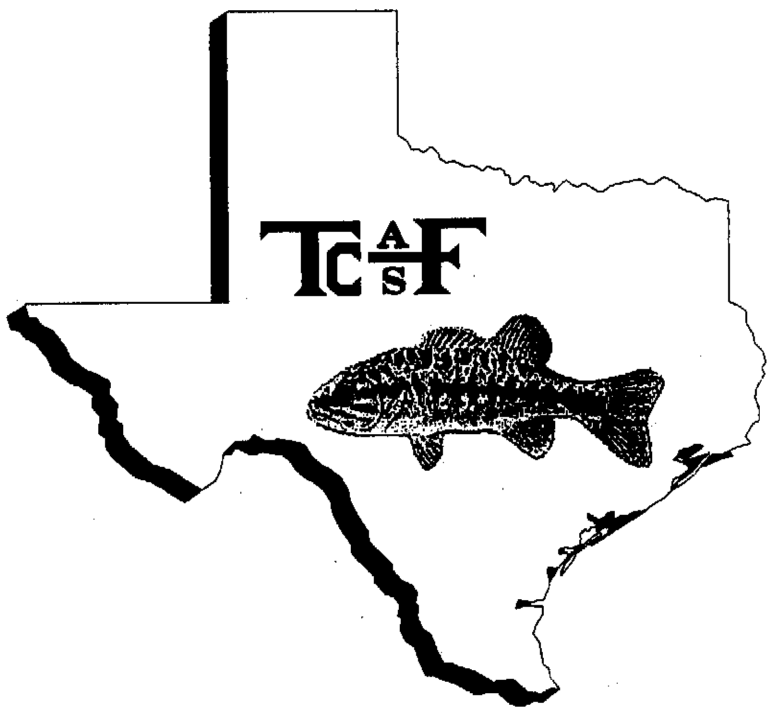
ANNUAL PROCEEDINGS of the TEXAS CHAPTER

AMERICAN FISHERIES SOCIETY



Athens, Texas
25 - 27 January 1998

VOLUME 20

TEXAS CHAPTER

AMERICAN FISHERIES SOCIETY

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

MEMBERSHIP

Persons interested in the Texas Chapter and its objectives are eligible for membership and should apply to:

Texas Chapter, American Fisheries Society
Secretary-Treasurer
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744

Annual membership dues are $8 for Active Members and $5 for Student Members.

ANNUAL PROCEEDINGS OF THE TEXAS CHAPTER AMERICAN FISHERIES SOCIETY

Annual Meeting
25-27 January 1998
Athens, Texas

1998 - 1999 Officers

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1999

Published by:
Texas Chapter, American Fisheries Society
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4200 Smith School Road
Austin, Texas 78744

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Technical Papers Presented at the Annual Meeting and Peer-Reviewed for Publication

PAST TEXAS CHAPTER PRESIDENTS AND MEETING LOCATIONS

DATE	PRESIDENT	LOCATION
1976		College Station
1976	Ed Bonn	Lake Brownwood
1977	Jim Davis	San Antonio
1978	Bill Rutledge	San Marcos
1979	Bobby Whiteside	College Station
1980	Richard Noble	Arlington
1981	Charles Inman	Austin
1982	Gary Valentine	Kerrville
1983	Don Steinbach	Lake Texoma
1984	Gary Matlock	Port Aransas
1985	Maury Ferguson	Junction
1986	Brian Murphy	San Marcos
1987	Joe Tomasso	Kerrville
1988	Dick Luebke	Abilene
1989	Mac McCune	San Antonio
1990	Bobby Farquhar	Lake Texoma
1991	Gene McCarty	Galveston
1992	Bill Provine	Kerrville
1993	Barbara Gregg	Port Aransas
1994	Loraine Fries	Lake Travis
1995	Pat Hutson	College Station
1996	Mark Webb	Pottsboro
1998	Katherine Ramos	Athens
1999	John Prentice	Corpus Christi

TEXAS CHAPTER AWARDS

Eight awards may be presented annually. Only members in good standing may make nominations. If nominations reviewed by the Awards Committee are found to be inadequate in one or all categories, awards need not be given. If multiple nominations are received and more than one nominee is considered outstanding, multiple recipients are permissible. The awards and their associated criteria are:

Outstanding Fisheries Worker of the Year - The nominees must be Chapter members in good standing. There are six specialization categories: Administration, Culture, Education, Management, Research, and Technical Support. An award may be presented in each area of specialization. All nominations must be accompanied by supporting data on contributions to one particular area of focus.

Special Recognition in Fisheries Work - The nominees do not have to be Chapter members. They may be individuals or organizations that have made substantial contributions to fisheries in Texas.

Outstanding Presentation at the Annual Meeting - The basic requirements are:

a. The presentation must be made by one of the authors.
b. At least one of the authors must be a Chapter member in good standing.
c. Members of the current Awards Committee shall be ineligible.

The award is for the presentation, not a manuscript or paper. Criteria for evaluation, made by the Awards Committee, and their relative values are:

a. Introduction - 10 points
b. Methods - 10 points
c. Organization - 10 points
d. Originality - 15 points
e. Technical Merit - 20 points
f. Delivery - 15 points
g. Visual Aids - 15 points
h. Other considerations - 5 points

Judges will evaluate each presentation immediately after it is given. They will not confer until after the last presentation. The decision will be made based on relative rankings assigned by the judges.

Scholarship Selection - Selection of scholarship recipients is made by members of the Scholarship Selection Committee. University representatives nominate students from their institutions for scholarship consideration. Selection is based on the following criteria:

a. Academic excellence
b. Professional activities
c. Promise of future professional involvement and significant contribution to the field of fisheries science.

TEXAS CHAPTER AWARDS RECIPIENTS

1977 Fish Culture - Don Steinbach (TAMU)
Fisheries Management - Edward Bonn (TPWD)
Fisheries Administration - David Pritchard (TPWD)
Fisheries Research - John Prentice and Richard Clark (TPWD)

1978 Fish Culture - Pat Hutson (TPWD)
Fisheries Education - Clark Hubbs (UT)
Fisheries Research - Clark Hubbs (UT)
Special Recognition - Edward Lyles (USFWS)

1979 Fish Culture - Robert Stickney (TAMU)
Fisheries Education - Richard Noble (TAMU)
Fisheries Management - Gary Valentine (SCS)
Fisheries Research - Phil Durocher (TPWD)
Special Recognition - Charles Inman (TPWD)

1980 None

1981 Fish Culture - Billy White (TPWD)
Fisheries Education - Bobby Whiteside (SWTSU)
Fisheries Management - Steve Smith (TUGC)
Fisheries Research - Al Green (TPWD)
Special Recognition - Jim Davis (TAMU)

1982 Fish Culture - Roger McCabe (TPWD)
Fisheries Research - Clell Guest (TPWD)
Special Recognition - Bob Hofstetter (TPWD)

1983 Special Recognition - Robert Kemp (TPWD)

1984 None

1985 Fisheries Education - Donald Wohlschlag (UTMSI)
Fisheries Research - Connie Arnold (UTMSI)

1986 Fisheries Management - Billy Higginbotham (TAES)
Fisheries Research - Robert Colura (TPWD)

1987 Fish Culture - Kerry Graves (USFWS)
Special Recognition - The Sportsmen's Club of Texas
Best Presentation - Kerry Graves (USFWS)

1988 Honorable Mention (culture) - Loraine Fries (TPWD)
Fisheries Research - Gary Garrett (TPWD)
Special Recognition - Kirk Strawn (TAMU)
Best Presentation - Joe Fries (USFWS)
Honorable Mention (presentation) - Catherine Dryden (TAMU)

1989 Fish Culture - Robert Vega (TPWD)
Fisheries Management - Joe Kraai (TPWD)
Fisheries Administration - Gary Matlock (TPWD)
Fisheries Research - Roy Kleinsasser and Gordon Linam (TPWD)
Honorable Mention (research) - Bob Edwards (UTPA)
Best Presentation - Robert Smith (TAMU)

1990 Fish Culture - Glen Alexander and David Campbell (TPWD)
Fisheries Management - Dave Terre (TPWD)
Fisheries Administration - Gene McCarty (TPWD)
Best Presentation - Joe Kraai (TPWD)
Scholarships - Tommy Bates (TAMU:1989), Michael Brice (TTU)

1991 Fish Culture - Jake Isaac (TPWD)
Fisheries Management - Mark Webb (TPWD)
Fisheries Administration - Pat Hutson (TPWD)
Fisheries Research - Ronnie Pitman (TPWD)
Special Recognition - The Wetland Habitat Alliance of Texas
Best Presentation - Mark Stacell (TPWD)
Scholarships - Jim Tolan (CCSU), Michelle Badough (SWTSU)

1992 Fish Culture - Camilo Chavez (TPWD)
Fisheries Education - Brian Murphy (TAMU)
Fisheries Management - Ken Sellers (TPWD)
Fisheries Research - Bob Colura (TPWD)
Special Recognition - Bobby Farquhar, Andy Sansom, and Rudy Rosen (TPWD)
Best Presentation - Maurice Muoneke (TPWD)

1993 Fisheries Management - Bruce Hysmith (TPWD)
Special Recognition - Joe Martin and Steve Gutreuter (TPWD)
Best Presentation - Jay Rooker (UTMSI)
Scholarships -Erica Schlickeisen (SWTSU), Brian Blackwell and Nancy McFarlen (TAMU)

1994 Fish Culture - Ted Engelhardt (TPWD)
Fisheries Management - Steve Magnelia (TPWD)
Fisheries Administration - Dick Luebke (TPWD)
Special Recognition - Bob Howells (TPWD)
Best Presentation - Travis Kelsey (SWTSU)
Scholarships - Kathyrn Cauble (SWTSU), Howard Elder and Kim Jefferson (TAMU)

1995 Fish Culture - Robert Adami (TPWD)
Fisheries Education - Bill Neill (TAMU)
Fisheries Management - Spencer Dumont (TPWD)
Fisheries Administration - Roger McCabe (TPWD)
Fisheries Research - Maurice Muoneke (TPWD)
Special Recognition - Tom Heffernan and Robin Reichers (TPWD)
S. Ken Johnson (TAMU)
Best Presentation (s) - Robert Weller (TTU), Robert D. Doyle (ACE)
Scholarships - Jay Rooker (UTMSI), Robert Weller (TTU), Gil Rosenthal (UT),
John Findiesen and Karen Quinonez (SWTSU)

1996 Fisheries Education - Billy Higginbothan (TAMU)
Fisheries Management - Gary Garrett (TPWD)
Fisheries Administration - Gene McCarty (TPWD)
Fisheries Research - Ivonne Blandon (TPWD)
Special Recognition - Reeves County Water Improvement Board
Best Presentation (s) - Craig Paukert (OSU), Gene Guilliland (ODWC)
Scholarships - Chad Thomas (SWTSU), Anna-Claire Fernandez (UTMSI),
Kenneth Ostrand, Dawn Lee Johnson
Technical Support - Jimmy Gonzales (TPWD)
Honorable Mention (technical support) - Eric Young (TPWD)

1997/1998 1 Fish Culture - Tom Dorzak (TPWD)
2 Fisheries Education - Robert Ditton (TAMU)
3 Special Recognition - Fred Janssen, Chris Cummings, Dan Lewis, Dan Strickland, and Gary Graham (TPWD), Jim Davis (TAMU)
4 Best Presentation (s) - to be announced at 1999 Annual Meeting
5 Scholarships - Tony Baker and Allison Anderson (TAMU), Patrick Rice (TAMU-Galveston), Laurie Dries (UT)

Abbreviations:
TPWD - Texas Parks and Wildlife Department
SWTSU - Southwest Texas State University
UT - University of Texas at Austin
UTPA - University of Texas/Pan American
TUGC - Texas Utilities Generating Company
ODWC - Oklahoma Department of Wildlife Conservation
TAMU - Texas A&M University
UTMSI - University of Texas Marine Science Institute
SCS - Soil Conservation Service
TTU - Texas Tech University
ACE - Army Corps of Engineers
TAES - Texas Agricultural Extension Service
USFWS - US Fish and Wildlife Service
CCSU - Corpus Christi State University
OSU - Oklahoma State University

PANEL DISCUSSION - "ECOSYSTEM MANAGEMENT"

JOHN PRENTICE, *Moderator*

The Benefits and Costs of Doing Ecosystem Management

HAROLD L. SCHRAMM, JR. *(U.S. Biological Resources Division, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State, Mississippi 39762)*

Ecosystem management is a way of doing business that addresses the biodiversity crisis by recognizing that ecosystems are connected in time and space and by considering the importance of human values in the process of natural resource management. In its present form, ecosystem management is neither a revolution to a biocentric world view nor a guarantee that ecosystem integrity will be maintained. Benefits of ecosystem management to fisheries resources include: (1) improved ecosystem integrity, which will result in improved water quality and more productive fisheries; (2) improved multi-agency and multi-jurisdiction cooperation and fewer adversarial roles; (3) greater ability to manage fisheries resources; and (4) greater professional recognition. Costs of ecosystem management include: (1) fiscal realities of staff and operations to meet additional responsibilities; (2) time frame of developing resource management plans; (3) time frame of response to habitat management; (4) developing legislative support; and (5) effectively communicating with a new (broader) constituency, without losing the support of traditional constituents, to achieve the majority support needed for ecosystem conservation.

