	86.4
Matagorda	Gizzard shad	20	260±36	69	90.0
San Antonio	Sea catfish	20	268±49	73	95.0
Lower Laguna Madre	Striped mullet	20	290±45	68	70.0
Galveston	Sea catfish	19	298±57	73	100.0
San Antonio	Black drum	20	309±27	84	95.0
Galveston	Sea catfish	20	324±22	73	75.0
Aransas	Striped mullet	40	331±32	68	85.0
Galveston	Sea catfish	20	336±80	73	70.0
Lower Laguna Madre[3]	Striped mullet	41	347±26	68	78.0
Aransas[1]	Striped mullet	20	351±22	68	95.0
Lower Laguna Madre	Striped mullet	20	362±35	68	75.0
Upper Laguna Madre[5]	Striped mullet	20	387±22	68	50.0
Upper Laguna Madre[5]	Black drum	20	430±31	84	70.0
Aransas[4]	Spotted seatrout	20	447±80	88	70.0

[a] Bay names having the same superscripts indicated that these groups were released during the same experiment

[b] From Matlock et al. (1978).

Table 2. The sequence in which each variable entered the regression analysis as a significant predictor of recovery rates, the multiple correlation coefficient as a result of the entry and the resultant regression coefficients and standard errors.

Sequence	Variable	Multiple Correlation Coefficient	Regression Coefficient	Standard Error of Coefficient
1	Mean length	0.704	0.6180	0.089
2	Mean length cubed	0.833	-2.1028×10^{-6}	0.415×10^{-6}
3	Species group	0.882	1.2597	0.446

The intercept was estimated to be -134.5502.

RECOVERY OF BENTHIC INFAUNA ASSOCIATED WITH REWORKED INTERTIDAL DREDGE MATERIAL

by

Robert R. Stickney, Stephen Wernsing[1]
J. Holt Williamson[2], Barry D. Redner[3]
and Robert B. McGeachin

Department of Wildlife and Fisheries Sciences
Texas A&M University
College Station, Texas 77843

ABSTRACT

Monthly sampling of the benthic infaunal community of Bolivar Peninsula, Galveston Bay, Texas, from July 1976 through December 1977 revealed that the establishment of marshes dominated by Spartina alterniflora and S. patens on reworked dredge material had little impact on recolonization. The numbers of taxa present and diversity of the benthic community were often highest in undisturbed reference areas, but the mean density of organisms was similar in both reference and experimental areas. Unplanted and planted areas in which reworking of the sediments had occurred were similar with respect to numbers of benthic taxa and diversity. Mean density of organisms varied seasonally but not as a function of planting regimen.

Elevation within the study area did affect the quality of the benthos collected. Insects and their larvae and pupae dominated samples from regions which were predominantly supratidal, whereas polychaetes and other more typically marine forms dominated the intertidal and subtidal samples.

Volatile solids levels varied slightly with time, but were similar across the site. The sediments were dominated throughout the study by fine sand.

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[1] Present address: U.S. Forest Service, Elko, Nevada

[2] Present address: U.S. Fish and Wildlife Service, Warmwater Fish Development Center, San Marcos, Texas

[3] Present address: Department of Biology, Memphis State University, Memphis, Tennessee

The establishment of a salt marsh on reworked dredge material did not alter the pattern of colonization nor subsequent development of the benthic community. The primary potential impact of marsh development on fisheries would appear to be related not to the quality or quantity of benthic organisms available as food, but to their availability as compared with benthic organisms inhabiting unvegetated areas.

INTRODUCTION

Maintenance dredging in the fresh and marine waters of the United States generates millions of cubic meters of dredge material annually, all of which must be disposed of in some environmentally sound manner. Among the numerous sources of this material is the Gulf Intracoastal Waterway (GIWW) which provides a protected navigable channel from the Florida Gulf coast through Texas. The GIWW is maintained by the U.S. Army Corps of Engineers to a depth of approximately 4 m, primarily by means of hydraulic dredging. In Texas, the GIWW traverses various bays but also exists in many regions as artificial cuts through supratidal areas. Maintenance dredging schedules are dependent upon shoaling rates.

Recolonization of benthic organisms in areas wherein the sedimentary framework is altered significantly by dredging can be very slow and the ultimate population may be significantly altered from that which existed prior to dreding (Sykes and Hall, 1970). Burial of benthic organisms by deposited dredge material can have a devastating impact, especially with respect to such sessile forms as the American oyster, <u>Crassostrea virginica</u> (Galstoff, 1964; Rose, 1973). However, when no significant alteration in sediment quality occurs as a result of dredging in environments characterized by high percentages of silt and clay, benthic recolonization may occur in as little as a few weeks post-dredging (Stickney and Perlmutter, 1975). Information on the recolonization of planted and unplanted dredge material by benthic organisms is available from North Carolina (Cammen, 1976a, 1976b) but is lacking from the Gulf of Mexico.

Environmental concerns have been raised in recent years with respect to many of the methods of dredge material disposal which are currently in use. As a part of the Dredged Material Research Program conducted by the U.S. Army Corps of Engineers, contracts for research to evaluate the feasibility of constructing marshes on dredge material were awarded during the mid-1970's. One of the areas selected for study was on Bolivar Peninsula, Galveston Bay, Texas. The primary objective of the study was to examine growth of smooth cordgrass (Spartina alterniflora) and marsh hay cordgrass (S. patens) planted on reworked dredge material either protected from wave action by a sandbag dike or left unprotected. As a part of that study, aquatic animal communities associated with the site were sampled. The purpose of this paper is to present information on the colonization and population dynamics of benthic organisms at the Bolivar Peninsual marsh development site. Previous papers have addressed other aspects of the study (Stickney and McGeachin, 1978; Stickney and Dodd, 1979; Stickney and Williamson, 1979).

MATERIALS AND METHODS

The Bolivar Peninsula marsh development site (Figure 1) was a 7.3 ha area which had received dredge material in 1974. Between January 29, and March 5, 1976, the sediments were reworked with earthmoving equipment and then evenly distributed across the site. A smooth, gently sloping

(0.67% grade) beach was formed during sediment reworking, leaving a vegetation-free area at the initiation of the study.

Following completion of earthmoving activity, runoff from upland areas and wave action led to significant erosion and deposition, resulting in large deviations from the designed slope in most areas but providing a more natural appearing beach.

A U-shaped sandbag dike was constructed around a large portion of the area (Figure 2) to protect the developing marsh from wave damage. Sandbags were PVC-coated nylon approximately 0.5 x 1.4 x 2.9 m which were filled in place. The dike was composed of a primary line of bags 305m long from the ends of the primary dike shoreward (Figure 2). Sinking and damage to the bags required that the contractor perform almost continuous maintenance through June 1977 after which no further alterations in the dike were undertaken.

A fence designed to keep goats, sheep and cattle from the site was completed by the Galveston District Corps of Engineers in October 1976. This fence was over 2 m in height and was augmented with a 48 cm high 2.5 cm mesh fence at the base to prevent rabbits from entering the area.

The area within the fence was developed according to a plan devised by U.S. Army Corps of Engineers, Waterways Experimental Station personnel in conjunction with Texas A&M University researchers. An upland area was partitioned into plots wherein various grasses, shrubs and trees were planted. The largest portion of the site was intertidal (Figure 2). Within the intertidal zone various regions were designated. Inside the confines of the sandbag dike, 270 individual small marsh plots (6 x 10 m) were established in nine blocks. Each block contained 30 plots. Duplicated plots within blocks received varying levels of fertilizer and were seeded or sprigged to _S. alterniflora_ or _S. patens_ or left unplanted (Webb, et al., 1978). Other regions within and outside of the dike remained either unplanted or were planted with a mixture of the two marsh grasses.

Benthic stations were established at five elevations along 12 transects representing five habitat types (total = 60 stations). Elevation 1 was located at the upper extreme of the intertidal zone (a region which was only flooded infrequently). Elevation 5 was established just inside the bayward dike in a region exposed only during spring low tides. Because of basin configuration and shoalness of Galveston Bay, and in response to strong seasonal winds which override the astronomical tides, prediction of both range and time of day of high and low tides was virtually impossible.

The 12 transects (identified by letters in Figure 2) represented 6 environments as follows:

Transects Z and J - Unplanted reference areas outside the fence.

Transects A and I - Unplanted areas within the fence, not protected by the sandbag dike.

Transects B and H - Alternating sprigs of *S. alterniflora* and *S. patens* within the fence, protected by the sandbag dike.

Transects X and Y - Unplanted areas within the fence, protected by the sandbag dike.

Transects C and G - Alternating sprigs of *S. alterniflora* and *S. patens* within the fence, protected by the sandbag dike.

Transects D and F - Small individual plots within the fence; unplanted; sprigged or seeded to *S. alterniflora* or *S. patens* and protected by the sandbag dike.

Wooden stakes, 5.08 cm in diameter and marked with the appropriate identification code, were placed at the 60 sampling stations. Sampling was conducted monthly from July 1976 through October 1977, and finally in December 1977.

From July 1976 through March 1977, 20 x 20 cm samples 20 cm deep were obtained by hand digging. This technique was designed for use during low tide and all sampling trips were initially planned to correspond with periods of spring lows. Because of wind domination of the tides in Galveston Bay, data were occasionally lost from stations which were inundated throughout a particular sampling trip. To circumvent this problem, a sediment corer, similar to that described by Holz, et al. (1972) was constructed. The corer consisted of a 10.2 cm diameter galvanized metal pipe approximately 45 cm in length to which was attached a coupling which reduced the diameter to 3.8 cm. A handle approximately 1 m in length was attached to the reducer coupling. During use the large diameter pipe was driven into the sediments to a depth of 20 cm. Duplicate samples were obtained monthly beginning in April 1977 and pooled for analysis.

Samples were fixed with 10% formalin in the field. In the laboratory the samples were washed through a 0.5 mm sieve and the retained material was placed for a minimum of 24 h in Rose Bengal stain (200 mg/l). Following staining, animals were separated from debris and preserved in either 40% isopropyl or 70% ethyl alcohol. After identification to the lowest possible taxon the animals were counted. Data were recorded in terms of the number of taxa present, number of individuals/m^2 and diversity. The Shannon-Weiner diversity function ($H' = -\Sigma\ pi \ln pi$, where pi is the proportion of species "i" in the sample) was used to calculate a diversity index for each sampling.

At 5.08 cm diameter core, 20 cm deep, was obtained monthly from June 1976 through December 1977 at each benthos station and analyzed for volatile solids and sediment grain sizes. Following collection, the core barrels were capped and stored on ice for return to the laboratory where they were frozen at -20°C until analyzed.

After thawing, the sediments in each core were thoroughly mixed. Subsamples of approximately 7-9 g were placed in tared aluminum weighing dishes and dried at 105°C for a minimum of 24 h. Dry weights were then determined to the nearest milligram after which the samples were placed in a muffle furnace for 1 h at 550°C. After cooling in a desiccator, ash-free dry weights were determined on the basis of weight loss on ignition and the values were used as a measure of volatile solids.

An additional 45-65 g of each mixed sediment sample was utilized for grain size analysis. Each sample was first placed in a tared 250 ml beaker and dried for a minimum of 24 h at 105°C and then dry sieved on a mechanical sieve shaker through sieves of 250 and 63 μ. Material passing through the 63 μ sieve was collected in a pan and added to the graduated cylinder. The larger size fractions were weighed. The volume of the graduated cylinder was brought to 1000 ml with dispersing agent and the determination of silt and clay fractions made by standard pipette analysis (Holme and McIntyre, 1971).