Developing the Texas Wetlands Conservation Plan

JULIE ANDERSON *(State Wetlands Planner, Texas Parks and Wildlife Department, Austin, Texas 78744)*

The Texas Parks and Wildlife Department, in cooperation with numerous entities, has recently completed the Texas Wetlands Conservation Plan (the Plan). The Plan focuses on non-regulatory, voluntary approaches to conserving Texas' wetlands. Its primary contributions to wetlands conservation include:

- Enhancing the landowner's ability to use existing incentive programs and other land use options through outreach and assistance;
- Developing and encouraging land management options that provide an economic incentive for conserving existing wetlands or restoring former ones; and,
- Coordinating regional wetlands conservation efforts, including mitigation and restoration.

Due to the extensive size and physiography of Texas, a "regional" approach was used to best characterize the diverse wetlands needs and resources of Texas. Three Regional Advisory Groups - one each in East Texas, the Panhandle, and the Gulf Coast - were formed to identify regional and statewide issues associated with conserving Texas wetlands, and to develop recommendations and proposals for action to address those issues. These results form the core of the Texas Wetlands Conservation Plan. These regions were selected because each represents a large wetland complex, and each has a distinct socioeconomic structure and specific land use.

The Regional Advisory Groups met over the course of one year to discuss solutions to five general categories of wetlands issues that they identified: education, economic incentives, conservation, private ownership, and governmental relations. Information form the three groups was combined into a single plan.

The Texas Parks and Wildlife Commission approved a resolution on April 17, 1997 supporting the Texas Wetlands Conservation Plan and the Governor signed it in July, 1997. The following groups were all represented on one or more of the Plan's advisory groups and gave their formal support for the Plan: Texas Farm Bureau, Texas Chemical Council, Wetland Habitat Alliance of Texas, Texas and Southwestern Cattle Raisers Association, Champion International Corporation, Texas Committee on Natural Resources, Texas Utilities Services, Inc., Ducks Unlimited, The Nature Conservancy of Texas, Texas Grain Sorghum Producers, Texas Rural Development Council, Big Thicket Association, International Paper, Texas Cattle Feeders Association, Texas General Land Office, Texas Natural Resources Conservation Commission, Texas Forest Service, Texas Water Development Board, Texas Agricultural Extension Service, Texas Department of Transportation, Texas Department of Agriculture, Texas State Soil and Water Conservation Board, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, and many private landowners.

Numerous implementation efforts are underway, including the Wetlands Project Site Registry.

USDA Programs to Assist Landowners in Ecosystem Restoration

GARY VALENTINE *(Natural Resources Conservation Service, Temple, Texas 76501)*

The 1996 Farm Bill, more correctly called the Federal Agriculture Improvement and Farm Act of 1996, offers some 20 programs that address conservation on agricultural lands. Most of these programs are administered by the Natural Resources Conservation Service (formerly Soil Conservation Service) and Farm Services Agency (formerly Agricultural Stabilization and Conservation Service). A brief description is given for 7 of these programs having the greatest opportunity for affecting fish and wildlife habitat in Texas:

- Conservation of Private Grazing Land focuses on conservation needs --- including fish and wildlife habitat --- of pasture, hayland and rangeland on private lands. It provides technical and educational assistance modeled on the traditional conservation operations of the Natural Resources Conservation Service.
- The Conservation Reserve Program (CRP) offers agricultural producers cost-share assistance, annual rental payments and incentive payments to establish permanent grass, forbs, legumes or tree cover on eligible cropland or marginal pasture for 10 to 15 years.
- The Environmental Quality Incentives Program (EQIP) provides financial incentives to address conservation needs --- including fish and wildlife habitat --- on cropland and land used for livestock operations. While the 6 other programs target specific resource concerns, this program encourages treatment of all conservation problems within each participating operation.
- The Highly Erodible Land Conservation Compliance Program requires USDA farm program participants who harm highly erodible land to implement a conservation management system that reduces erosion to an acceptable level.
- The Wetland Conservation Compliance Program, better known as "Swampbuster," is a disincentive program that ties wetlands conservation to eligibility for USDA farm program benefits.
- The Wetlands Reserve Program (WRP) assists landowners in restoring wetlands in agricultural production to their original condition through cost-share agreements and easements.
- The Wildlife Habitat Incentives Program (WHIP) provides landowners with both technical and cost-share assistance to improve fish and wildlife habitat. Development and improvement of wildlife habitat is the primary purpose of this program.

Although not a program, the National Conservation Buffer Initiative of the NRCS promotes the establishment, preservation, enhancement, restoration and reclamation of conservation buffers by farmers, ranchers and other landowners to improve soil, water and air quality while enhancing fish and wildlife habitat. Technical and cost-share assistance is provided through CRP, EQIP, WRP, WHIP and other USDA programs.

Ecosystem Management

CARL FRENTRESS *(Regional Waterfowl Biologist, Texas Parks and Wildlife Department, Athens, Texas 75751-6849)*

My professional experience always has required ecosystem considerations. My first employment activities were involved with studies of conditions relevant to redhead ducks that utilized the bays and estuaries of the Lower Texas Coast, particularly the Laguna Madre -- a large ecosystem. Subsequent work with nongame species and the statewide habitat project provided insights to the value of holistic approaches to land management. Similarly, I encountered the need for this approach in conducting the responsibilities of a district regulatory biologist. My work as regional waterfowl biologist actually leaves no alternative other than an ecosystem approach to wetland conservation (aka waterfowl habitat management). For instance, scientific studies demonstrate the connection of the biology of ducks such as mallards or wood ducks to phenomena associated with bottomland hardwood forests. Much of my current work is centered around uniting private landowner initiatives with the functions and values of wetland ecosystems throughout East Texas. To reach meaningful and sustainable solutions, ecosystem management must be adopted and practiced by the majority of society at large, not just resource professionals and a few lay subscribers. As best they can, ecosystems continue to function; our challenge is to effectively demonstrate the host of ecological values in order to establish public support sufficient to sustain these natural resources.

A Case History of Human Alterations to Upper Texas Coastal Ecosystems

JAMES A. SUTHERLIN *(Wildlife Division, Texas Parks and Wildlife Department, J.D. Murphree Wildlife Management Area, Port Arthur, Texas 77640)*

The Upper Texas Coast represents the Gulf Coast from Galveston Bay, east to Sabine Lake. This region is also known at the Texas Chenier Plain, the westernmost geologic delta of the Mississippi River. Since soon after the American Civil War, Sabine Lake and Sabine Pass have been developed to accommodate navigation associated with commerce in East Texas. Over fifty per cent of Texas' losses of emergent coastal marsh habitats in this century have occurred within the Sabine Lake Ecosystem. Economic development has resulted in major hydrologic alterations and changes in ecological functions of the Sabine Lake system, including associated rivers and marshes. Discussion will include a historical perspective on impacts of development and a proactive philosophy on wetland ecosystem restoration and ecosystem function.

An Ecological Investigation of Robbins Slough Drainage, Mad Island Wildlife Management Area: Ecosystem Response to Management Strategies

M. TODD MERENDINO *(Wildlife Division, Texas Parks and Wildlife Department, Bay City, Texas 77414)*

Natural drainage patterns along many areas of the Texas coast have been severely altered by construction of the Gulf Intracoastal Waterway (GIWW) and other channelization projects. At Mad Island Wildlife Management Area drainage patterns have been altered by two such projects; the GIWW and Culver Cut Ditch. Concomitant with changes in freshwater and saltwater flow patterns in Rattlesnake Island and Savage Marsh, has been a change in vegetative species composition from that which is more characteristic of fresh (<0.5 ppt), intermediate (3.5 ppt), and brackish (8.5 ppt) marshes to that more characteristic of brackish and saline (>15 ppt) marshes. Erosion of shorelines and loss of organic matter has occurred due to barge traffic and tidal action along the GIWW. This study investigated attempts to restore freshwater inflow and regulate saltwater intrusion via installation of two water control structures and two earthen plugs.

The focus of this study is to obtain baseline ecological data on numerous components and evaluate component responses to water management strategies. Site characteristics (water and soil quality), vegetation, and distributions and abundances of aquatic and avian organisms will be examined spatially and temporally over a minimum of 3 years. At least one year of monitoring will follow each of three proposed management implementation phases. Fish, alligators, birds, water and soil parameters, and vegetation are being intensively monitored and monitoring will be discussed.

TECHNICAL SESSION ABSTRACTS

Spatial and Temporal Distribution of Fishes of the Upper Colorado River, 1987-1995

F. GELWICK *(Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843-2258)*
O. THORNTON *(Ivie Reservoir Field Office, HCR 82, Box 4B, Leaday, Texas 76888)*
R. MARTIN AND X. WU *(Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843-2258)*

Collection of fishes from shallow riffle-pool habitats used as foraging sites by the Concho River water snake *Nerodia harteri paucimaculata* were begun after the establishment of Ivie Reservoir near the confluence of the Concho and Colorado rivers. Fifteen sites (5 each upstream of Ivie Reservoir on the mainstem of the Colorado and Concho Rivers, and 5 downstream of Ivie Reservoir on the mainstem Colorado River) were collected annually. Seven artificial riffle sites (6 upstream and 1 downstream of Ivie Reservoir on the mainstem Colorado River) were collected annually after 1990, and an additional 59 collections were made throughout the upper Colorado River drainage. A total of 39 species from 11 families were collected. A canonical correspondence analysis of sites, species and environmental variables indicates effects of longitudinal position within the drainage, and chloride concentration in water samples. The GIS database for these locations indicates fish community compositions are also related to percentage of land use/cover categories (e.g., reservoirs, strip mines-quarries, scrub-brush-range, and deciduous forest) within these watersheds.

Spatial and Temporal Variation in Fish Distributions and Assemblage Structure in the Upper San Jacinto River System

M. E. HERBERT AND F. P. GELWICK *(Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843-2258)*

Fishes were collected seasonally (February, May, August, December) for 1 year in tributaries of the West Fork (13 sites) and East Fork (9 sites) of the San Jacinto River. All sites were within or bordering the Sam Houston National Forest. West Fork tributaries were isolated from each other by Lake Conroe. Fishes were collected in a 100-m stream reach by seining and backpack electrofishing. A total of 42 species were collected. Species distributions and assemblage structure were related to the seasonal variation in discharge and other instream habitat conditions and physico-chemical water conditions. Species richness decreased across sites with increasing seasonal variation in discharge in both forks. Preliminary analyses show that Spearman's Rank correlation and Morisita's index decrease with increasing seasonal variation in flow in the unimpounded East Fork system. West Fork sites above Lake Conroe show either no relationship or show increases with increasing variation in flow. This suggests that patterns of seasonal assemblage stability and persistence have been influenced by the presence of Lake Conroe. Lake Conroe may buffer seasonal changes in assemblage structure in tributary streams through a stable source of potential colonizing fishes. Other results also indicate that the presence of Lake Conroe influences some species' presence or absence and relative abundance in tributary streams.