General Linear Models (GLM) and Duncan's Multiple Range procedures were run on the data utilizing SAS (Barr, et al. 1976). Statistical tests were collected at the 0.05 level of significance.

RESULTS AND DISCUSSION

Polychaetes, crustaceans and mollusks dominated the benthos at the Bolivar Peninsula marsh development site (Table 1). Recognition of most organisms was to species level, but in some cases family or even order represented the lowest recognizable taxon. With the exception of the beetle family Staphylinidae, the adults of which were commonly collected, most of the insects appeared as larval or pupal stages. Keith and Hulings (1965) sampled along the beach on the Gulf of Mexico side of the Bolivar Peninsula and collected only four species in common with the present study (the polychaetes Diopatra cuprea, Streblospio benedicti and Spiophanes bombx and the mollusk Mulinia lateralis). This lack of similarity is indicative of natural environmental differences between the protected estuarine side of the peninsula and the seaward side.

Numbers of taxa collected monthly ranged from a mean low of 3.7 in August 1976 to a mean high of 8.0 in March 1977 (Table 2). Numbers of taxa collected from January through March were significantly higher than during other periods. Since the mean numbers of taxa present during the early phases of the study (July through September 1976) were not significantly different from those of August through October 1977, it is apparent that typical species numbers were present within a short time after sediment reworking.

Mean monthly density (numbers of individuals/m^2) indicated that development of the benthic community was still underway when sampling was started (Table 2). Densities were significantly lower in samples from July through November 1976 than during all other months except October 1977, confirming the late winter and spring maximum development of the benthos indicated by the mean numbers of taxa present.

Mean diversity ranged from 0.80-1.21 (Table 2). While diversity was low during the first two months of sampling, there was no distinct pattern attributable to either recolonization after disruption of the sediments or seasonal variations. Diversities observed during this study were within the ranges of those obtained in previous work on dredging impact in coastal waters (Stickney and Perlmutter, 1975; Cammen, 1976b). Thus, a well established benthic community was present when sampling was initiated, and while it continued to develop in density during the early phases of the study, typical diversity levels had been approached by the onset of sampling.

Percentages of volatile solids in the sediments (indicative of the amount of organic material present) showed a pattern of reduced levels during winter and spring and higher ones in summer (Table 3). While significant differences in volatile solids means did occur throughout the study period, the means ranged only from 0.8-1.36%, and may have not been biologically important.

Coarse sand comprised between 1-2% of the total sedimentary material. Fine sand decreased slightly from about 90% at the start to 83% at the end of the study, while silt and clay both increased with time (Table 3). The greatest temporal change occurred in the clay fraction, where a nearly 5% increase was observed. Changes in sediment composition may have been too small to elicit a response from the benthic community.

Mean numbers of taxa along the various transects were similar except in the reference areas (transects J and Z) where significantly more animals were recovered (Table 4). This dinstinction also held for mean diversity, but not density. Numbers of individuals/m^2 were similar among the 12 transects, and while some significant differences did occur, no habitat type appeared to be unique. There was no indication that the presence of the sandbag dike influenced mean number of taxa, density or diversity.

Observed differences in the reference area from the other habitat types with respect to mean numbers of taxa and diversity cannot be explained on the basis of mean volatile solids percentages or grain sizes. While some significant differences did occur among the habitat types with respect to the sedimentary factors measured, no clear pattern emerged (Table 5). The highest mean silt level did occur in the reference area (transect Z); however, the second highest mean level (8.89%) was observed not only in the reference area (transect J) but also in the mixed, protected area (transect G). Lowest mean silt and clay levels were observed in the unprotected areas within the fence (Table 5). Thus, regions outside of the dike demonstrated both some of the highest and lowest mean silt levels.

Mean clay percentages were lowest in the bare and mixed planted, unprotected areas. Clay levels were not significantly higher in the reference area than in several other habitats (Table 5).

In an attempt to determine if the higher mean numbers of taxa and diversities within the reference areas were temporally controlled, the benthos data were subjected to comparative analyses by month and transect. When examined in that manner, the highest mean numbers of taxa were associated with one or both of the reference transects during all but four months (December 1976; April, June and December 1977). From October 1976 through June 1977 and again in October 1977, no significant difference occurred among the 12 transects. During August 1976 the mean number of taxa present along transect Z (6.8) was significantly higher than along any other transect, including transect J. During no month were both reference transects significantly different with respect to mean numbers of taxa from all transects in the other habitat types.

Data presented in Table 4 demonstrated no overall significantly higher mean density in the reference areas than in other habitat types. That analysis was confirmed when the data were examined on a month by month basis by transect. Only during October 1976 did transect Z exhibit significantly higher organism density than all other transects. During that month the mean numbers of individuals/m^2 along transect J ranked eighth among the 12 transects. Mean densities were numerically highest along transect Z during July, August and October 1976, as well as April and December 1977, but those values were not significantly higher than means obtained from one or more of the other transects except during October 1976. In no case did densities along both reference transects rank above all others.

Mean diversity was numerically highest along transect J during July, September, October and December 1976, and during every month of 1977 except January and December. Diversity was highest along transect Z during all months when it was not highest along transect J with the exception of January 1977 when the highest diversity was associated with transect X and no significant differences were found among the 12 transects. In many cases where either transect J or Z ranked highest in diversity the value was significantly greater than most, but not all others. The observed pattern continued throughout the study, indicating that some activity or physical factor was affecting diversity within the fence. This was more apparent along transect J than Z and was not a consistent finding. Since diversity ranged only over a few tenths of a unit, the differences, while often statistically significant, were subtle, and may have had little or no biological importance.

Mean numbers of benthic taxa, density and diversity were next examined with respect to elevations (Table 6). Elevations 1 and 2 (Figure 2) were significantly lower in all three factors. There was a general increase in mean numbers of taxa, density and diversity in an offshore direction with elevations 1 and 2 being similar (and not statistically different) as were elevations 4 and 5. The observed differences related to the fact that the upper beach elevations were characterized primarily by a few taxa of insects while the truly intertidal forms only became important at and below elevations 3 where daily inundation through tidal influence was almost assured.

The overriding importance of the tide in determining the density and diversity of organisms relative to elevation at the Bolivar Peninsula marsh development site can also be inferred from comparison to Table 6 with the mean volatile solids and grain size percentages among the five elevations presented in Table 7. Volatile solids varied little with elevation, although there was a tendency for the lowest percentages to occur at the elevational extremes. Coarse sand did decrease with decreasing elevation, probably in response to winnowing by wave and tidal action. Since the amount of coarse material present in the sediments was very low, the observed differences were likely of little importance to the benthic organisms inhabiting the site. Fine sand did not vary significantly with elevation. There was a tendency toward increased silt in the offshore direction, but the magnitude of the differences was small. The mean percentage of clay at elevation 1 was significantly less than at the other elevation, a probable result of wave and tide activity.

Cammen (1976a) also found that differences in total numbers and diversity of benthic organisms collected from dredge material either left bare of planted with S. alterniflora were related primarily to elevation. He compared dredged material benthos with that of a natural marsh and found close similarities. Cammen suggested that such factors as similarity of dredge material to natural marsh sediments with respect to elevation and particle size, natural sedimentation rates, the proximity of dredge faunal communities contributed to the observed relationships.

In conclusion, the various perturbations which occurred at the Bolivar Peninsula marsh development site following reworking of the sediments with earthmoving equipment appeared to have had little impact on subsequent development of the benthic infaunal community, although the experimental area did show reduced numbers of taxa and diversity when compared with reference areas. Colonization by most species appeared to be rapid, with the community having become well developed by the time sampling was initiated. The same taxa were present throughout the study area and did not change appreciably with time. Seasonal peaks in abundance of benthic organisms were apparent and usually occurred in the winter and spring.

Sediment differences between the reference transects and the other habitats were not sufficient to explain differences which existed within the benthos community. The presence of an established benthic community in the references areas for at least 2 years prior to disruption of the sediments in the experimental area may have been a factor.

Establishment of a marshland on reworked dredge material at the Bolivar Peninsula marsh development site did not seem to have any large effect, either negative or positive, on the benthos community.

The rather artificial marshland which was created at the site has aesthetic value and may provide shelter for young fish and epibenthic invertebrates while at the same time increasing the amount of detritus available to the decomposer community on a seasonal basis. The availability of benthic organisms to fish which feed upon them may have been reduced in the planted portions of the site; thus the net value of the marshland to fisheries remains unknown.

ACKNOWLEDGMENTS

This research was supported, in part, by the U.S. Army Corps of Engineers Dredged Material Research Program under Contract No. DACW39-76-C-0109 with the Texas Agricultural Experiment Station. We would like to express our appreciation to Donald Harper for assistance in identification of the animals collected. Field and laboratory assistance by J.D. Dodd, Jim Webb, Bill Yingst, Susan Chamberlain, Davis Loper and Denise Hudson is gratefully acknowledged. Assistance in key punching was provided by Miss Karen Hamilton and Mrs. Loretta Mokry. Finally, we would like to acknowledge the logistical support, conceptualization, advise and field assistance of John Lunz and Buddy Clarain of the Waterways Experiment Station.

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Figure 1. Location map of the salt march study area in southeastern Texas. (GIWW indicates the Gulf Intracoastal Waterway.)

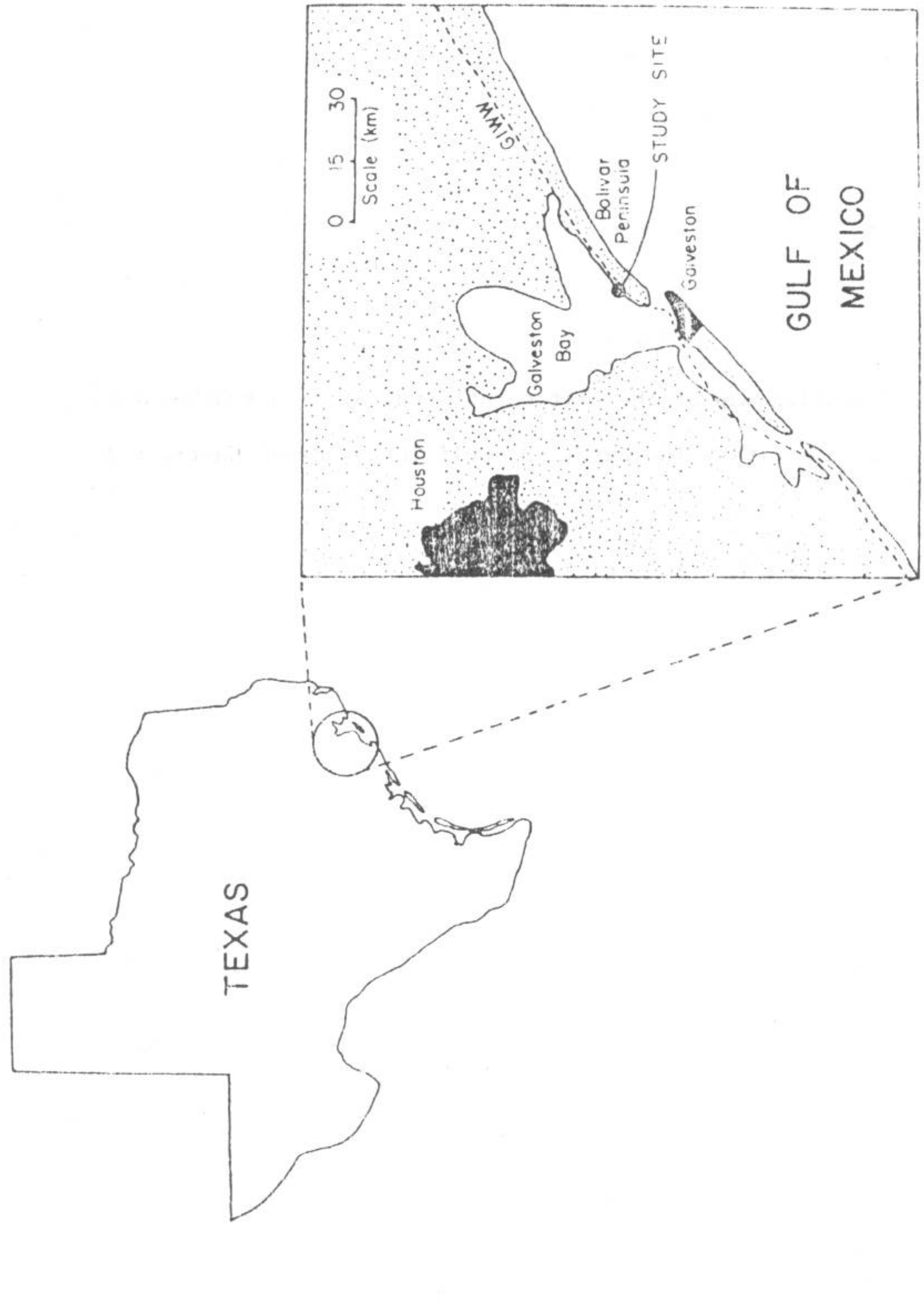
TEXAS
Houston
Galveston Bay
Bolivar Peninsula
STUDY SITE
Galveston
GIWW
0 15 30
Scale (km)
GULF OF MEXICO

Figure 2. Diagram of the salt marsh study area indicating benthos sampling stations (closed circles) by elevation and transect. For descriptions of habitats, see text.

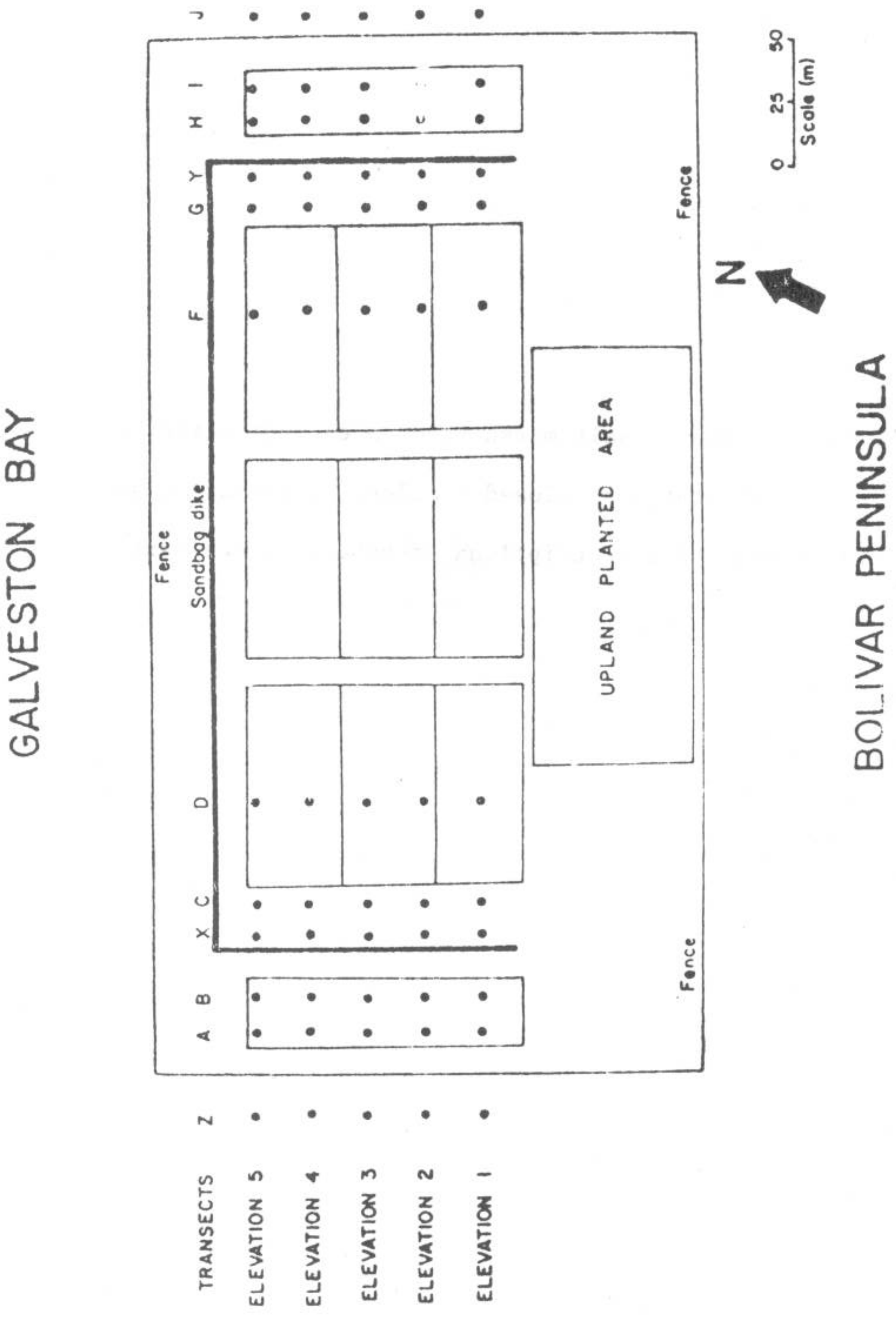
GALVESTON BAY
Fence
Sandbag dike
Fence
Fence
UPLAND PLANTED AREA
N
0 25 50
Scale (m)
BOLIVAR PENINSULA
TRANSECTS
Z
A
B
X
C
D
F
G
Y
H
I
J
ELEVATION 5
ELEVATION 4
ELEVATION 3
ELEVATION 2
ELEVATION 1

Table 1. Benthic invertebrates collected at the Bolivar Peninsula marsh development site from July 1977 through December 1978.

- Phylum Annelida
  - Class Oligochaeta
    - Oligochate sp. 1
    - Oligochate sp. 2
- Phylum Rhynchocoela
  - Class Polychaeta
    - Family Amphinomidae
      - *Pseudoeurythoa ambigua*
    - Family Capitellidae
      - *Mediomastus californiensis*
      - *Heteromastus filiformis*
      - *Capitella capitata*
    - Family Glyceridae
      - *Glycera americana*
    - Family Goniadidae
      - *Glycinde solitaria*
    - Family Neriedae
      - *Nereis succinea*
      - *Laeonereis culveri*
    - Family Onuphidae
      - *Diopatra cuprea*
    - Family Orbiniidae
      - *Scoloplos foliosus*
      - *Scoloplos fragilis*
    - Family Paraonidae
      - *Aricidea* sp. 1
      - *Arucidea* sp. 2
    - Family Pectinariidae
      - *Pectinaria gouldi*
    - Family Phyllodocidae
      - *Eteone heteropoda*
    - Family Pilargidae
      - *Parandalia fauveli*
      - *Sigambra tentaculata*
    - Family Spionidae
      - *Streblospio benedicti*
      - *Spiophanes bombyx*
      - *Scolelepsis squamata*
      - *Polydora* sp.
    - Family Terebellidae
      - *Pista palmata*
- Phylum Arthropoda
  - Class Insecta
    - Order Diptera
    - Order Coleoptera

      - Family Cicindelidae
      - Family Carabidae
      - Family Staphylinidae
  - Class Crustacea
    - Order Decapoda
      - Family Callinassidae
      - Family Xanthidae
      - Family Ocypodae
        - *Ocypode quadrata*
        - *Uca pugilator*
    - Order Cumacea
    - Order Isopoda
      - Family Anthuridae
        - *Xenanthura brevitelson*
    - Order Amphipoda
      - Suborder Gammaridea
        - Family Haustoriidae
        - Family Oedicerotidae
    - Order Cyclopoida
    - Order Harpacticoida
- Phylum Mollusca
  - Class Gastropoda
      - Family Naticidae
        - *Polinices duplicata*
  - Class Pelecypoda
      - Family Mactridae
        - *Mulinia lateralis*
      - Family Solenidae
        - *Ensis minor*
      - Family Tellinidae
        - *Macoma constricta*
      - Family Psammobiidae
        - *Tagelus plebius*
    - Order Pholadomyoida
      - Family Periplomatidae
        - *Periploma inequale*

Table 2. Mean number of taxa, density (numbers of individuals/m^2) and diversity (H') of animals collected monthly from July 1976 through December 1977. (Values within columns followed by the same letter are not significantly different at the 0.05 level.)

Month	Number of Taxa	Density	Diversity
1976 Jul	4.2ef	788e	0.91de
Aug	3.7f	785e	0.80e
Sep	4.7cdef	799e	1.07abcd
Oct	5.1bcde	980e	1.10abcd
Nov	5.7bc	857e	1.19ab
Dec	6.0b	1577de	1.13abc
1977 Jan	7.2a	2602cd	1.21a
Feb	7.9a	4771ab	1.19ab
Mar	8.0a	5443a	1.08abcd
Apr	6.2b	5704a	1.00bcde
May	5.6bc	3778bc	1.06abcd
Jun	5.2bcde	2879cd	0.95cde
Jul	5.6bc	2758cd	1.01abcde
Aug	4.8cdef	2540cd	0.99bcde
Sep	5.3bcd	2376cd	1.06abcd
Oct	4.3def	1573de	0.95cde
Dec	5.4bcd	2806cd	1.11abc

Table 3. Mean volatile solids percentage and grain size percentages during each month from June 1976 through December 1977. (Values within columns followed by the same letter are not significantly different at the 0.05 level.)

Date	Volatile Solids	Course Sand: >250μ	Fine Sand: 63-250μ	Silt	Clay
1976 Jun	1.04bcde	-	-	-	-
Jul	1.20ab	2.01a	90.37abc	5.12de	2.46d
Aug	1.15bcd	1.58ab	91.57a	4.33e	2.51d
Sep	1.09bcde	1.60ab	90.84ab	4.81e	2.75d
Oct	0.98cdef	1.84ab	90.56ab	4.84e	2.90d
Nov	0.93def	1.54ab	88.98abcd	6.04cde	3.38cd
Dec	0.83f	1.53ab	85.69ef	5.66cde	2.40d
1977 Jan	0.91ef	1.46ab	89.62abc	5.79cde	3.18cd
Feb	-	1.61ab	88.15bcde	6.60bcd	3.64bcd
Mar	0.80f	1.16b	87.12cdef	6.91abcd	4.85b
Apr	0.80f	1.09b	88.09bcde	6.62bcd	4.29bc
May	0.81f	1.27ab	87.52bcdef	6.57bcd	4.38bc
Jun	1.10bcde	1.07b	85.11efg	7.37abc	7.02a
Jul	0.93ef	-	-	-	-
Aug	1.06bcde	1.11b	83.86g	7.72ab	7.53a
Sep	1.36a	-	-	-	-
Oct	1.16bc	-	-	-	-
Nov	-	1.28ab	84.34fg	7.61ab	7.35a
Dec	1.00bcdef	1.37ab	83.08g	8.49a	7.12a

Table 4. Mean Number of taxa, density (numbers of individuals/m^2) and diversity (H') of all animals collected along each transect from July 1976 through December 1977. (Values within columns followed by the same letter are not significantly different at the 0.05 level.)