Comparative Fish Assemblage Structure of a Naturally Disturbed vs. a Tailwater Stream in Central Texas

ALLISON A. ANDERSON *(Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843-2258)*

Tailwater areas (directly downstream of a dam) of flood-control dams have a number of features that could affect assemblage composition. Discharges from these types of dams are usually hypolimnetic and cold, and reduced temperature may affect growth, egg size, and development. These areas also lack the seasonal scouring floods that provide habitat heterogeneity in a natural stream. Such disturbances play an important role in the life history strategies of fishes. This study examined the relative representation of life history strategies in assemblages of a tailwater and a natural stream in central Texas. Results from two years of sampling show that the natural stream is higher in total fish abundance but lower in total biomass. Abundances of opportunistic or "r-type" species (*Gambusia affinis* and *Etheostoma spectabile*) were higher in the tailwater, whereas cyprinids (periodic strategists that respond to large-scale environmental heterogeneity) were dominant in the natural stream. Relative equilibrium or "K-type" strategists (*Lepomis spp.*) had similar abundances between streams. *Lepomis megalotis* was dominant on both streams, however non-indigenous *L. auritus* dominated centrarchid biomass in the tailwater. *Micropterus spp.* were more numerous and had a higher relative biomass in the natural stream.

Habitat Use by Arkansas River Shiner and Speckled Chub in the Canadian River, New Mexico-Texas

TIMOTHY H. BONNER, GENE R. WILDE, RICHARD JIMENEZ, JR., AND REYNALDO PATINO *(, Department of Range, Wildlife, and Fisheries Management, Texas Tech University, Lubbock, Texas 79409-2125)*

We studied habitat preference of the Arkansas River shiner *Notropis girardi* and the speckled chub *Macrhybopsis aestivalis* in the Canadian River, New Mexico-Texas. Arkansas River shiners comprised 35% and speckled chub 22% of fishes collected between Ute Reservoir (New Mexico) and Lake Meredith (Texas). Arkansas River shiners and speckled chubs were collected over a wide range of physicochemical conditions. We collected Arkansas River shiners from waters ranging in conductivity from 0.7 to 14.4 mmhos, temperatures from 0.4 to 31.7°C, dissolved oxygen concentrations from 3.4 to 16.26 mg/l, and turbidities from 4.3 to 10390.0 NTU's. We used multivariate analysis to determine that out of nine habitat variables, the Arkansas River shiner preferred habitats with moderate turbidities (2750 to 3750 NTUs), with some preferences for current (0.2-0.6 m/s), conductivity (7-9 mmhos), and depth (2-9 cm). We collected speckled chubs from waters ranging in conductivity from 0.7 to 14.0 mmhos, temperature from 0.1 to 31.6°C, dissolved oxygen concentration from 4.6 to 16.3 mg/l, and turbidity from 4.3 to 7750 NTUs. Speckled chubs preferred habitats from 0.4 to 0.6 m/s in current and from 3250 to 5250 NTUs in turbidity.

Community Structure of Stream Fishes in the Upper Brazos River

KENNETH G. OSTRAND AND GENE R. WILDE *(Department of Range, Wildlife, and Fisheries Management, Texas Tech University, Lubbock, Texas 79409-2125)*

The Brazos River has been altered throughout its course by the construction of reservoirs. Such alterations have been implicated in reductions in distribution and abundance of several species of minnows in Great Plains streams. In the Brazos River, distribution and abundance of the speckled chub *Macrhybopsis aestivalis*, plains minnow *Hybognathus placitus*, smalleye shiner *Notropis buccula*, and the sharpnose shiner *Notropis oxyrhynchus*, have declined in recent years. We collected fish from 13 sites in the upper Brazos River during 1997. A total of 14 species of fish were collected, of which Red River pupfish *Cyprinodon rubrofluviatilis* comprised the largest proportion (37.9%), followed by plains minnow (25.2%), smalleye shiner (14.8%), sharpnose shiner (7.4%), and speckled chub (0.8%). Abundance of sharpnose shiner and smalleye shiner were positively correlated with turbidity ($P < 0.05$). Red River pupfish abundances were positively correlated ($P < 0.05$), and smalleye shiner abundances were negatively correlated with conductivity (i.e., salinity) ($P < 0.05$). Conductivity decreased and turbidity increased with stream order ($P < 0.05$). Fish species diversity differed among 4th ($D_2 = 0.53$), 5th ($D_2 = 0.83$), and 6th ($D_2 = 0.75$) stream orders ($P < 0.001$). Patterns in the structure of stream fish assemblages in the upper Brazos River indicate that conductivity and turbidity are important abiotic variables.

Trends in Composition of the Texas Commercial Shrimp Fleet, 1986-1996

KURTIS K. SCHLICHT *(Texas Parks and Wildlife Department, Seabrook Marine Lab, P. O. Box 8, Seabrook, Texas 77586)*

Long term data on the composition of the Texas commercial shrimp fleet were analyzed to identify trends in numbers, size, license classes and home port distribution for the period 1986-1996. The total number of licensed commercial shrimp boats decreased 50% during this period for 5811 in 1986 to 2861 in 1996. The largest decrease in licenses (949) over the ten year period was for vessels ≤7.6 m in length. Vessels between >7.6-16.8 m in length holding combination bay/bait licenses showed the greatest increase from 120 in 1986 to 324 in 1996. In 1995, the majority (90%) of all licensed vessels were registered in coastal counties. Vessels registered in the Houston-Pasadena-Baytown ports accounted for 46% of all vessels licensed in 1995, which represented nearly a three-fold increase in total vessel contribution from these ports compared to 1986 (16% of all licensed vessels). Changes in the composition of the Texas commercial shrimp fleet may be attributed to several factors: changes in the economic value of the shrimp industry, declines in catch despite increases in effort by commercial shrimpers, and increased changes in regulations and license fees.

Southeast Area Monitoring and Assessment Program (SEAMAP) Longline Monitoring of Adult Finfish in the Texas Territorial Sea

TOM WAGNER *(Texas Parks and Wildlife Department, Coastal Fisheries Division, 702 Navigation Circle, Rockport, Texas 78382)*

Texas Parks and Wildlife Department Coastal Fisheries Division staff, in cooperation with the Gulf States Marine Fisheries Commission and Southeast Area Monitoring and Assessment Program (SEAMAP), have monitored adult finfish populations in the Texas Territorial Sea (TTS) from 1992 through present. Longlines (366-meters in length) baited with 100 hooks were deployed in TTS waters off Port Aransas for a period of two hours, with sets repeated six time/month during March through May of each year. Catch were enumerated and measured, and live red drum *Sciaenops ocellatus* were either tagged and released, used as broodstock for TPWD saltwater hatcheries, or otoliths removed for age and growth studies. From 1992 through 1997, forty-four longline sets were completed catching 416 finfish. Red drum (52%), sharks *Carcharhinus spp.* (22%) and hardhead catfish *Arius felis* (8%) were the predominant species caught throughout the study period. Routine longline monitoring of adult finfish, such as red drum, provides an effective management tool for fishery managers, especially when sampling protocol is consistent across jurisdictional boundaries.

Sampling Bias Associated with Stream Access

PAUL E. BALKENBUSH AND WILLIAM L. FISHER *(Oklahoma Cooperative Fish and Wildlife Research Unit, Department of Zoology, Oklahoma State University, Stillwater, Oklahoma 74078)*

We investigated the effects of sampling site access on estimates of fish abundance in two eastern Oklahoma streams. Fish were sampled with electrofishing at public and remote access sites on Baron Fork Creek in northeastern Oklahoma and Glover River in southeastern Oklahoma. We verified differences in recreational use and habitat between access types in both streams. Recreational use was generally higher at public than remote access areas in each stream. Public areas in Glover River had higher fish densities, were deeper, but had less instream cover than remote areas. However, mean density of centrarchid species, mean depth, and frequency of cover types at public and remote areas in Baron Fork Creek were not significantly different. Although we did not observe a consistent trend between streams in fish abundance at public and remote access sites, our findings indicate that accessibility sampling from public access areas may yield biased estimates of population size. Therefore, we suggest caution when making inferences about populations based on samples taken from these areas.

Littoral Habitat Use by Fishes in Lake Conroe, Texas

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The 1981 stocking of grass carp *Ctenopharyngodon idella* into Lake Conroe, Texas, resulted in dramatic changes to the reservoir's littoral zone. Prior to 1981, as much as 45% of the reservoir's surface area was covered with aquatic macrophytes. Today, less than 5% of the shoreline contains aquatic macrophytes. In addition, due to extensive home development, approximately 60% of the shoreline has been converted to structurally simple bulkhead. The remaining 35% of Lake Conroe's littoral zone habitat consist of complex riprap (7%) and undeveloped, unvegetated, sandy shoreline (28%). As structurally complex littoral zone habitat provides important foraging sites, protection from predation, and nursery areas for many species of fish, it is important to understand how the dramatic changes in the shoreline habitat may be affecting the littoral fish communities within the lake. For 1 year, each of the four different littoral habitat types were sampled seasonally to determine the number of species/m^2, individuals within a species/m^2 and biomass/m^2 of habitat sampled. Four permanent sites were chosen in each habitat type. Sites were surrounded with a large (91.5 m) blocknet. The inside area of the blocknet was measured and electrofished exhaustively. Data from three seasons indicate that riprap and vegetated areas support the highest biomass of fish as well as the highest numbers of species per area sampled. This information will be useful in planning habitat-restoration projects in reservoirs, or when designing or refining mitigation requirements in reservoirs where desirable fish habitat is being removed or degraded by human activities.

Limited Entry in Recreational Fisheries -- Has Its Time Come?

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The relation between catch and effort is examined in the context of recreational fisheries. The concept of limited entry as a means of increasing angler catch rates is developed, empirical data demonstrating the catch-effort relationship is presented and ramifications of limited entry in fisheries management are discussed. Limited entry may have a place in the future of freshwater fisheries management.

Annual Proceedings of the Texas Chapter, American Fisheries Society 20:7-12, 1998

Effects of Changing from a 14-Inch to a 16-Inch Minimum Length Limit on Largemouth Bass in Two Fluctuating Reservoirs

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Abstract.—Largemouth bass *Micropterus salmoides* populations were managed with a 14-in minimum length limit (MLL) from 1 September 1985 through August 1992 and with a 16-in MLL beginning 1 September 1992 in Brownwood and Coleman reservoirs, Texas. The 16-in MLL was implemented to increase angler catch rates and maintain harvest during low-water periods by increasing abundance of largemouth bass. Angler harvest declined considerably in both reservoirs. Total angler catch rates were similar, but angler catch rates and harvest of legal-length largemouth bass declined significantly. Total electrofishing catch per unit effort (CPUE) and CPUE of 14- to 15.9-in largemouth bass was similar before and after implementation of the 16-in MLL. Growth of largemouth bass did not change but may have been too slow (4 or more years to reach 16 in total length) to sustain adequate abundance of legal length largemouth bass. The 16-in MLL failed to significantly improve recreational fishing during low-water periods despite implementation immediately following two years of high water levels. A 16-in MLL was an ineffective alternative to a 14-in MLL in these fluctuating reservoirs.

Largemouth bass *Micropterus salmoides* populations at Brownwood and Coleman reservoirs were managed with 14-in minimum length and 5-fish daily bag limits from 1 September 1985 to 31 August 1992. Prior to 1 September 1985, largemouth bass populations were regulated with 10-in minimum and 10-fish daily bag limits. This regulation was changed to the 14-in minimum length limit (MLL) to increase size and number of adult largemouth bass and extend harvest during low-water years. Initially, this regulation satisfied these objectives (Follis et al. 1991); however, few largemouth bass ≥ 16 in were available to anglers in years following implementation of the 14-in MLL despite adequate growth rates.