Transect	Habitat	Number of Taxa	Density	Diversity
J	Reference	7.0a	1831b	1.41a
Z	Reference	7.3a	2942ab	1.25b
A	Bare, Unprot.	5.2b	2529ab	0.92d
I	Bare, Unprot.	5.2b	2011b	0.96d
B	Mix, Unprot.	5.4b	2143ab	1.08cd
H	Mix, Unprot.	5.1b	2212ab	0.93d
X	Bare, Prot.	5.7b	2489ab	1.10c
Y	Bare, Prot.	5.1b	2490ab	0.94d
C	Mix, Prot.	5.2b	3349a	0.92d
G	Mix, Prot.	5.6b	3426a	1.04cd
D	Small plots, Prot.	5.4b	2879ab	1.02cd
F	Small plots, Prot.	5.6b	2780ab	1.06cd

Table 5. Mean volatile solids percentage and grain size percentages along each transcect from June 1976 through December 1977. (Values within columns followed by the same letter are not significantly different at the 0.05 level.)

Transect	Habitat	Volatile Solids	Coarse Sand: >250μ	Fine Sand: 63-250μ	Silt	Clay
J	Reference	0.87fg	0.76d	83.24f	8.89b	4.42cde
Z	Reference	1.08cde	1.17cd	82.74f	12.99a	5.41abc
A	Bare, Unprot.	0.91fg	1.61b	90.58abc	4.22e	3.64defg
I	Bare, Unprot.	0.75g	0.99cd	93.05a	3.41e	2.58g
B	Mix, Unprot.	0.87fg	1.40bc	90.08bc	4.24e	3.19efg
H	Mix, Unprot.	0.81fg	0.90cd	91.69ab	4.54e	2.83fg
X	Bare, Prot.	1.22bc	1.58b	87.90cd	5.65cd	4.87bcd
Y	Bare, Prot.	0.85fg	0.83d	89.72bc	5.89c	4.20cde
C	Mix, Prot.	1.64a	4.66a	82.80f	6.07c	6.33a
G	Mix, Prot.	1.12bcd	0.99cd	84.67ef	8.89b	5.46abc
D	Small Plots, Prot.	1.25b	1.55b	86.04de	6.78c	5.78ab
F	Small Plots, Prot.	0.96def	0.82d	89.24bc	6.04c	3.93def

Table 6. Mean number of taxa, density (numbers of individuals/m^2) and diversity (H') of all animals collected at each elevation from July 1976 through December 1977. (Values within columns followed by the same letter are not significantly different at the 0.05 level.)

Elevation	Number of Taxa	Density	Diversity
1	4.0a	1306a	0.90a
2	3.8a	1341a	0.85a
3	5.8b	2861b	1.10b
4	7.3c	4005c	1.19bc
5	7.5c	3522bc	1.24c

Table 7. Mean volatile solids percentage and grain size percentages at each elevation from June 1976 through December 1977. (Values within columns followed by the same letter are not significantly different at the 0.05 level.)

Elevation	Volatile Solids	Coarse Sand: >250μ	Fine Sand: 63-250μ	Silt	Clay
1	0.95bc	2.10a	88.21	5.05a	3.54a
2	1.11a	1.89a	88.04	5.15a	4.43b
3	1.04ab	1.28b	87.08	6.80b	4.83b
4	0.99bc	0.90c	87.19	7.53b	4.72b
5	0.93c	0.99bc	87.81	6.94b	4.38b

PRELIMINARY HYBRID STRIPED BASS (*Morone chrysops* x *Morone saxatilis*) FEEDING STUDY

by

David L. Campbell
Texas Parks and Wildlife Department
Tyler, Texas 75709

ABSTRACT

A preliminary study to determine the best feeding method of 5 to 40 day old hybrid bass (white bass x striped bass) was made at the Tyler Fish Culture Station during 1979. Eight different diets were used. The combination of *Artemia sp*., *Chlorella sp*., and *Chlamydomonas sp*. followed by Master Mix F-45 Starter produced the best results.

INTRODUCTION

Previous studies have shown the Tyler Bio-Disc recirculated water system can produce over 32 kg of fish/cu m of water giving the system the potential of producing over a million 3.2 cm fingerling striped bass.

This system has certain limitations because of the process of growing algae to eliminate the free ammonia. Feeds with high levels of iodine retard growth of algae and in turn reduce effectiveness of the system. The feeds used in this study were especially selected because previous testing had shown they do not retard the algae growing process of the Bio-Disc system. However, these feeds had not been proven to be suitable for achieving an acceptable growth rate for the hybrid striped bass.

The purpose of this study was to select the feed or feed combination that produced the best survival rate after 20 days of feeding and then convert the fish to a feed compatible to the Bio-Disc system such as Master Mix

F-45 or the Washington Flake for another 20 days.

METHODS AND MATERIALS

Facilities

The hybrid striped bass experimental feeding facility consisted of two 150 liter and six 26 liter glass aquariums equipped with flow through water systems. Each 150 liter aquarium was provided with a center partition, nine 1.9 cm air lift pumps for circulation and a 2.54 cm stand-pipe. The stand-pipe was 33 cm high, giving a free-board of 7.6 cm. The tubular stand-pipe covers were 0.5 mm bar mesh screen. Each 36 liter aquarium was provided with a 35 mm long mic-a-pore air tube for circulation. Air for all the aquariums was provided by a 1 hp regenative air blower.

Water Quality

The pH, carbon dioxide, dissolved oxygen and water temperature were checked daily before the first feeding. The pH and carbon dioxide were checked with a Hach DR - EL/2 kit, dissolved oxygen with a Delta Scientific Model 75 Oxygen meter and water temperature with a Taylor permafused mercury thermometer.

Measuring and Examinations

Total length determinations were made by measuring 10 fish selected at random at the end of each separate feed study. These determinations were recorded in centimeters. A Bristoline 3000 microscope was used to make bacteria and stomach examinations. Bacteria examinations were made on two fish after mortalities began. To verify ingestion of the new feed, stomach examinations were made after three separate feedings the second day after a new feed was introduced. Two fish were selected at random five minutes after feeding.

Fry

On April 24, 1979, approximately 52,000 two-day old fry were obtained from the Louisiana Toledo Bend Hatching Station. Upon arrival, they were placed in a 150 liter holding tank. When the fry were 5 days old, 1,590 were removed from the holding tank and stocked at the rate of 7.36 fish/liter (265 each) in six 36 liter aquariums and started on six separate pre-determined feeding programs. The remainder of the fry were kept in the holding aquarium and fed brine shrimp until they were 10 days old. At that time two 150 liter aquariums were stocked at the rate of 37.6 fish/liter (5,000) in aquarium 7 and 4.6 fish/liter (611) in aquarium 8. Nine days later aquariums 9 and 10 (36 liter) were stocked with 19 day old fish at the rate of 7.36 fish/liter (265 fish each).

Feeding Programs

Aquarium 1 - was fed diet #1 (cyclops) with an initial feeding of 12,000 cyclops and thereafter eight times each day at a rate of 600 at 2 hr intervals.

Aquarium 2 - was fed diet #2 (hard boiled chicken egg yolk) eight times each day at a rate of 1/4 yolk at 2 hr intervals.

Aquarium 3 - was fed diet #3 (cyclops and algae) with an initial feeding of 12,000 cyclops thereafter they were fed eight times each day at a rate of 600 at 2 hr intervals. The algae was fed three times each day at a rate of 50,000 cells per feeding.

Aquarium 4 - was fed diet #4 (brine shrimp) eight times each day at the rate of 50 ml of brine shrimp at 2 hr intervals.

Aquarium 5 - was fed diet #5 (brine shrimp and algae) eight times each day at the rate of 50 ml of brine shrimp at 2 hr intervals. The algae was fed three times each dayat the rate of 50,000 cells per feeding.

Aquarium 6 - was fed diet #6 (Master Mix F-45 starter) eight times each day at the rate of 0.5 of Master Mix F-45 starter at 2 hr intervals.

Aquarium 7 and 8 - were fed diet #7 (brine shrimp, algae and Master Mix F-45 starter) 200 ml of brine shrimp eight times a day 150,000 cells of algae three times a day for five days. Then brine shrimp (200 ml, eight times daily) and Master Mix F-45 starter (4 g, eight times daily) was fed for five days, then Master Mix F-45 starter was fed by automatic feeder 24 hr/day for 10 days.

Aquarium 9 - was fed diet #8 (Washington Flake) at a rate of 0.5 g of flake eight times each day at 2 hr intervals.

Aquarium 10 - was fed diet #6 (Master Mix starter) at the rate of 0.5 g eight times each day at 2 hr intervals.

RESULTS AND DISCUSSION

The water temperature at the beginning of the feeding experiment was 20 C, gradually increasing to 26.6 C on the 37th day. The dissolved oxygen was 8.0 mg/1 at the beginning and never fell below 6 mg/1 in the aquariums. The pH was constant at 7.2 and the carbon dioxide started at 5 mg/1 and never rose more than 0.2 mg/1. Water temperature of 20 C, dissolved oxygen of 6 to 8 mg/liter, carbon dioxide of 5 mg/liter and a pH of 7 to 7.5 are generally considered optimum for hybrid striped bass culture.

All fry started on diet #1 and diet #3 died within 11 days (Table 1). Adult cyclops were too large for the fry to eat and the young were too hard to separate; also, cyclops attached themselves to the sides of the aquarium.

All fry on diet #2 were dead after 12 days. Stomach examinations revealed the egg yolk was being consumed although it was nutritionally deficient.

The fry started on diet #4 had a survival rate of 94% at the end of the 20 days and a mean length of 1.2 cm.

The fry started on diet #5 were in good condition at 20 days with a 96% survival and a mean length of 1.4 cm. This diet produced the best results in fish growth and general appearance. Microscopic examination revealed a green substance in the digestive tract of this groups, indicating that some algae was being consumed.

The fry started on diet #6 were dead in 10 days. Apparently the feed did not stay suspended long enough for small fry to feed.

The fry fed diet #7 grew well for the first 37 days. The survival was 73% for aquarium 7 and 72% for aquarium 8. On the 37th day the water temperature rose to 26.6 C, a Myxobacteria problem set in, high mortalities began and the program was terminated on the 40th day. At this time aquarium 7 had 32% survival with a mean length of 2.8 cm and aquarium 8 had 56% survival with a mean length of 2.9 cm. This feed combination appeared to be the best. The stocking rate (Table 1) did not make a significant difference in the percentages of survival for the first 37 days.

After 10 days, the 29 day old fry on diet #8 had not grown and were in generally poor condition, so this segment of the program was discontinued.

All the 19 day old fry started on diet #6, were dead after 10 days except one large fish, which indicated cannibalism. However, daily observations showed the fish were in a gradually weakening condition.

CONDITION

The results of this study indicated that the brine shrimp played an essential part in the feeding of the hybrid bass for the first 20 days of feeding. Although there was no replication of tests for verification, the results suggest that the algae may fill a dietary need of hybrid striped bass.

The best method for converting the 10 day old fry from a live diet to a dry diet was to overlap the live and dry diet for a number of days rather than abruptly changing from one to the other.

Although the growth to 2.9 cm in 40 days was not as good as desired, the results were sufficient to recommend a feeding schedule of brine shrimp for 10 days, brine shrimp and algae for 5 days, brine shrimp and Master Mix F-45 starter for 5 days, then Master Mix F-45 starter alone for 20 days in the Tyler Bio-Disc System.

Further investigation should be made of using the Washington Diet for 5 day old fish with different particle size and composition.

Table 1. The results of feeding different diets to hybrid striped bass.

Aquarium Number	Diet	Stocking Rate (fry/liter)	Age of Fry (days) (when stocked)	Days Fed	T.L. Fry (cm) (at harvest)	Percent Survival
1	Cyclops (#1)	7.36	5	11	-	0
2	Chicken egg yolk (#2)	7.36	5	12	-	0
3	Cyclops & algae (#3)	7.36	5	11	-	0
4	Brine Shrimp (#4)	7.36	5	20	1.2	94
5	Brine Shrimp & algae (#5)	7.36	5	20	1.4	96
6	Master Mix (#6)	7.36	5	10	-	0
7	Brine shrimp, algae, & Master Mix (#7)	37.60	10	30	2.8	32
8	Brine shrimp algae, & Master Mix (#7)	4.60	10	30	2.9	56
9	Washington Flake (#8)	7.36	19	10	1.2	60
10	Master Mix (#6)	7.37	19	10	-	0.4

LOCATION AND DESCRIPTION OF STRIPED BASS SPAWNING GROUNDS, BRAZOS RIVER, TEXAS

by

Charles J. Mulford
Texas Parks and Wildlife Department
Fort Worth, Texas 76114

ABSTRACT

Natural reproduction of striped bass has occurred for the first time above Lakes Granbury and Whitney located on the Brazos River. Spawning locations were estimated from egg ages and average river velocities upriver from collection sites. Physical characteristics described at each spawning site were: river width, depth, volume and velocity of flow and water temperature. Striped bass reproduced further upriver and under a wider range of flow conditions than previously reported in the literature.

INTRODUCTION

A condition thought necessary for establishment of self-sustaining (reproducing) striped bass populations in reservoirs is that the river above must be able to suspend semi-buoyant striped bass eggs for the approximate 40-h incubation period (Stevens 1969). This condition has been satisfied in numerous areas throughout the South and West where spawning occurred at flow velocities ranging from 1.1 to 1.8 m/s (Woodhull 1947; Calhoun and Woodhull 1948; Tresselt 1952; Vladykov and Wallace 1952; Scruggs and Fuller 1955; Bayless 1972).

Brazos River flows above Lakes Granbury and Whitney were believed suitable for successful striped bass reproduction. Consequently, fingerling striped bass were stocked in Lake Granbury, 1972 thru 1976 and Lake Whitney 1973 thru 1976. If natural reproduction occurred, knowledge of spawning location would be useful to locate sources of brood fish for hatchery production; enable establishment of spawning sanctuaries if deemed necessary; enhance management decisions concerning future stocking of appropriate reservoirs; and insure adequate consideration for striped bass in final reservoir project designs. The objective of this study was to locate and describe principal spawning grounds of striped bass in the Brazos River above Lakes Granbury and Whitney.

I wish to express appreciation to the U. S. Fish and Wildlife Service for support of this study under the Federal Aid in Fish and Wildlife Restoration Program. Special credit is due T. Salmon and D. Boyd for aid in data collection. Mr. Salmon also assisted in compilation of data. I also wish to express appreciation to the various Department personnel who edited and reviewed the manuscript.

MATERIALS AND METHODS

The Brazos River section (Fig. 1) studied is located in North Central Texas approximately 70 km southwest of the Dallas-Fort Worth metroplex. The upstream boundary of the study section was Possum Kingdom Dam, which releases water from 24 m beneath the surface of Lake Possum Kingdom. Approximately 182 km downstream are headwaters of 3,521-ha Lake Granbury. Surface waters released from Granbury Dam flow approximately 111 km to the headwaters of 9,535-ha Lake Whitney.

Throughout the study area the Brazos River is characterized by narrow, shallow riffles and long, wide pools. The river bed varies from sand to large gravel. Physicochemical and biological characteristics have been described by Forshage (1972).

Various physical characteristics of the Brazos River were monitored daily, February thru May, 1977 and 1978. Flow rates were obtained from the United States Geological Survey (U.S.G.S.) for gaging stations near Palo Pinto, Dennis and Glen Rose (Fig. 1). Discharges from Lakes Granbury and Possum Kingdom were obtained from the Brazos River Authority. Velocity was determined with a General Oceanics, Model 2030 digital flowmeter during high and low flow periods. Daily water temperatures (mid-day) were collected below the Possum Kingdom and Granbury Dams and the U.S.G.S. gaging stations at Dennis.

Gill nets and electrofishing were used to monitor upstream movement and/or sexual development of mature striped bass. Multifilament gill nets were 30.5 m long and 2.4 m deep. Bar mesh sizes were 8.9 or 10.2 cm. Overnight gill net sampling was conducted biweekly, February thru April, 1977 and 1978 in the study area. Total amount of gill net set was 1158 m in 1977 and 2164 m in 1978. Electrofishing was conducted periodically below Granbury Dam, February thru April, 1977 and 1978 for approximately 8-10 h each year. Total length and weight were recorded and place of capture noted for each striped bass collected. Fish were sexed and gonadal condition determined using categories described by Scruggs (1957).

Egg collection in the river was not initiated until eggs taken from mature females caught in gill nets or by electrofishing were found within 15 h of ovulation, as described by Bayless (1972). Egg nets were funnel-shaped, 1-mm knitted nylon mesh fitted to a tubular plastic frame (1.2 m x 0.3 m) with a detachable cod end to allow sample removal.

Nets were set in the river at bridge crossings and other areas where access was available (Fig. 1). Two to four nets were fished at various levels between surface and bottom in the area of greatest current as determined with the flow meter. Nets were set weekly, April and May, 1977 and 1978 and fished for 2-4 h each sampling period; 27 h in 1977 and 33 h in 1978. Samples were removed at 0.5-h intervals and fish eggs and larvae preserved in formalin.

Pearson (1938), Bayless (1972) and Hogue et al. (1976) were used as guides to identify eggs and larval fishes. Striped bass egg ages (hours after fertilization) were determined using stages of egg development as described by Bayless (1972) and Brown and Hassler (1973).

Spawning locations were estimated from egg ages and average river velocities upstream from collection sites. Physical characteristics (width, depth, volume and velocity of flow and water temperature) were then collected at each spawning site. High flows in 1977 hindered collection of some data; consequently, width and depth were estimated, flow velocities were measured at river locations nearby and flow volumes were determined from Granbury Dam releases and Glen Rose gaging station readings.

Additional gill net and seine sampling was conducted in both lakes to substantiate successful spawns. Seining was done in May and June, 1977 with a 7.9-m bag seine (6.4-mm nylon mesh) at various sites near the river channel on brushy flats and near windswept beaches. Two 61-m drags were made in each area after sunset, and fishes were identified and sorted. A total length of 5550 m was seined. Seining was not done in 1978 since striped bass fingerlings were not collected by this method in 1977. Gill net sampling was done October thru December, 1977 and 1978 with 45.7- x 2.4-m multifilament nets with bar mesh of 2.5 or 3.8 cm. Overnight sets were made near long tapering points, beaches and brushy flats near deep water. Sets were made throughout the lakes in 1977; however, nets were fished in lower reservoir areas in 1978 where striped bass were found to concentrate in fall and winter. Total amount of gill net set was 2070 m in 1977 and 2330 m in 1978. Total length and weight were recorded and a scale sample taken from each striped bass netted. Young-of-the-year fish were identified as those displaying no annuli on projected scales.

RESULTS AND DISCUSSION

Adult striped bass were widely dispersed in the Brazos River throughout the study area during the 1977 spawning season. This was particularly true between Lake Whitney and Granbury Dam where 60 fish were collected at 10 different sites. Of these fish, 82 percent were collected after massive water releases from Granbury Dam on 28 and 29 March (mean daily discharge, 1014 m^3/s) and 73 percent were caught immediately below Granbury Dam. Only two adult fish were collected between Lake Granbury and Possum Kingdom Dam.

In 1978, movements of adult striped bass were apparently much reduced. No fish were collected between Lake Granbury and Possum Kingdom Dam. Only 12 fish were netted between Lake Whitney and Granbury Dam, all of these being caught within approximately 34 km of Lake Whitney headwaters. Two additional striped bass were caught by electrofishing immediately below Granbury Dam. This restricted distribution of adult striped bass probably resulted from lower flows in 1978 (Table 1), since mean monthly volumes of flow were significantly lower in 1978 than in 1977 ($t = 5.70$; df = 38; $P < 0.05$). There was insufficient water in many riffle areas in 1978 to allow migration.

In both years, mature striped bass were collected immediately above Granbury Dam during the height of the spawning season. These fish were probably attracted by discharge currents associated with surface water releases from Lake Granbury.

Data regarding collection of adult striped bass raises serious questions about upstream migration as reported by Smith (1969) and Erickson (1975). If striped bass migrated upstream during the spawning season, more than two fish should have been collected above Lake Granbury, especially since flows above both reservoirs (Table 1) did not differ significantly ($t = 1.87$; df = 18; $P < 0.05$). It seems unlikely fish would migrate upriver from Lake Whitney and not from Lake Granbury when exposed to similar stimuli. Both up and downstream migration were noted by Scruggs (1957) and Scruggs and Fuller (1955) in Cooper River, South Carolina and by Combs (1976) above Keystone Reservoir, Oklahoma. The abundance of striped bass in the river between Lakes Granbury and Whitney in 1977 possibly resulted from downstream migration of striped bass over the Granbury Dam. The extremely high discharges over Granbury Dam on 28 and 29 March could easily have carried fish downstream, especially since mature fish were previously found immediately above the dam.

In 1977, no striped bass eggs were collected upstream from Lake Granbury; therefore, location of spawning sites was not possible. However, 17 eggs were collected in surface nets upriver from Lake Whitney at two collection sites on 18 and 19 April (Table 2, Fig. 1). Mean egg diameter was 2.8 mm. Two spawning locations were determined to be approximately 51 and 109 km above Lake Whitney (Fig. 1). At the upper site, which was just downstream from Granbury Dam, the river was about 81 m wide and 3 m deep. Flow volume was 61.6 m^3/s, flow velocity 1.3 m/s and water temperature 19 C. At the lower site the river was approximately 94 m wide and 3 m deep. Flow volume was 35.4 m^3/s, flow velocity 0.8 m/s and water temperature 20 C.

On 1 and 10 May, 1978, 24 striped bass eggs were collected in surface nets upriver from Lake Granbury at one collection site (Table 2, Fig. 1). Mean egg diameter was 2.7 mm. These eggs all came from the same spawning area determined to be approximately 151-164 km above Lake Granbury, just downstream from Possum Kingdom Dam (Fig. 1). At this site the river was characterized by a series of pools approximately 78 m wide and 2 m deep with a flow volume of 1.4 m^3/s, a flow velocity of 0.2 m/s and a water temperature of 23 C. Twenty-one striped bass eggs were collected in surface nets upriver from Lake Whitney at three collection sites 25 April thru 4 May, 1978 (Table 2, Fig. 1). These eggs (mean diameter 2.7 mm) came from two spawning locations determined to be at approximately the same locations as in 1977. At the upper site the river was about 46 m wide and 2 m deep with a flow volume of 0.6 m^3/s, a flow velocity of 0.03 m/s and a water temperature of 20 C. At the lower site the river was approximately 67 m wide and 2 m deep with a flow volume of 1.5 m^3/s, a flow velocity of 0.01 m/s and a water temperature of 22 C.

Low flow conditions in 1978 (Table 1) made it impossible for mature striped bass to migrate upsteam from Lake Whitney to the lower spawning site, except during a 72-h discharge (15 m^3/s) from Granbury Dam, 11-14 April. Such "attraction" discharges may be necessary to allow mature striped bass to reach suitable spawning areas when low flows occur during the spawning season.