On 1 September 1992, experimental 16-in MLL and 5-fish daily bag limits were implemented for largemouth bass in Brownwood and Coleman reservoirs. Our objective was to evaluate the effectiveness of these limits to increase angler catch rates and maintain harvest during low-water periods by increasing total largemouth bass abundance and abundance of 14- to 15.9-in largemouth bass.

Study Areas

Brownwood Reservoir is a 2,954-ha impoundment built in 1933 on Pecan Bayou, a tributary of the Colorado River, in Brown County, Texas. Coleman Reservoir is a 809-ha impoundment built in 1966 on Jim Ned Creek, a tributary of the Colorado River, in Coleman County, Texas. Their main uses are flood control, water supply, and recreation. Both reservoirs experienced substantial fluctuations (up to 8 ft) in water level during the study period.

Methods

Fixed-access creel surveys were conducted on both reservoirs on 9 d (5 weekend days and 4 weekdays) during April-June of each year from 1987 to 1990 and 1992 to 1996. Creel surveys were used to estimate angler harvest, catch, and directed effort.

Spring and fall daytime electrofishing were used to estimate largemouth bass abundance as measured by catch per unit effort (CPUE) of all largemouth bass and CPUE of largemouth bass 14- to 15.9-in total length. Each unit of effort was 1 h of electrofishing. Fixed electrofishing stations were chosen to represent available habitat. Prior to 1993, electrofishing was done with 60 cycles/second pulsed DC from single rectified 120 cycles/second AC. Twelve anodes were suspended 5 feet in front of the boat from a T-boom. Beginning in 1993, a Smith-Root 5.0 GPP electrofishing unit with two-umbrella, four-anode arrays was used. Pulsators were set with pulsed DC at 50-500 volts, 60 cycles/second, and 30-60% of range. Effort was 1.0-1.5 h of electrofishing time.

Angler harvest, catch, and effort, electrofishing CPUE, and growth rates of largemouth bass from 1987-1992 were compared to those from 1993-1996 with a Wilcoxon Rank-Sum test (Snedecor and Cochran 1989). The significance criterion was $\underline{P} \leq 0.05$.

Otoliths were used to determine age of largemouth bass. Growth of largemouth bass was estimated using mean length at age at capture.

Results

Brownwood Reservoir

Angler harvest significantly declined following implementation of the 16-in MLL (Figure 1). Total angler catch rates did not change following implementation of the 16-in MLL (Figure 1). Angler catch rates of legal-length largemouth bass declined from 21% of the total catch to 6% of the total catch following implementation of the 16-in MLL. Directed effort for largemouth bass did not change (Figure 1).

There was no significant difference in electrofishing total CPUE or CPUE of 14- to 15.9-in largemouth bass following implementation of the 16-in MLL (Figure 2). Growth of largemouth bass did not change following implementation of the 16-in MLL either (Table 1).

Coleman Reservoir

Harvest of largemouth bass significantly declined following implementation of the 16-in MLL (Figure 1). Total angler catch rates did not change following implementation of the 16-in MLL (Figure 1). Angler catch rates of legal-length largemouth bass declined from 29% of the total catch to 10% of the total catch following implementation of the 16-in MLL. Directed effort for largemouth bass showed a declining trend since 1993, but there was no significant change following implementation of the 16-in MLL (Figure 1).

Fall electrofishing total CPUE significantly declined following implementation of the 16-in MLL (Figure 3). There was no corresponding change in spring electrofishing total CPUE (Figure 3). Electrofishing CPUE of 14- to 15.9-in largemouth bass was similar before and after implementation of the 16-in MLL in both spring and fall (Figure 3). Largemouth bass growth did not change following implementation of the 16-in MLL either (Table 1).

Discussion

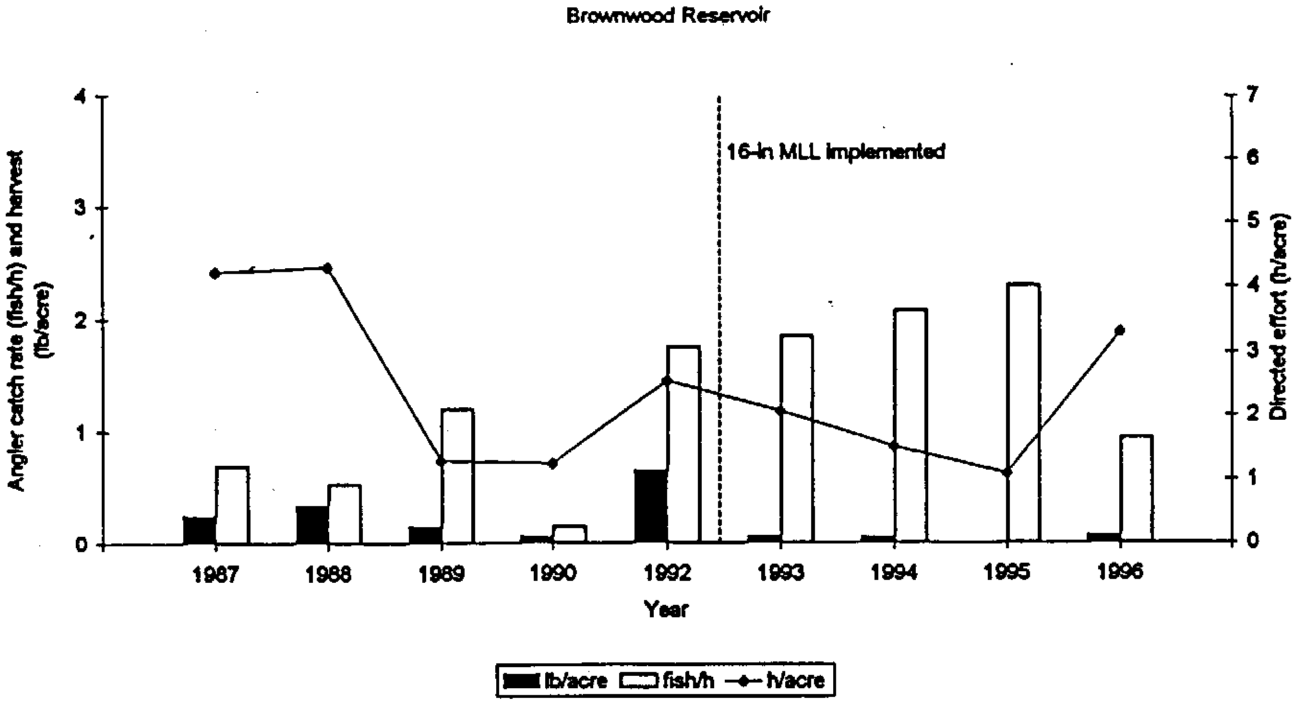
The objective of the 16-in MLL on Brownwood and Coleman reservoirs was to improve fishing during low-water periods by increasing abundance of largemouth bass. Fortunately, each time period, pre and post 16-in MLL, contained a low-water period. Also, there was a 2-year period with high water levels immediately prior to implementation of the 16-in MLL. We evaluated a 16-in MLL during a low-water period following ideal conditions for largemouth bass growth, recruitment, and survival.

Fishing was not improved because harvest was virtually eliminated, total angler catch rates were not increased, and angler catch of legal-length largemouth bass declined approximately three-fold in these reservoirs. Mitchell and Sellers (1989) also observed significant declines in harvest with no change in total angler catch rates on Tradinghouse Creek Reservoir, Texas, when the MLL was changed from 10 in to 16 in total length. Ager (1989) found no changes in angler catch rates or harvest when the MLL was changed from 12 in to 16 in at West Point Reservoir, Georgia. An important aspect of minimum length and daily bag limits is a sociological goal of catching a limit of legal-length largemouth bass. Prior to the 16-in MLL, there was more harvest and a much better chance of catching legal-length largemouth bass in these reservoirs.

We also expected an increase in largemouth bass total abundance and abundance of 14- to 15.9-in largemouth bass following implementation of the 16-in MLL. This did not occur. Other researchers have observed significant increases in largemouth bass density with a 16-in MLL following a far less restrictive limit (Hall et al. 1986; Ager 1989), while Mitchell and Sellers (1989) found no change in largemouth bass density when the MLL was increased in Tradinghouse Creek Reservoir. Gigliotti and Taylor (1990) found benefits of catch and release are lost when noncompliance is approximately 15% or higher; however, we believe this was not a problem since noncompliance was 7% (based on length-frequencies of harvested fish). Evidently, increasing the limit from 14 in to 16 in was not enough to affect abundance of largemouth bass in Brownwood and Coleman reservoirs.

Growth may have been too slow to allow sufficient numbers of largemouth bass to reach 16 in or longer. Perhaps, for the 16-in MLL to be successful, growth of largemouth bass to 16 in should occur in 3 to 4 years and not 4 to 6 years which occurred in Brownwood and Coleman reservoirs. In Tradinghouse Creek Reservoir, largemouth bass reached 16 in by age 3 (Mitchell and Sellers 1989). Not only was largemouth bass growth considerably slower in Brownwood and Coleman reservoirs, but an additional 1 to 2 years were required to grow from 14 in to 16 in total length.

The 16-in MLL produced no positive changes in largemouth bass abundance, angler catch rates, harvest, or utilization of the recreational fishery. Perhaps a 16-in MLL is not an effective alternative to a 14-in MLL in fluctuating reservoirs with characteristics similar to Brownwood and Coleman.



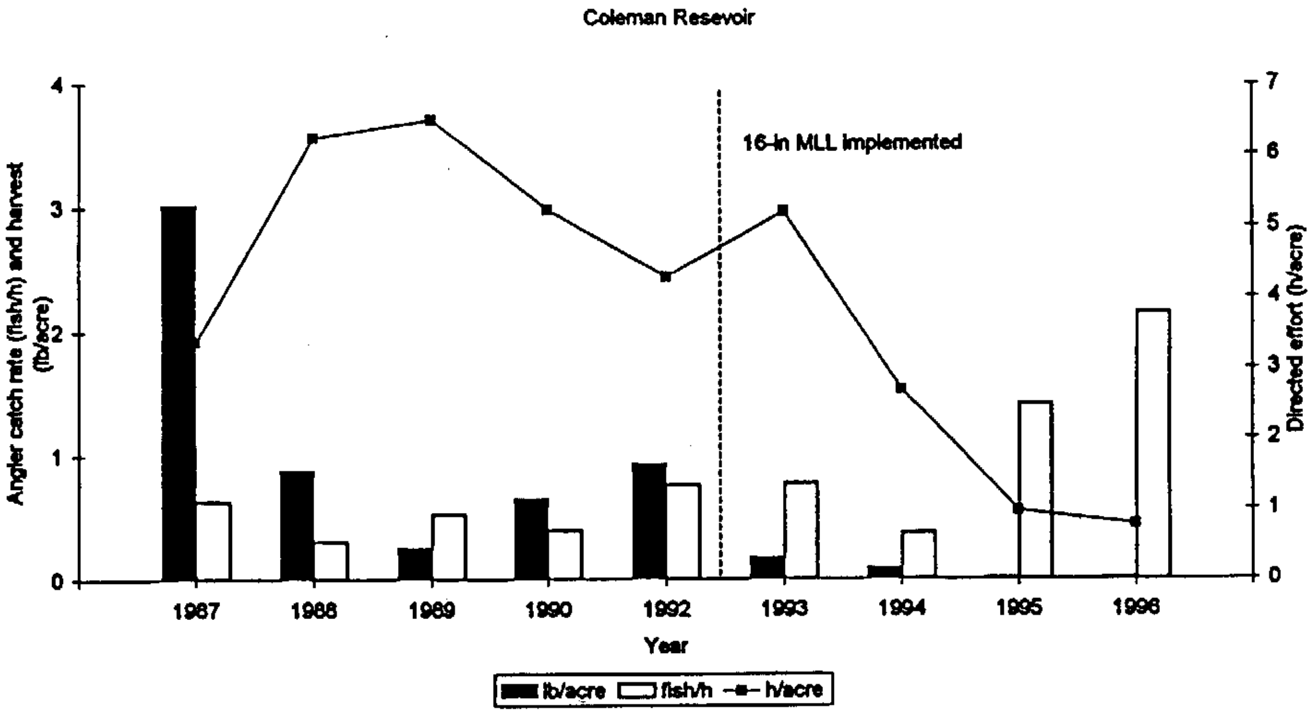
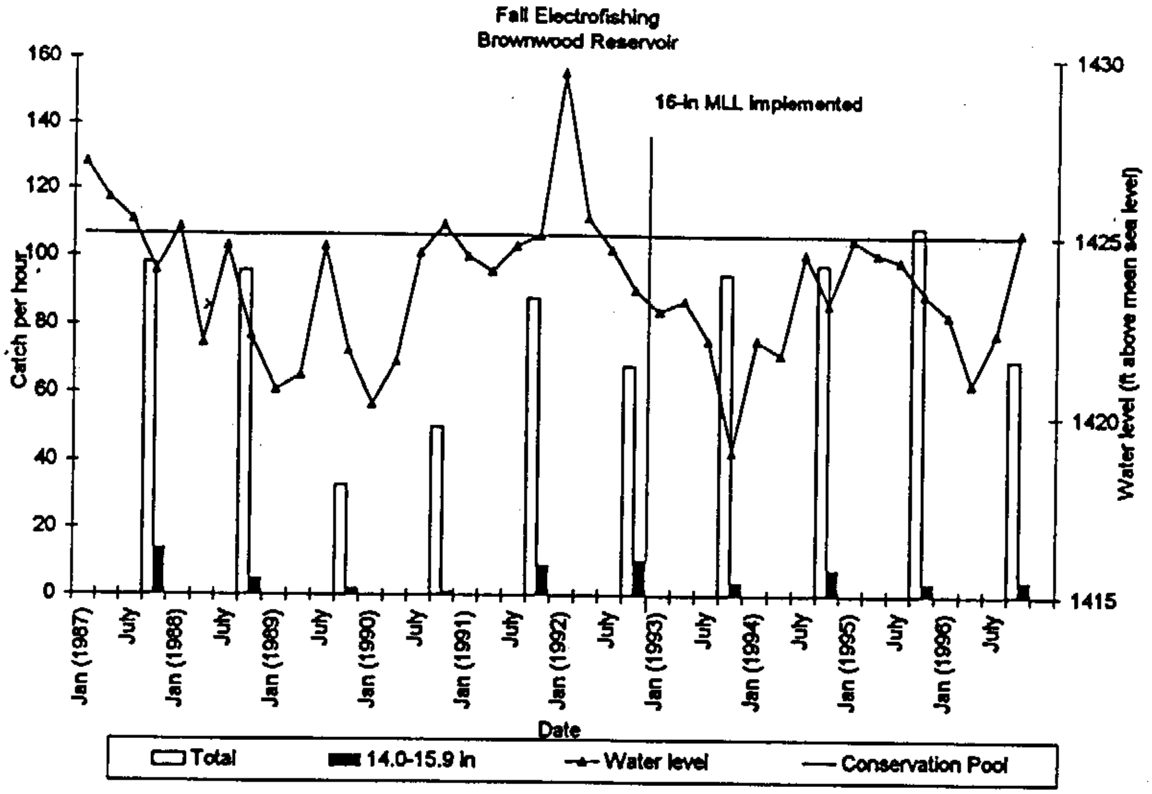


FIGURE 1.---Harvest (lb/acre), angler catch rates (fish/h), and directed effort (h/acre) of largemouth bass at Brownwood and Coleman reservoirs from spring creel surveys (1987-1996).



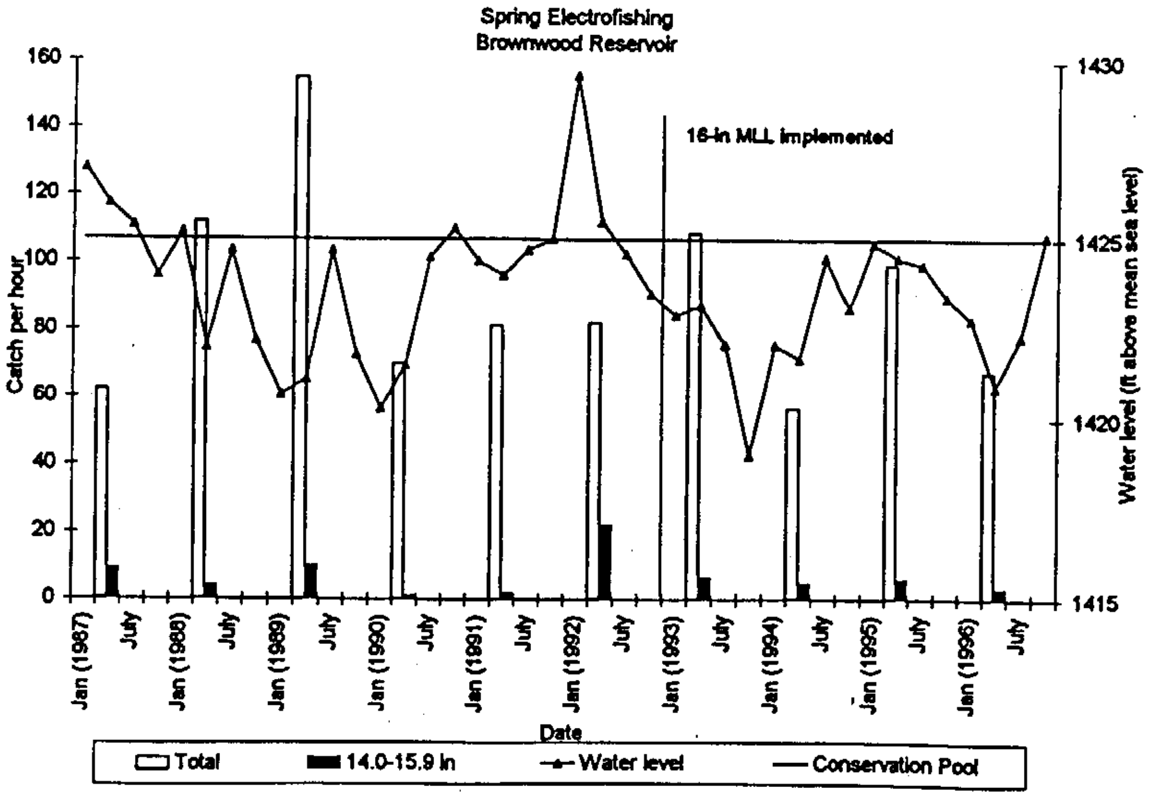
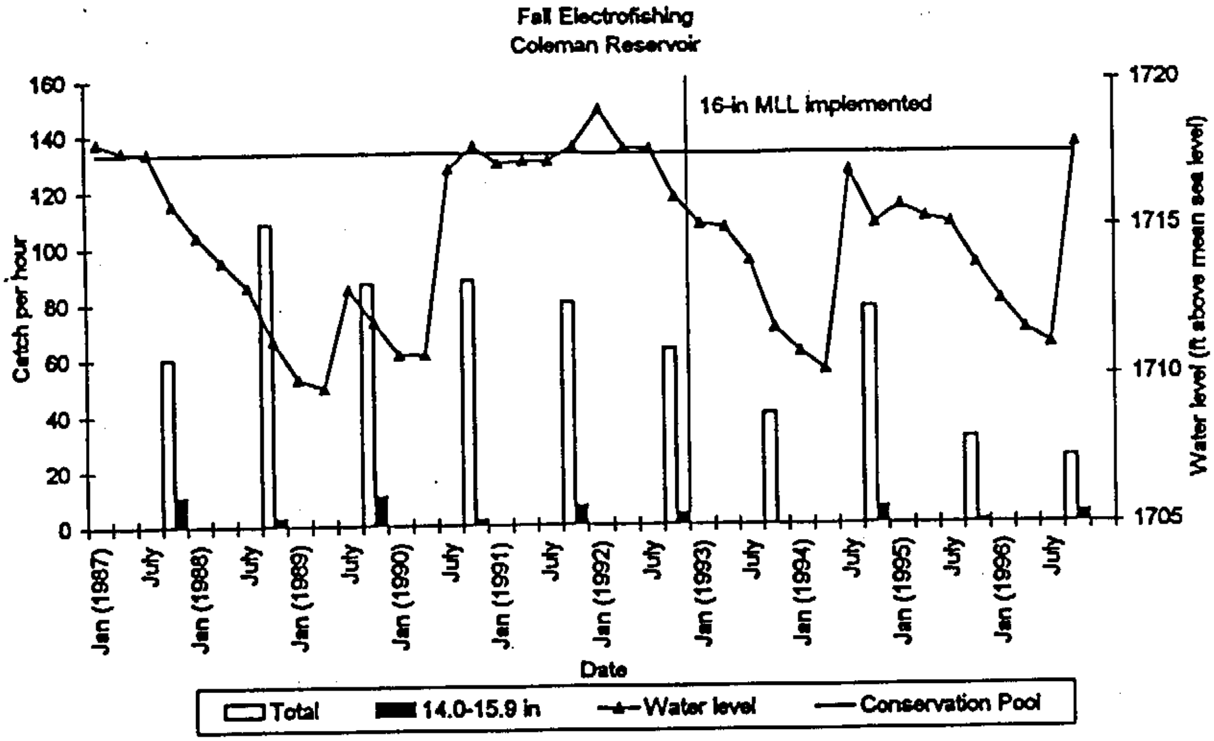


FIGURE 2.---Spring and fall electrofishing catch per unit effort of largemouth bass and quarterly water levels from Brownwood Reservoir 1987-1996.



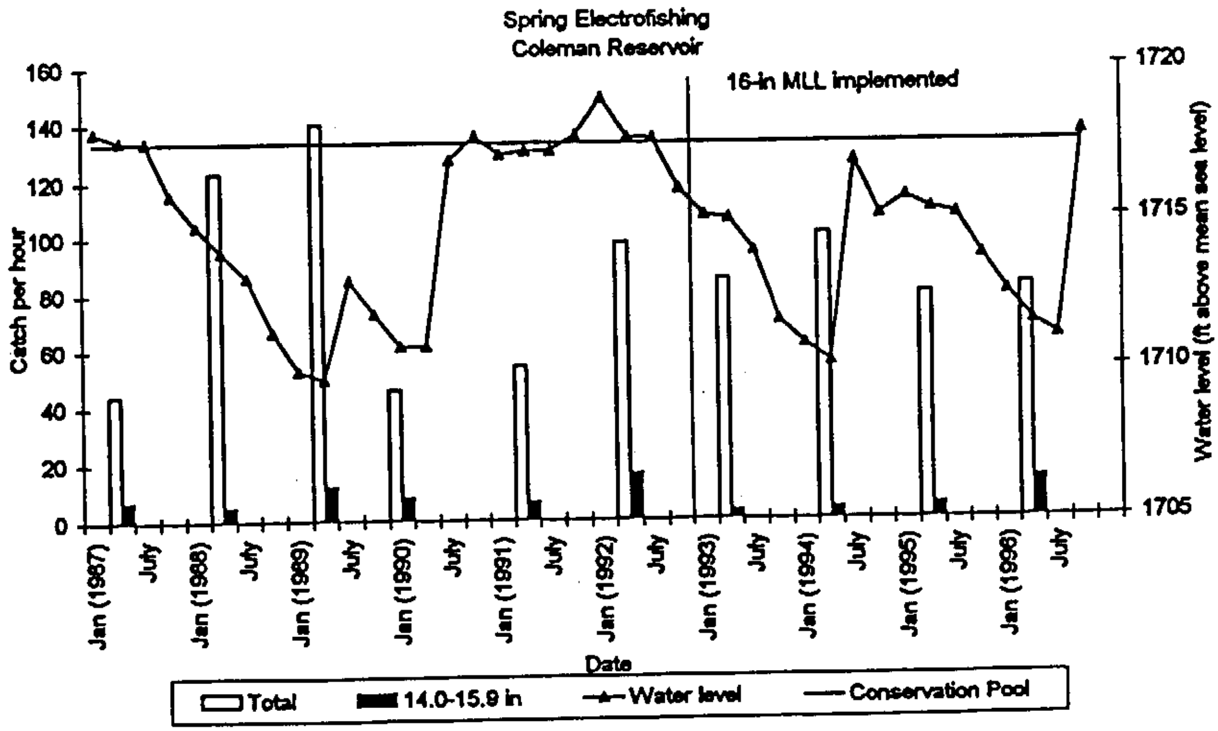


FIGURE 3.---Spring and fall electrofishing catch per unit effort of largemouth bass and quarterly water level elevations from Coleman Reservoir 1987-1996.