During the 1977 spawning season, water temperatures above both reservoirs showed a similar, gradual warming trend (Table 1). However, in 1978 February water temperatures were considerably lower than those in 1977, and were followed by an abrupt warming during March and April. This probably caused spawning in 1978 to occur 1-2 wk later.

Flow velocities at 1978 spawning sites were considerably less than those reported in other studies. Vladykov and Wallace (1952) noted spawning grounds in Maryland were located in reaches of rivers where velocities were 1.1-1.3 m/s. Scruggs (1957) reported striped bass spawning in South Carolina rivers where the average flow velocity was 1.8 m/s. Collection of eggs in surface nets during extremely low flows in the Brazos River may have been attributed to relatively high salinity which may exceed 1.9 ppt (Forshage 1972). This salinity would improve buoyancy of eggs and make flow velocity less important.

Two of the three spawning grounds located in this study were further upstream from the reservoirs (151-164 and 109 km above Lakes Granbury and Whitney, respectively) than those reported elsewhere. Scruggs (1957) noted striped bass spawned approximately 17 km above Lake Marion in the Conagree River, South Carolina. Neal (1968) reported spawning grounds were located 40-61 km above Kerr Reservoir, Virginia in the Roanoke River and 39-72 km in the Dan River. Since the two distant spawning grounds in this study were located in close proximity to Possum Kingdom and Granbury Dams, they may represent areas utilized by resident tailrace populations of striped bass.

Although no eggs were collected above Lake Granbury in 1977, spawning apparently occurred, as two young-of-the-year striped bass were netted from the lake that fall. The collection of 11 young-of-the-year striped bass from Lake Whitney confirmed spawning above that reservoir.

In 1978, no striped bass young-of-the-year were collected in Lake Granbury, even though eggs had been collected upstream. However, 58 young-of-the-year striped bass collected in Lake Whitney confirmed another spawning above that reservoir.

CONCLUSIONS

Striped bass spawned in 1977 and 1978 above both Lakes Granbury and Whitney under a wide range of flow conditions. The 1978 spawns at flow velocities far less than those of 1977 indicate flows in the Brazos River are not as important to successful striped bass reproduction as thought.

Figure 1. Gaging stations (∗), egg net sites (○) and striped bass spawning areas (●-●-●) on the Brazos River, Texas, 1977-78.

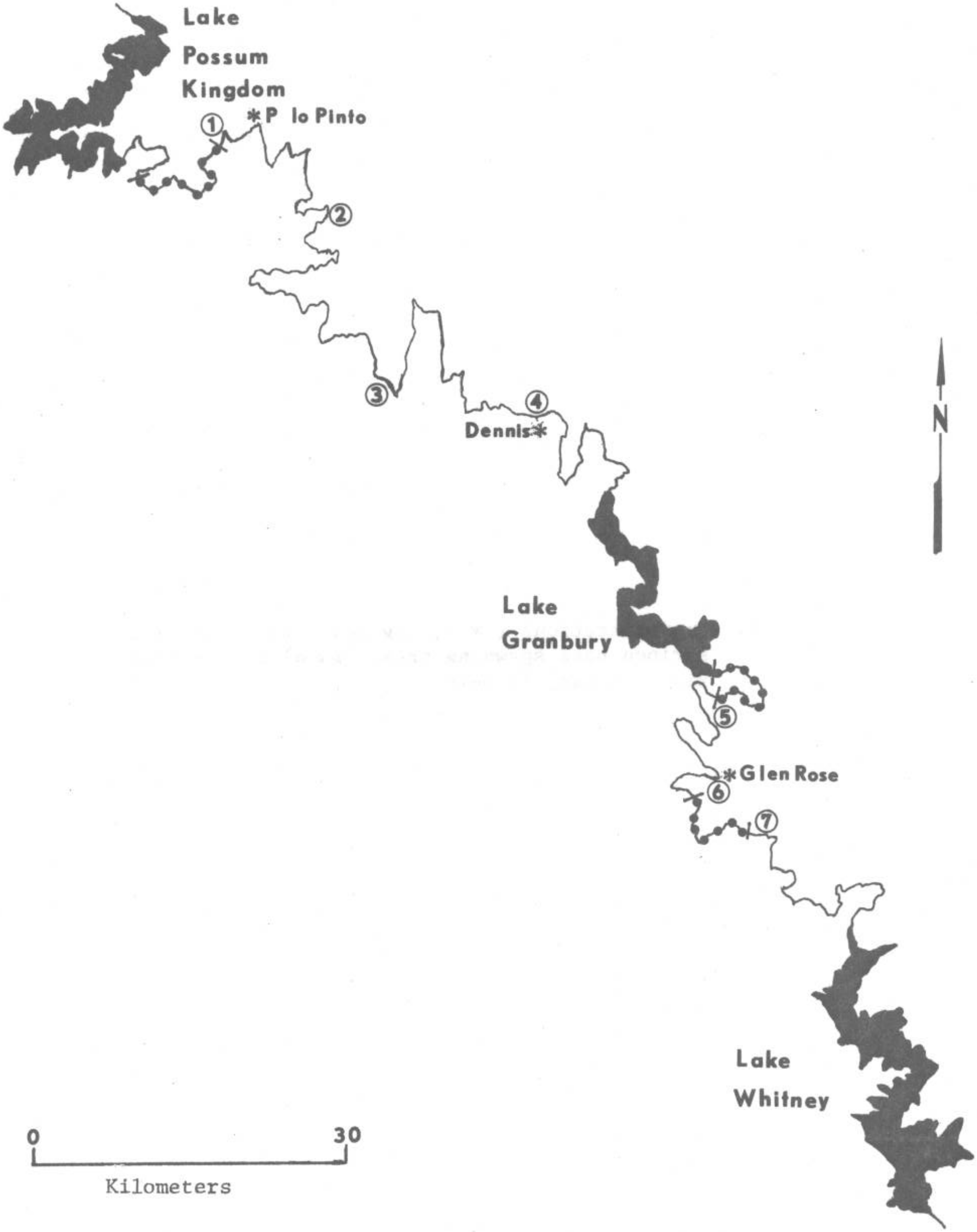
Lake
Possum
Kingdom
①
*Palo Pinto
②
③
④
Dennis*
Lake
Granbury
⑤
*Glen Rose
⑥
⑦
Lake
Whitney
N
0
30
Kilometers

Table 1. Mean monthly volumes of flow (m^3/s) and water temperatures (C) monitored at U.S.G.S. gaging stations and Possum Kingdom and Granbury Dams, Brazos River, Texas, February thru May, 1977-78.

Physical Characteristic	Sampling Station	1977				1978			
		Feb.	Mar.	Apr.	May	Feb.	Mar.	Apr.	May
Volume of Flow	Possum Kingdom Dam	3.62	1.53	25.43	34.89	2.18	1.05	0.57	3.06
	Palo Pinto	5.75	7.87	26.65	40.30	2.92	1.64	3.74	2.97
	Dennis	10.93	60.21	44.46	57.77	3.46	1.81	10.99	3.85
	Granbury Dam	14.53	76.18	40.55	57.89	2.21	2.24	3.48	5.48
	Glen Rose	12.55	83.29	37.24	47.52	2.21	2.21	3.14	3.77
Water Temperature	Possum Kingdom Dam	13.1	13.9	16.2	---	6.6	12.2	16.9	---
	Dennis	14.7	17.2	20.4	---	7.4	15.7	24.2	25.5
	Granbury Dam	10.2	13.8	18.0	---	4.4	9.8	17.0	19.6

Table 2. Striped bass egg collection data, Brazos River, Texas, 1977-78.

Date	Location* (Station No.)	Mean Velocity of Flow (M/S)	Mean Water Temperature ($^{\circ}$C)	Number of Eggs Collected	Hours After Fertilization	Egg Displacement (km)
04-18-77	FM 56 (7)	0.79	20	7	4.3	12.2
04-19-77	Hwy. 67 Bridge (6)	0.61	20.4	10	21.7	47.1
04-25-78	Mitchell Bend (5)	0.27	21.4	4	13.1 - 30.4	12.4 - 28.7
04-27-78	FM 56 (7)	0.15	23.3	15	5.2 - 11.2	3 - 6.5
05-03-78	Mitchell Bend (5)	0.55	15.8	1	10	19.6
05-04-78	Hwy. 67 Bridge (6)	0.34	16.4	1	52	64.5
05-01-78	Hwy. 4 Bridge (1)	0.18	25.8	2	7.5	4.9
05-10-78	Hwy. 4 Bridge (1)	0.18	22.5	22	1.8 - 27.8	1.2 - 18.3

* See Fig. 1 for station number location.

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COMPARISON OF GROWTH RATES, SEX RATIOS, REPRODUCTIVE SUCCESS AND CATCHABILITY OF THREE SUNFISH HYBRIDS

by

Paul S. Crandall
Texas Parks and Wildlife Department
Ingram, Texas 78025

Philip P. Durocher
Texas Parks and Wildlife Department
Austin, Texas 78744

ABSTRACT

Hybrid sunfish, male bluegill (*Lepomis macrochirus purpurescens*) x female green (*Lepomis cyanellus*), male bluegill x female redear (*Lepomis microlophus*), and male green x female redear were stocked in ponds and their growth, sex ratios, reproductive success, and catchability compared. Bluegill x green and green x redear hybrids exhibited the fastest growth with bluegill x green showing the best overall growth and condition. All three hybrids were predominantly males. Reproduction occurred, but appeared to be less than that of parent species. Bluegill x green hybrids were the easiest to catch on baits tested.

INTRODUCTION

The high reproductive potential of sunfishes (*Lepomis* spp.) often results in overabundant stunted populations. Fishery managers have experimented with various approaches to the solution of this problem with some degree of success. One popular area of study has been the use of sunfish hybrids.

Hybridization experiments involving green sunfish (*L. cyanellus*), bluegill (*L. macrochirus*) and redear sunfish (*L. microlophus*) have produced several types of hybrids which appear less prolific and faster growing than their parent species. Henderson and Whiteside (1975) reported average absolute growth rate of male green x female redear hybrids was greater than that of either green or redear sunfish. Ricker (1948) stated the rate of reproduction of male bluegill x female redear hybrids in Indiana ponds was so low that overcrowding did not occur and their growth was relatively rapid throughout life. Childers and Bennett (1961) indicated that in high density populations, the male bluegill x female green hybrid would grow faster than their parent types because of this hybrid's superior ability to compete for food and space. These reports show the benefits from sunfish hybridization, but comparisons are needed between various crosses to identify the most desirable hybrid(s). The present study was conducted to evaluate growth rates, sex ratios, reproductive success, and catchability of bluegill x green, bluegill x redear, and green x redear hybrids to determine which would be most suitable for stocking in Texas waters.

Appreciation is expressed to hatchery personnel and biologists of the Texas Parks and Wildlife Department who assisted in collection of data. Special thanks are extended to hatchery superintendent George White for maintaining the hybrid sunfish ponds and assisting in all phases of the sampling operations.

MATERIALS AND METHODS

All experiments were conducted at the Lewisville Fish Hatchery in Denton County, Texas. The water supply is from Lewisville Reservoir adjacent to the hatchery and is slightly alkaline (total alkalinity approximately 115 ppm) with an average pH of 8.2 and total hardness of 137 ppm.

During May, 1976, male bluegill x female green (BG), male bluegill x female redear (BR), and male green x female redear (GR) hybrids were produced by pairing mature parents in nursery ponds. Parents were sexed before stocking to assure proper pairings.

The subspecies of bluegill, *lepomis macrochirus purpurescens* was chosen for the BG and BR crosses because it generally attains a larger size and grows faster than *L. m. macrochirus* (Hubbs and Allen, 1944).