TABLE 1.—Mean total length (in) at age at capture of largemouth bass collected by spring electrofishing at Coleman Reservoir, Texas, and fall electrofishing at Brownwood Reservoir, Texas, 1988 through 1996. Standard deviations are in parentheses.

Reservoir	Age 1	Age 2	Age 3	Age 4	Age 5
Brownwood					
1988-1992	9.3(1.0)	12.0(1.3)	14.3(1.5)	14.1(1.2)	15.5(2.7)
1993-1996	9.3(1.1)	11.9(1.1)	13.7(1.2)	14.7(1.2)	15.6(0.8)
Coleman					
1988-1992	6.5(1.2)	9.6(2.0)	12.8(2.4)	15.7(1.3)	18.5(1.7)
1993-1996	7.2(1.1)	10.7(1.3)	13.3(0.6)	15.4(1.6)	17.0(0.9)

Acknowledgments

We thank L. Buchanan, R. Cole, M. Gardner, R. O'Keefe, J. Lee, and J. Vasquez for their assistance with data collection, and E. Altena, J. Dean, B. Farquhar, G. Jons, R.W. Luebke, C. Munger, M. Reed, and B. Zerr for their critical review of the manuscript. Funding for this study was provided by Federal Aid in Sport Fish Restoration, Grant F-30-R of the Texas Parks and Wildlife Department.

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Annual Proceedings of the Texas Chapter, American Fisheries Society 20:13-14, 1998

Chemoreceptivity in Largemouth Bass

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Abstract.--The response of juvenile largemouth bass *Micropeterus salmoides* olfactory and gustatory senses were tested to six amino acids: methionine, proline, serine, alanine, leucine, and phenylalanine. Amino acids were injected separately into small cotton pellets and introduced into aquaria containing individual largemouth bass. Responses were observed and recorded. Proline-injected cotton pellets induced the greatest response and interest of the fish, including consumption of the pellet on two of five occasions. Leucine and alanine induced some positive attraction, but substantially less than that of proline. Serine and phenylalanine induced very little positive response; whereas, largemouth bass essentially were repelled by methionine.

Introduction

Fisherman are always searching for better ways to attract fish to their bait. Artificial lures incorporate a myriad of schemes designed to entice fish through movement, color, sound, taste, and smell. A variety of fish attracting sprays and impregnated baits have been developed based upon research into what odors attract fish. Quinn (1990) found largemouth bass to be attracted to a number of amino acids. Of those tested, he concluded proline, leucine, phenylalanine, and glutamine were the best attractants to largemouth bass. Other substances such as banana extract, pheromones, and salt have also demonstrated attractive qualities. Six amino acids, including some previously tested by Bambanek (Quinn 1990), were tested in this study to determine the response they incited in juvenile largemouth bass.

Methods

Ten juvenile largemouth bass ranging in total length from 5.5 cm to 6.25 cm were maintained in a 151-L aquarium where they were fed sliced earthworms daily. Response tests were performed in a 76-L aquarium. Prior to each response test, the 76-L aquarium was half-filled with water that had been treated to remove ammonia, chloramine, and chlorine. Next a small white cotton pellet (about 3 mm in diameter) was soaked in one of six amino acids (except in the control test which was left dry). The pellet was then placed into the test aquarium about 8 cm from one end. A randomly selected fish was removed from the holding aquarium and introduced at the end of the test aquarium opposite that of the cotton pellet. The fish was observed for five minutes for the following information: time to first reaction or sensing of the cotton pellet; fish movement; reaction response to cotton pellet (positive or negative); time spent tasting the pellet; and whether the pellet was consumed. Each amino acid tested was replicated with five different randomly selected fish. The test aquarium was drained and cleaned after each test. T-tests were performed comparing fish response time to each amino acid and the control.

Results

Significant differences were detected in fish response times between cotton pellets soaked in amino acids and those which were not (Table 1). Fish exhibited a positive response (sought after the pellet) to every amino acid tested except methionine, which appeared to repel the fish. The degree of response toward the amino acids varied, but generally began with a notable twitching which occurred just before starting of an active pursuit (or avoidance) of the amino acid-soaked cotton pellet. This twitching was assumed to be the fish's first contact with the scent and usually occurred one to two minutes after introducing the fish into the aquarium. . In the case of methionine, the largemouth bass would swim to the opposite end of the aquarium from the cotton pellet and vertically align themselves against the side. As for the other amino acids, the fish would circle the aquarium apparently in pursuit of the scent. If and when the pellet was discovered, the fish would either reject it, taste it, and/or consume it.

Proline incited the greatest interest of the amino acids tested. All five largemouth bass searched at least one minute for the proline-soaked pellet. Each fish circled the cotton pellet many times and would eventually orient themselves at a 45^0 angle to the pellet with their head pointing at the pellet. The fish would either remain in that position and slowly move downward or attempt to eat the pellet. Two of five proline-soaked pellets were consumed.

Largemouth bass did not respond as strongly to leucine and alanine as with proline. Only three of the five fish tested for each amino acid searched at least one minute for the cotton pellets soaked in the respective amino acids. None of these pellets were consumed. Serine and phenylalanine aroused even weaker responses. Only one fish searched for the serine-soaked pellet; whereas, none sought out the phenylalanine. Time to first response to the serine scent was the longest of any observed (about two minutes).

TABLE 1.---Comparison of largemouth bass response time between selected amino acids, and between the amino acids and a control. (NS = Not Significant).

	Mean Response Time(s)	Methionine	Proline	Serine	Alanine	Leucine	Phenylalanine	Control
Methionine	85.4**	-	NS	NS	NS	NS	NS	9.681*
Proline	82.8**	NS	-	NS	NS	NS	3.396*	13.16**
Serine	124.4**	NS	NS	-	NS	NS	NS	3.948*
Alanine	45**	NS	NS	NS	-	NS	8.890*	30.01**
Leucine	88.4**	NS	NS	NS	NS	-	2.703*	10.78**
Phenylalanine	147.2**	NS	3.396*	NS	8.890*	2.703*	-	16.37**
Control	300**	9.681*	13.16**	3.948*	30.01**	10.78**	16.37**	-

*P 0.01
**P 0.001

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Annual Proceedings of the Texas Chapter, American Fisheries Society 20:15-30. 1998

Ecological Evaluation of an Open and Impounded Marsh in the Brazoria National Wildlife Refuge, Texas: Phase I and II

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Abstract.---In 1969, a variable-crest weir was constructed on a coastal marsh within the Brazoria National Wildlife Refuge (BNWR), Texas. The weir, when active, functions to retain water in the marsh during winter low tides to maintain vegetation and critical bird habitat; however, fishes are potentially impacted by the effects of the weir structure on egress and ingress to crucial nursery habitats. Two study sites, one impounded and one open, located on Salt Lake in the BNWR were selected to determine the effects of the weir structure on fish and crustacean populations and movements. The study was divided into two phases; Phase I (July 1995 to July 1996) in which the weir was open and Phase II (May 1997 to March 1998) in which the weir was closed. The results of Phase I showed little differences in both the physicochemical and biotic components of the marsh. During Phase II, the results revealed significant physicochemical and biotic differences between the open and impounded marsh. The closed water-control structure, low tides, and heavy rainfall throughout Phase II resulted in significant differences of physicochemical parameters among all sampling locations. Distribution, recruitment, and migration of species into and out of the impounded area appeared only minimally restricted by the closed water-control structure; however, a few species (e.g. brown shrimp, code goby, pinfish, bay anchovy, white shrimp, gulf menhaden, and tidewater silverside) were unable to negotiate the weir resulting in a lower species diversity and higher species dominance in the impounded location. Management recommendations, based on the results of both studies, include closing the weir from early fall through late winter or early spring to hold water in the marsh for over-wintering waterfowl, and monthly crest manipulation during closure coinciding with high tide events to allow for water circulation and organism migration.

Introduction

The diversity of wildlife and fisheries species occupying coastal marshes is largely regulated by the quality and quantity of available habitat. The rapid loss and alteration of coastal marshes have reduced the quality and quantity of habitat thus resulting in reduced wildlife and fisheries populations in most areas. As increasing demands are placed on coastal marshes, special management practices become essential to maintain wetland habitats (Nyman et al. 1990).

An important technique for management of saltmarshes, particularly in areas that cannot support a continuous impoundment levee or maintain constant minimum water levels, is the construction of weirs. Weirs resemble low dams where the top or crest normally is placed 13.8 cm below the elevation of the surrounding marsh to allow a bidirectional flow of water across the structure (Rogers et al. 1992). Earthen plugs or stop logs can be used to raise the crest to block water flow and maintain a basin of water in the marsh behind the structure.

Weirs are installed for various reasons including prevention of saltwater intrusion, increasing waterfowl habitat, reducing marsh loss, revegetating saltmarsh areas, and decreasing breeding areas for saltmarsh mosquitoes (Rogers et al. 1994). However, these water-control structures disrupt normal estuarine water flows and potentially affect marine transient species. Saltmarshes provide shallow water habitat critical to the recruitment of larval and juvenile individuals of transient species, which spend much of their life cycle in the estuary (McHugh 1967; Haedrich 1983; Boehlert and Mundy 1988). These organisms can be affected by reduced water exchange (Rogers and Herke 1985), constricted ingress and egress, and alteration of habitat (Herke et al. 1984). Positive effects of weirs on resident species, those which reside in the estuary throughout their life cycle, include decreased competition and predation (Rogers et al. 1994).

Coastal marshes undergo important seasonal cycles that affect the hydrology and biota of the marsh. Water-control structures, such as weirs, alter seasonal hydrologic, physicochemical, and biotic patterns. In Texas, no studies have been conducted to evaluate the effects of water-control structure placement or closure on the hydrology and biota of the marsh. Therefore, our study's objectives were to evaluate the effects of a weir structure and a closed weir on selected physicochemical and biotic dynamics in a central Texas coastal marsh, and to provide management recommendations to Brazoria National Wildlife Refuge (BNWR) personnel based on fishery community dynamics and water quality.

Study site

The BNWR is located 10.5 km northeast of Freeport on the upper Texas coast in Brazoria County. The refuge contains several saltmarshes that are located along the southernmost portion of the Galveston Bay system. Tidal exchange between marine waters and marshes in the area occurs through the Freeport Harbor Channel and along the Gulf Intracoastal Waterway (GIWW). The major rivers in the area are located south of the BNWR and include the Brazos and San Bernard, which discharge directly into the Gulf of Mexico.

Salt Lake, the study site within the refuge, contains both the open and impounded marsh site locations (Figure 1). Salt Lake is approximately 2 km (wide) X 1.7 km (long) and is connected to the GIWW by two tidal creeks and Nicks Lake. Although subjected to daily tidal regimes, (due to shallow depth) winds are more influential than tides on water levels. The weir site is located at 29^{0}02.773' N X 95^{0}14.870' W, and the control site (at the mouth of Salt Bayou) is located at 29^{0}02.176' N X 95^{0}16.077' W. The sites, 1.6 km apart, are affected similarly by tidal regimes, precipitation, weather, and seasonality.

The study area was divided into two sites, Site 1 (weir site) and Site 2 (control site). Site 1 was subdivided into two locations A (in front of the weir) and B (behind the weir). Site 2 was divided into two locations by the refuge boundary, C (within the refuge boundary) and D (outside the refuge boundary) (Figure 1). Each sampling location has a shoreline perimeter of approximately 290m.

The water-control structure, a variable crest weir, modifies water flow and levels by the placement and removal of stop logs that fit horizontally across the openings. The 2.8 m (high) x 4.5 m (wide) weir is connected to the west shoreline of the marsh by a 1.3 m (high) x 9.2 m (long) dam. The east shoreline of the marsh is connected to the right side of the weir. Oyster *Crassostrea virginica* beds were observed adjacent to the weir, but not in the open marsh.

Methods

This study was performed in two phases based upon weir closure. The weir remained open during Phase I and closed during Phase II. Sampling was conducted twice monthly during Phase I, July 1995 - July 1996, and monthly for Phase II, May 1997 - March 1998, at all four locations (A, B, C, D). Six stations within each location were randomly selected for each sampling event, providing for three replicates each of light traps and bag seine.

Light traps (30 x 30 x 30 cm) were used to sample larval fishes. The general design of the light traps followed Mueller et al. (1993). Trap modifications included all plexiglass construction (rather than a combination of plexiglass and PVC) and the absence of a built-in holder for the light source. A single, green, 12-h cyalume chemical light stick was placed in each trap to serve as the light source. Light traps were deployed approximately one hour before sunset and retrieved approximately one hour after sunrise. Traps were placed as close to shore as water depths would allow and were held in position with an anchored PVC pipe. Organisms collected were preserved in 10% formalin and returned to the laboratory for identification, enumeration, and measurement. When more than 20 individuals of one species were collected, a random subsample of 20 was measured and the remaining sample counted.

A 10 x 1.3 m seine with a 1.3 x 1.3 x 1.3 m bag with 3 mm bar mesh was used to sample juvenile and adult fishes. The seine was pulled 10m along the shoreline for each replicate.

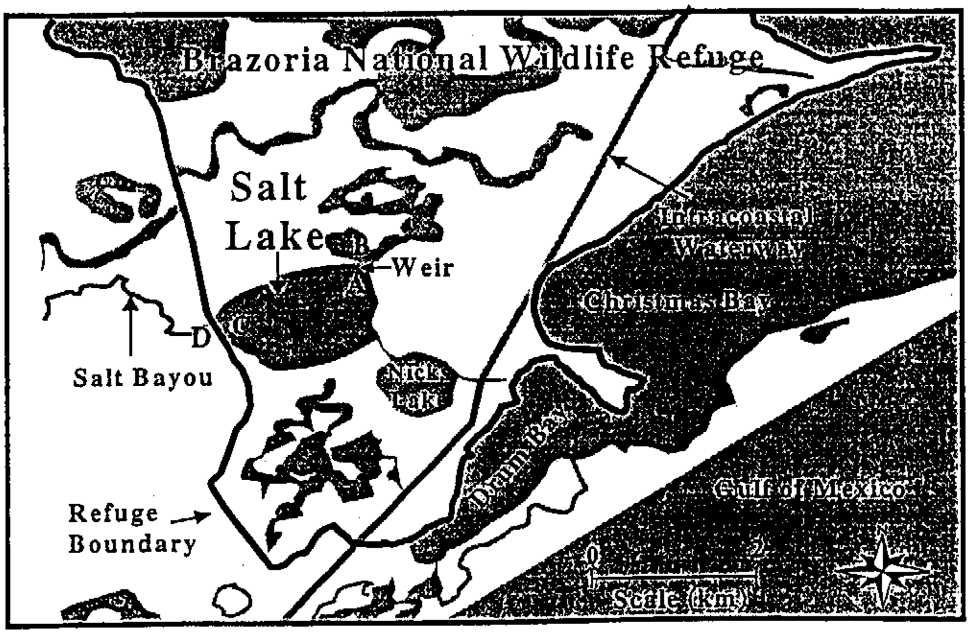

FIGURE 1.---Map showing the weir and four sampling locations in Salt Lake in the Brazoria National Wildlife Refuge, Texas.

All fauna collected were identified, enumerated, and measured. When more than 20 individuals of one species were collected, a random subsample of 20 was measured and the remaining sample counted. Only organisms that could not be positively identified in the field were returned to the lab.

Physicochemical data were collected using a Hydrolab Surveyor II, measuring water depth (m), water temperature (°C), dissolved oxygen (mg/L), pH, conductivity (S/cm^3) and salinity (ppt). Surface (0.1 m) water quality was measured at deployment (late afternoon) and retrieval (early morning) of the light traps at each sampling location. Surface and bottom water quality was measured prior to seining (mid-morning, early afternoon).

Differences in physicochemical readings and species collected among locations were determined using analyses of variance (ANOVA) at a 0.05 level of significance. Where differences were significant, they were identified using the least significant difference (LSD) multiple range test. To determine variance in data among locations and the factors causing the variance, Principle Component Analyses (PCA) were used.

To further compare the species data among sampling locations, Shannon's Diversity Index and Simpson's Dominance Index were used to characterize and compare species diversity and species dominance (base 10; Pielou 1966). Pearson's Correlation Coefficients were then utilized to determine correlations between diversity, dominance, and catch to physicochemical parameters.

Results

Physicochemistry

Nineteen physicochemical surveys were conducted during Phase I; whereas seven were conducted during Phase II. Using a one-way ANOVA, no significant differences among locations were detected for dissolved oxygen or temperature during Phase I. However, three dates showed significant difference among locations for pH and four dates for salinity and conductivity (Table 1). During Phase II, all sampling dates at all times of water quality measurement showed significant differences in water quality data among the four sampling locations (Table 2).

For Phase I, the PCA indicated that the major factor creating the variance in physicochemical data among locations at times of light trap deployment was temperature (44.4%), while the second factor was salinity (23.1%) (Figure 2A). For times of light trap retrieval, the PCA again extracted temperature as Factor 1 (48.7%); Factor 2 (22.2%) was dissolved oxygen (Figure 2B). Temperature was also determined as Factor 1 (43.8%) at times of bag seine deployment, while Factor 2 (25.6%) was pH (Figure 2C). The PCA scatter plots showed slight variation among the four sampling locations, with the least variation observed at times of bag seine utilization.

For Phase II, the PCA indicated that the major factor creating the variance in conditions among sampling locations at times of light trap deployment and retrieval was also temperature (64.9% and 65.3%, respectively), while the second factor was salinity (25.4% and 26.6%, respectively) (Figures 3A and 3B). The PCA again extracted temperature as Factor 1 (65.3%) and salinity as Factor 2 (25.0%) at times of bag seine utilization (Figure 3C). The PCA scatter plots show extensive variation among the four sampling locations with the most variation at light trap retrieval.

Biology

A total of 51,409 individuals were collected during Phase I, representing 16 orders, 31 families, and 52 species (Table 3). Light traps contributed 15,852 of those individuals (30.8%) and 32 species. Nine of these species were commercially or recreationally important and constituted 83.9%. Fishes represented six of these nine species and 47.9% of the catch. The bay anchovy *Anchoa mitchilli* was the most abundant fish (19.2%) followed by Gulf menhaden *Brevoortia patronus* and red drum *Sciaenops ocellatus* which made up 13.9% and 9.4% of the catch, respectively. Crustaceans (5709 individuals) were represented by three species: white shrimp *Penaeus setiferus*, brown shrimp *P. aztecus*, and blue crabs *Callinectes sapidus*. White shrimp was the most abundant crustacean (27.4%), while blue crab was the least abundant (4.3%).

Bag seine collections contributed 35,557 individuals (69.2%) and 45 species. Twelve of the 45 species collected were commercially/recreationally important and constituted 91.3% of the total bag seine collection. Fishes, representing

TABLE 1.--- Physicochemical parameters that significantly varied ($P \leq 0.05$) among locations during Phase I (July 1995 to July 1996) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Underlining indicates locations that are not significantly different. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Date	pH		Conductivity		Salinity	
	P	locations	P	locations	P	locations
6 Nov 1995			0.002	A B C D	0.002	A B C D
18 Nov 1995	0.010	A B C D	0.000	A B C D	0.001	A B C D
9 Feb1996			0.017	A B C D	0.017	A B C D
10 Mar 1996	0.026	A B C D				
19 Apr 1996	0.048	A B D C				
16 Jun 1996			0.015	A B C D	0.001	A B C D

TABLE 2.---Physicochemical parameters that significantly varied ($P \leq 0.05$) among locations at times of light trap deployment and retrieval and bag seine during Phase II (May 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Underlining indicates locations that are not significantly different. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Date	Conductivity	Dissolved Oxygen	pH	Salinity	Temperature
Light Trap Deployment					
15 May 1997	A B C D	A B C D	A B C D	A B C D	A B C D
25 Jun 1997	AB C D	A B CD	A B C D	AB C D	A B C D
29 Jul 1997	AB C D	AC B D	A B C D	AB C D	A B C D
26 Aug 1997	ABC D	BC A D	AB C D	ABC D	ABC D
30 Sep 1997	AB C D	A B CD	ABD C	AB C D	
21 Jan 1998	AB CD		A B C D	A B CD	A B C D
03 Mar 1998	A B CD	A BCD	A B CD	A B CD	A B C D
Light Trap Retrieval					
15 May 1997	A B CD	AB CD	AB C D	A B CD	BD A C
25 Jun19 97	A B C D	ACD B	AC B D	AB C D	A B C D
29 Jul 1997	AB C D	AB C D	A B C D	AB C D	A B C D
26 Aug 1997			AB CD	BCD A	AB C D
30 Sep 1997		ACD B			
21 Jan 1998	AB C D		A B C D	A B CD	A B C D
03 Mar 1998	AB C D	BC A D		AB C D	AB C D
Bag Seine Utilization					
15 May 1997	AB C D	AC B D	AB C D	AB C D	AB C D
25 Jun 1997		A B CD	A B CD		AD B C
29 Jul 1997	AB CD			AB CD	
26 Aug 1997	ABC D	AC B D	A B C D	AB C D	AB C D
30 Sep 1997	AB C D	A B CD	A B C D	A B C D	BCD A
21 Jan 1998	AB CD	ABD C	A B C D	A B C D	A B C D
03 Mar 1998	AB C D	A B CD	ACD B	A B CD	A B C D