In July, 1976, nursery ponds were drained and fingerling F_1 hybrids collected and stocked into 12 rearing ponds (four ponds/hybrid cross) at a rate of approximately 1500/ha. Ponds ranged from 0.23 to 0.34 ha, and the water supply for each pond was filtered with fine-meshed saran (20 meshes/cm) sock filters to prevent contamination by other fish species. At the time of stocking, 200 hybrids of each cross were individually weighed (gm) and measured (TL in mm) to determine mean size. Hybrids in half of the ponds were used to compare hybrid growth rates (two ponds/hybrid). Those in the remaining ponds were used for catchability experiments.

Rearing ponds were drained during the autumn of 1977 and again in 1978, and hybrids collected for measurement. Those collected in 1977 were held in concrete troughs; approximately 50 of each hybrid were anesthetized with quinaldine and individually weighed and measured and subsequently dissected for sex ratio determinations. Growth data (length and weight) were compared by analysis of variance to test for differences between years, and hybrids. Von Bertalanffy growth curves (Ricker 1975) were also calculated. Length-weight relationships were used to compare condition.

Hybrid offspring (F_2) were removed and counted each year to compare reproductive success. In 1977, after all fish were removed, ponds were refilled and restocked with remaining F_1 hybrids from the original stock.

Catchability experiments were conducted during June, 1978. For 4 days, each of the six angling ponds was fished by two anglers for 1 h. One angler used an artificial lure (dry flies) and the other live bait (earthworms) fished near the bottom. The sequence in which ponds were sampled was chosen at random for the first sampling day and rotated daily so all ponds were sampled at different times. Catch was recorded as number of hybrids caught for each angling hour. During the week following fishing, each pond was drained and hybrids counted to determine number present.

Catches were converted to percentages [(catch per hour/number present) x 100] and tested for differences between hybrids and bait types using a 3 x 2 factorial design (three hybrids, two bait types) with eight replications (angler hours) per combination. Percentages were transformed (arcsin transformation) for analysis.

RESULTS AND DISCUSSION

Growth Rates

The BG, BR, and GR hybrid sunfishes were similar in size at the time of stocking (Table 1). During their first year of life, BG and GR attained larger sizes, in terms of length and weight than BR. BG continued to grow faster through the 1978 growing season, but in this same period the average growth of BR surpassed GR. By the end of the study period, mean lengths of BG and GR were significantly greater ($P < 0.05$). Although there was no significant difference in mean lengths between BG and GR, BG hybrids were larger and the mean weight exceeded that of GR. Von Bertalanffy growth curves illustrated BG began growing more rapidly during their second year of life (Figure 1). Comparisons of the hybrids' length-weight relationships revealed the greater weight gains of BG for each increase in length (Figure 2).

Several factors probably contributed to the greater growth and superior condition of BG during their second year. This hybrid may be more capable of utilizing small fish as a food item. All ponds contained a relatively large number of small sunfish (hybrid offspring) and during sampling operations in 1978, several regurgitated sunfish were noted in troughs containing BG hybrids. Bailey and Lagler (1938) evaluated growth of the BG reciprocal cross and concluded that when a sunfish reached a size permitting a fish-eating diet, the environmental restraint to growth was removed.

Another factor which may have contributed to the greater overall growth of BG was the reduced density of this hybrid in one pond, due to winter mortalities. However, BG hybrids in the replicate pond were also longer and heavier than either BR or GR, and their survival rate over the 2-year period was similar to that of the other two hybrids.

Information from available literature suggests the density of hybrids in all ponds was not high enough to inhibit their growth rates. The original stocking rate (1500/ha) was lower than those recommended by other investigators. Lewis and Heidinger (1973) suggested stocking male redear x female green sunfish at approximately 2,000 fingerlings/ha for good growth and Ricker (1948) reported excellent growth of BR hybrids (454 gm in 3 yr) stocked at densities of 5,000 fingerlings/ha.

According to Lewis and Heidinger (1971), there is enough natural food in most warmwater, unfertilized ponds to support a standing crop of almost 340 kg of fish/ha. The highest standing crop of sunfish observed in the present study was 295 kg/ha. This standing crop occurred in a pond containing BG hybrids and is further indication that the more rapid growth of BG was independent of density.

Sex Ratios

Hybrids (F_1) produced in this study were predominantly males with GR hybrids exhibiting the greatest imbalance in sex ratios. The percentage of males in the four ponds containing this hybrid ranged from 93-95%. The percentages of males were much lower for BG (66-78%) and BR hybrids (62-72%). Results from hybrid sunfish studies in other states differ from these findings. Childers (1967) investigated sex ratios of laboratory-produced hybrids in Illinois and found the percentage of males was relatively low among GR (48%) and high among BG and BR (97% each). A similar imbalance (97% males) was noted for BR hybrids in Indiana (Ricker, 1948) and for BG hybrids (87% males) in Michigan (Laarman 1973).

Differences in hybrid sunfish sex ratios were discussed by Lewis and Heidinger (1973) who stated such discrepancies were due to genetic differences in parental fish from different areas. In support of this statement, the sex ratios of GR hybrids investigated in Texas ponds by Henderson and Whiteside (1975) was similar (99% males) to those in the present study. The relatively low percentage of males for BG and BR hybrids produced at the Lewisville hatchery may be attributed to the subspecies of bluegill (*L. m. purpurescens*) used for these crosses.

Because hybrid sunfishes are predominantly males, the extent of their reporduction has been considered dependent on the number of F_1 hybrid females present (Henderson and Winckler, 1968). Using this criterion, the BR hybrids (28-38% females) had the greatest reproductive potential followed by BG (22-34% females) and GR (5-7% females); however, actual numbers of F_2 hybrids collected from ponds are contradictory. Combining 1977 and 1978, the greatest number of F_2 hybrids were collected in ponds containing GR (67,487), followed by BR (30,462) and BG (19,031). Because ponds were drained in the fall (3-5 months after spawning), this may be more an indication of survival than reproductive success. The inadvertent stocking of largemouth bass (*Micropterus salmoides*) in one pond containing BR hybrids during 1978 may have adversely affected both reproductive success and survival of the F_2 offspring. Predation by parent F_1 hybrids may also have affected survival.

Results from other studies on reproductive success of sunfish hybrids are also inconsistent. Henderson and Whiteside (1975) investigated GR hybrids and stated no offspring were produced in a pond containing three pairs of mature F_1 hybrids. In constrast, Henderson and Winckler (1968) reported an average of 300 offpsring were reared per GR female in small hatchery ponds. Childers (1967) found an abundance of F_2 hybrids were produced by GR, but the exact quantities were not given. According to Childers and Bennett (1961), BG and BR failed to produce offspring in two Illinois ponds. In contrast, Laarman (1973) documented reproduction of BG in three small research impoundments, and Ricker (1948) reported abundant F_2 generations were produced by BR in Indiana ponds.

Although F_1 hybrids in the present study reproduced, the number of offspring which survived through their first summer was relatively low for all crosses. Although a sterile hybrid was desired, the relatively low number of offspring surviving may serve to sustain hybrid populations without problems of overpopulation and stunting. Unfortunately, the fertility of these hybrids will probably permit them to backcross with their parents and outcross with other species. To be a more effective management tool, BG, BR, and GR introductions should be made in waters free of other sunfish.

Catchability

Differences between the percent catch of the three hybrids and the two bait types were highly significant ($P < 0.01$). A test of means showed the catch of BG to be significantly greater ($P < 0.05$) than the other two hybrids (Figure 3). BG hybrids were the easiest to catch on both artificial lures and live bait. There was no significant difference in the total catch of BR and GR. In comparing these two hybrids, BR was caught almost exclusively on live baits, whereas GR were more vulnerable to artificial lures.

The vulnerability of BG to angling was first documented by Childers (1967) who noted problems of overharvest. He reported anglers completely eliminated a natural population of BG hybrids (approximately 10,000 fish) from a lake during the opening week of fishing. Reasons for the relatively high catchability of BG in the study are not apparent, but it may be related to behavioral characteristics peculiar to this hybrid. Childers and Bennett (1967) observed responses of hybrids to baited hooks and concluded some kinds of hybrid sunfishes are more aggressive than others, less wary, and less able to learn by observation how to avoid being caught. It was obvious to fishermen who participated in the catchability experiments that BG hybrids were considerably more vulnerable to angling. Supplemental stockings of this hybrid may be necessary to sustain a fishery.

CONCLUSIONS AND RECOMMENDATIONS

Because of its rapid growth, good condition, and high catchability, the BG hybrid is more desirable than BR and GR for stocking in Texas waters. BR and GR grew somewhat slower than BG and were significantly harder to catch.

Even though the percent F_1 females was high (22-34%), numbers of BG (F_2) offspring which survived through the first summer were low and unlike the parent species, supplemental stockings of this hybrid may be necessary to maintain the fishery. Because the possibility of back crossing does exist, it may be necessary to stock this hybrid in waters with no established sunfish populations.

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Table 1. Mean length (mm), weight (gm), and increments of male bluegill x female green (BG), male bluegill x female redear (BR), and male green x female redear (GR) F_1 hybrid sunfish from Lewisville State Fish Hatchery, Lewisville, Texas, 1976-78. Means are from a sample of 100 fish for each hybrid, each year. Stocking rate was 1500/ha.

	BG		BR		GR	
	Length	Weight	Length	Weight	Length	Weight
1976	38(0.27)*	0.9(0.02)	39(0.52)	1.0(0.05)	31(0.40)	0.8(0.02)
Increment	160	181.1	142	122.0	166	152.2
1977	198(1.35)	182.0(5.86)	181(0.76)	123.0(1.92)	197(0.86)	153.0(2.30)
Increment	22	70.0	12	15.0	6	7.0
1978	220(0.91)	252.0(4.13)	193(0.83)	138.0(2.11)	203(0.65)	160.0(2.06)

* ( ) Denotes standard error.

Figure 1. Von Bertalanffy growth curves and equations for male bluegill x female green (BG), male bluegill x female redear (BR), and male green x female redear (GR) F_1 hybrid sunfishes, Lewisville State Fish Hatchery, Lewisville, Texas, 1976-1978. L_t = Length at age t, T = time when length would theoretically be zero.

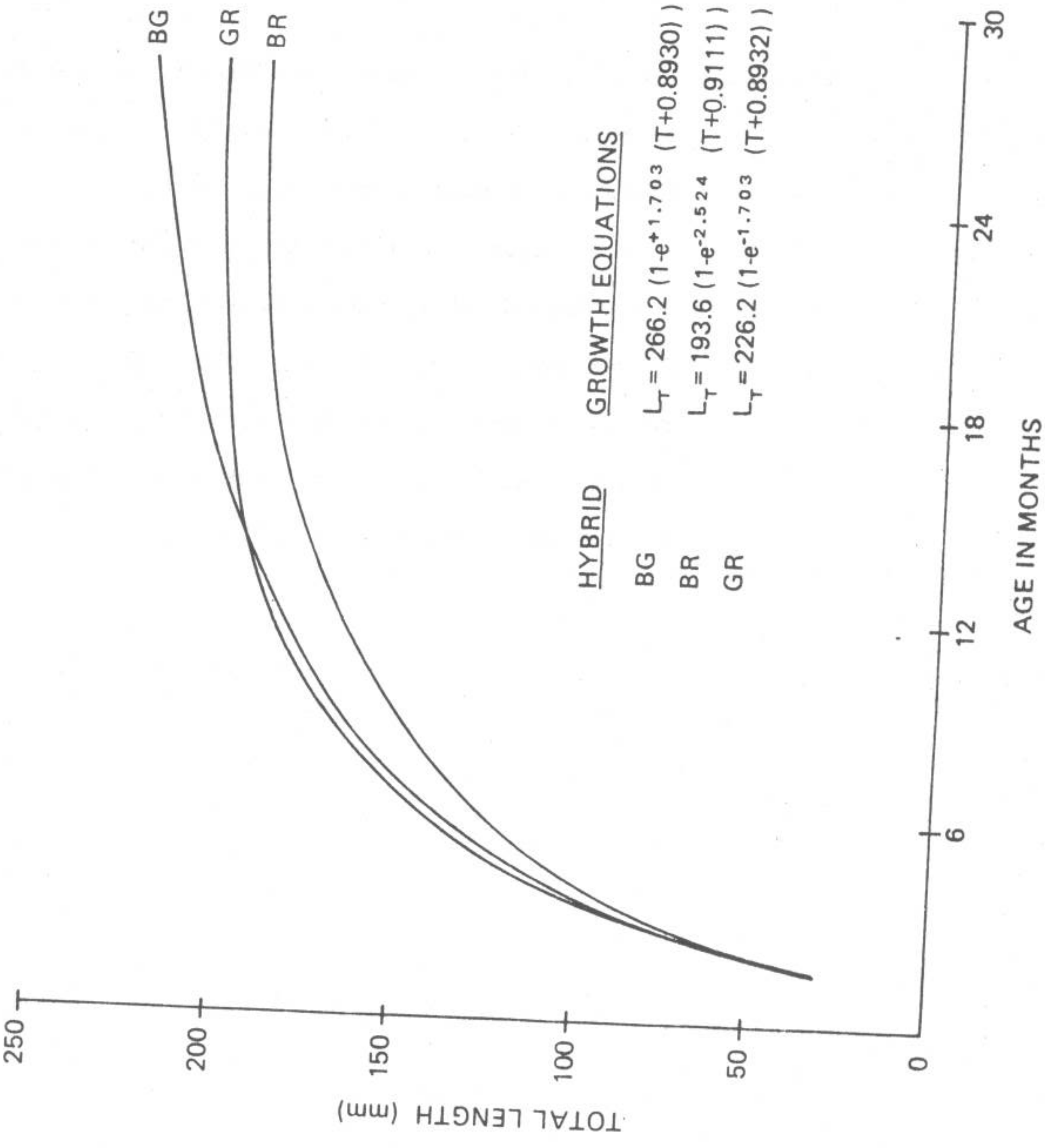

TOTAL LENGTH (mm)
0
50
100
150
200
250
AGE IN MONTHS
6
12
18
24
30
BG
GR
BR
HYBRID
GROWTH EQUATIONS
BG $L_T = 266.2\ (1-e^{+1.703}\ (T+0.8930)\ )$
BR $L_T = 193.6\ (1-e^{-2.524}\ (T+0.9111)\ )$
GR $L_T = 226.2\ (1-e^{-1.703}\ (T+0.8932)\ )$

Figure 2. Length (lt)(mm) - weight (wt)(gm) relationships of male bluegill x female green (BG), male bluegill x female redear (BR), and male green x female redear (GR) F_1 hybrid sunfish, Lewisville State Fish Hatchery, Lewisville, Texas 1976-1978. Curves were derived from the following logarithmic relationships: BG, Log(wt) = -5.008 + (3.160) Log(lt); BR, Log(wt) = -5.138 + (3.191) Log (lt); GR, Log(wt) = -4.229 + (2.793) Log(lt).

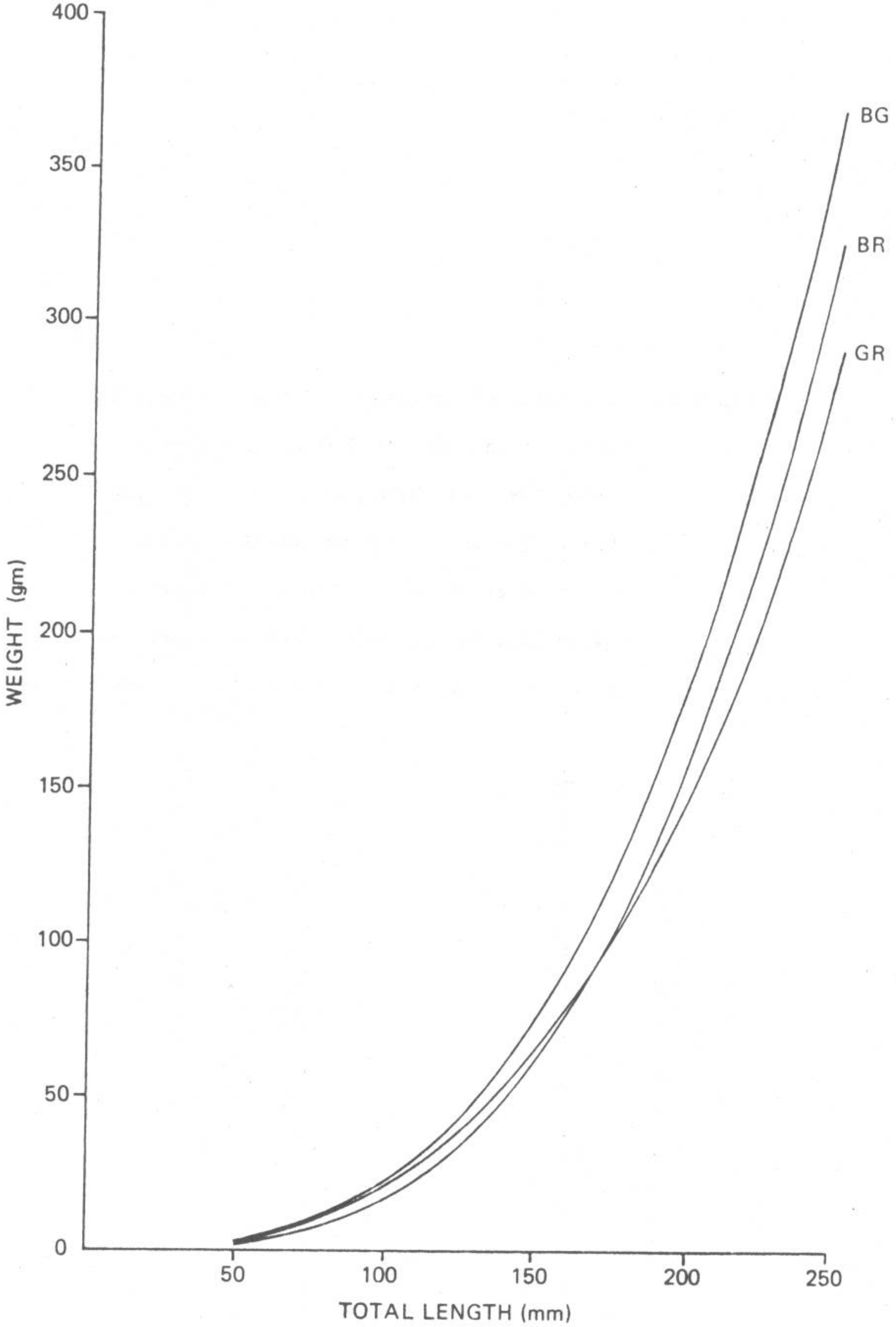
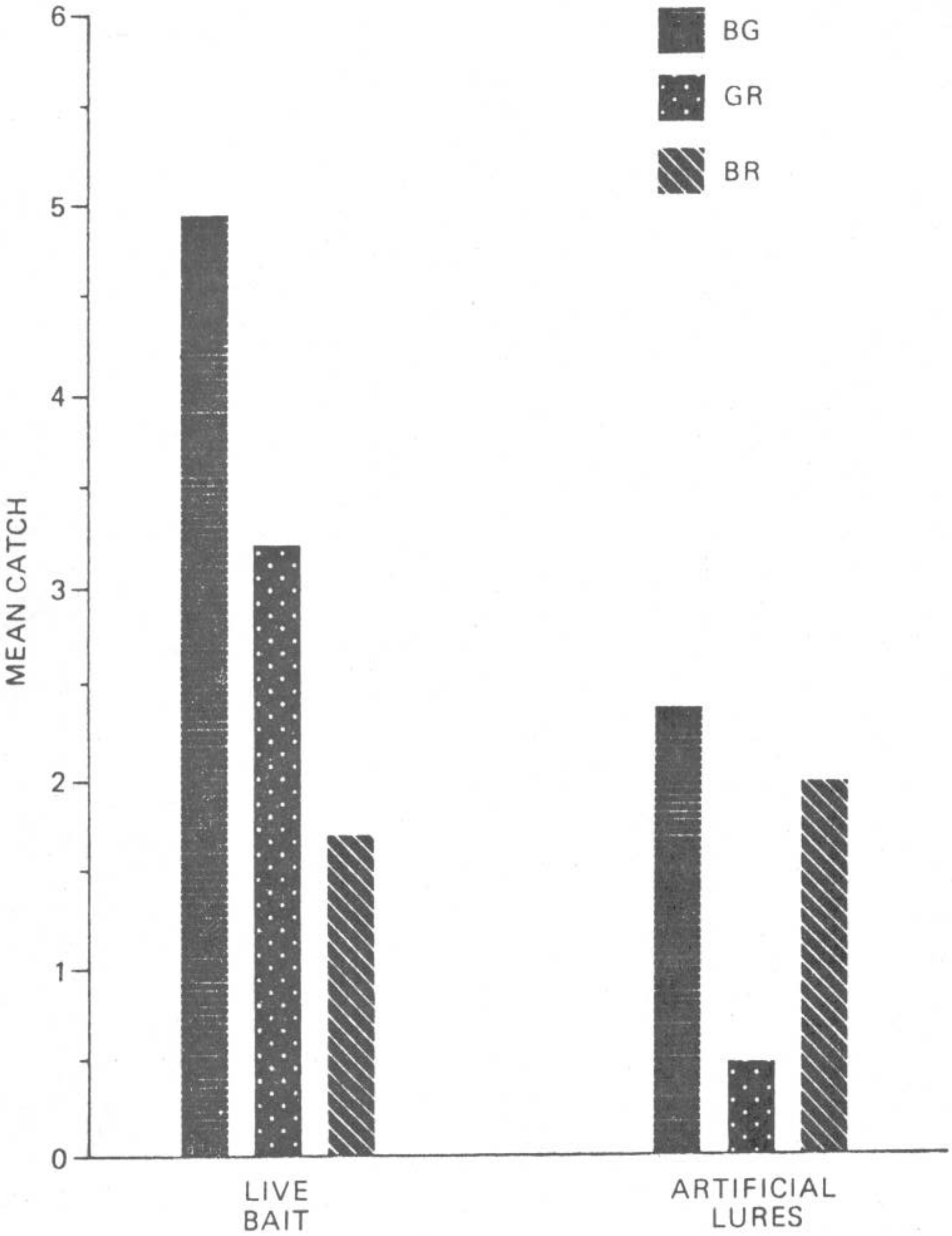

400
350
300
250
200
150
100
50
0
WEIGHT (gm)
50
100
150
200
250
TOTAL LENGTH (mm)
BG
BR
GR

Figure 3. Mean catch per angler hour of male bluegill x female green (BG), male bluegill x female redear (BR), and male green x female redear (GR) F_1 hybrid sunfish on artificial lures and live bait at Lewisville State Fish Hatchery, Lewisville, Texas, 1978. Catch expressed as [(number caught/total number present) x 100].



6
5
4
3
2
1
0
MEAN CATCH
BG
GR
BR
LIVE BAIT
ARTIFICIAL LURES

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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