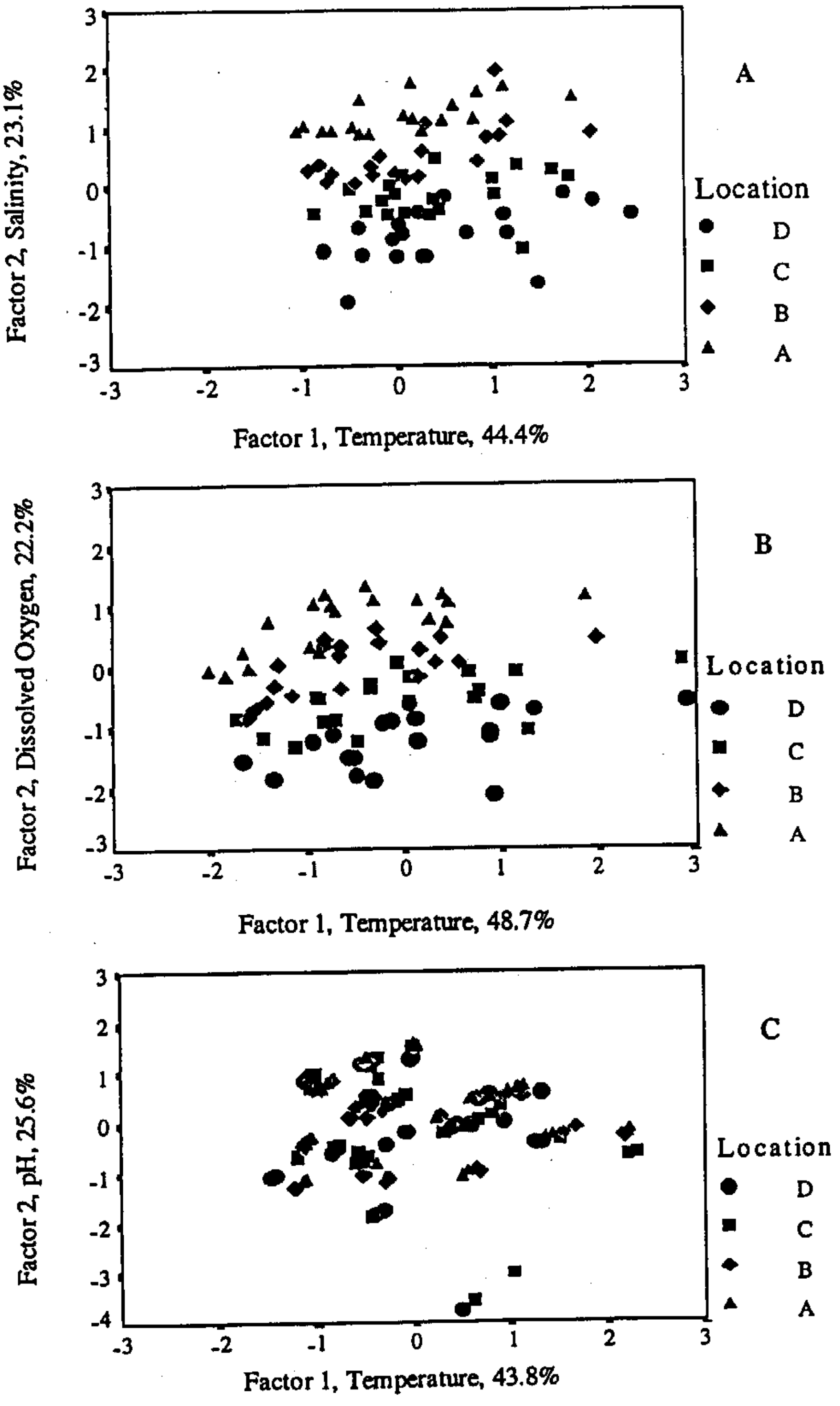

FIGURE 2.—Principal component analysis scatter plot showing spatial variation in water quality parameters at times of A) light trap deployment, B) light trap retrieval, and C) bag seine utilization in Salt Lake in the Brazoria National Wildlife Refuge, Texas between July 1995 and July 1996. Location A is located in front of the weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

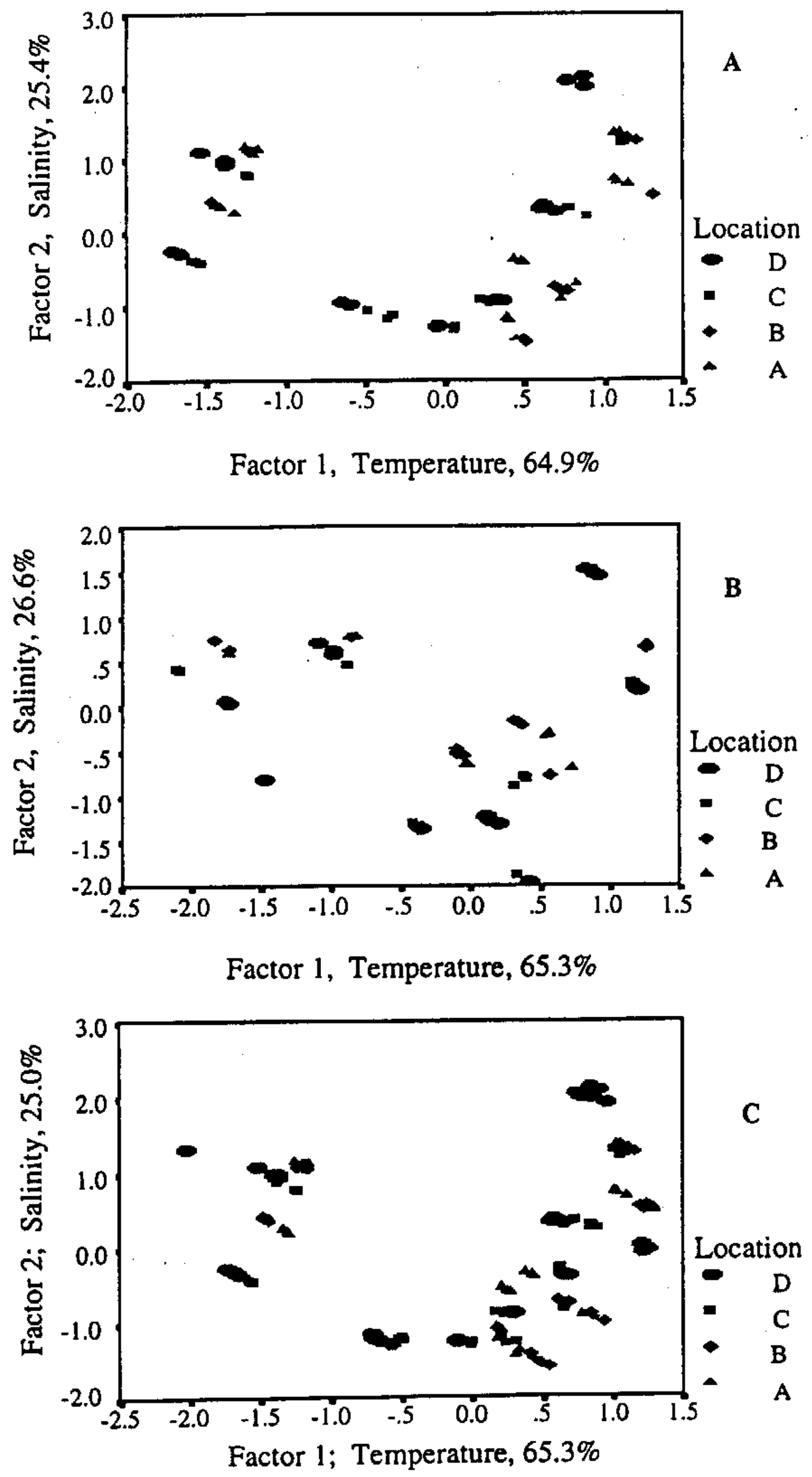

FIGURE 3.---Principal component analysis scatter plot showing spatial variation in water quality parameters at times of A) light trap deployment, B) light trap retrieval, and C) bag seine utilization in Salt Lake in the Brazoria National Wildlife Refuge, Texas between May 1997 and February 1998. Location A is located in front of the weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

TABLE 3.—Species and abundance collected during Phase I (July 1995 to July 1996) and Phase II (May 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas.

Species	Common Name	Phase I Light Trap	Phase I Bag Seine	Phase II Light Trap	Phase II Bag Seine
Achirus lineatus	Lined sole	40	18	3	6
Adinia xenica	Diamond killifish	5	55	3	0
Anchoa mitchilli	Bay anchovy	3045	2560	203	289
Archosargus probatocephalus	Sheepshead	0	0	0	1
Arius felis	Hardhead catfish	0	11	0	9
Bairdiella chrysura	Silver perch	28	79	0	8
Brevoortia patronus	Gulf menhaden	2199	11581	1156	7411
Callinectes sapidus	Blue crab	674	738	141	135
Caranx hippus	Jack crevalle	1	1	0	2
Chaetodipterus faber	Atlantic spadefish	0	7	0	0
Cynoscion arenarius	Sand seatrout	0	93	0	1
C. nebulosus	Spotted seatrout	34	37	5	116
Cyprindon variegatus	Sheepshead minnow	41	362	2	71
Dorosoma cepedianum	Gizzard shad	0	8	0	0
Elops saurus	Ladyfish	0	0	0	2
Etropus crossotus	Fringed flounder	0	10	0	0
Eucinostomus argenteus	Silver jenny	0	79	0	4
Fundulus grandis	Gulf killifish	2	208	3	10
F. pulvereus	Bayou killifish	13	42	0	2
F. similis	Longnose killifish	1	20	0	0
Gobionellus hastatus	Sharptail goby	0	0	4	1
G. shufeldti	Freshwater goby	0	3	1	0
Gobiosoma robustum	Code goby	191	24	64	0
G. bosci	Naked goby	93	11	218	6
Gymnothorax spp.		1	1	0	0
Harengula jaguana	Scaled sardine	64	15	0	0
Hemicaranx amblyrhyncus	Bluntnose jack	0	1	0	0
Lagodon rhomboides	Pinfish	465	943	203	90
Leiostomus xanthurus	Spot	0	136	0	1
Lepisosteus oculata	Spotted gar	0	0	0	1
Lucania parva	Rainwater killifish	0	0	0	3
Menidia beryllina	Tidewater silverside	1586	981	251	244
Menticirrhus americanus	Southern kingfish	0	2	0	0
Micropogon undulatus	Atlantic croaker	0	72	16	124
Mugil cephalus	Striped mullet	777	1386	21	60
M. curema	White mullet	0	1	0	0
Oligoplites saurus	Leatherjacket	3	106	0	2
Opsanus beta	Gulf toadfish	1	0	0	0
Paralichthys lethostigma	Southern flounder	51	73	5	33
Penaeus aztecus	Brown shrimp	687	2345	177	1332
P. setiferus	White shrimp	4348	8632	623	810
Peprilus burti	Gulf butterfish	0	1	0	0
Poecilia latipinna	Sailfin molly	0	26	0	0
Polydactylus octonemus	Eight-fingered threadfin	0	0	0	15
Prinotus tribulus	Big headed searobin	0	16	0	0
Sciaenops ocellata	Red drum	1489	7833	145	262
Sphoeroides parvus	Least puffer	0	1	0	0
Strongylura marina	Atlantic needlefish	0	1	0	0
Sygnathus louisianae	Gulf pipefish	1	1	0	0
S. scovelli	Chain pipefish	1	0	0	0
Symphurus plagisusa	Black cheek tonguefish	5	30	1	7
Synodus foetens	Inshore lizardfish	3	8	0	0

nine species, were the most abundant organism collected with 20,737 individuals (58.3%). Gulf menhaden was the dominant species (32.8%), followed by red drum (13.6%) and bay anchovy (7.2%). Crustaceans were dominated by white shrimp (24.3%).

During Phase II, a total of 14,302 individuals were collected representing 9 orders, 20 families, and 35 species (Table 3). Of the total, 24.1% were collected by light traps and 75.9% by bag seine.

Of the 21 species collected by light traps, 10 were commercially/recreationally important and constituted 76.8% of the total collection. Fishes represented seven of these 10 species and 1551 individuals (62.2%). Gulf menhaden was the most abundant fish (46.3%) followed by bay anchovy (8.1%) and red drum (5.8%). Crustaceans (941 individuals) were represented by white shrimp, brown shrimp, and blue crab. White shrimp was the most abundant crustacean (66.2%).

Bag seine collections contributed 11,058 individuals (75.9%) and 32 species. Ten of the 32 species collected were commercially/recreationally important. These 10 species constituted 95.6% of the total collection. Fishes, representing eight species, were the most abundant organism collected with 8296 individuals (78.5%). Gulf menhaden was the dominant species (89.3%) followed by bay anchovy (3.5%) and red drum (3.2%). Crustaceans (21.5%) were dominated by brown shrimp (58.5%).

Spatial Dynamics of Species

Comparison of catches by location for light traps during Phase I revealed that only two species varied in catch by location, pinfish *Lagodon rhomboides* (P=0.05) and southern flounder *Paralichthys lethostigma* (P=0.01) for which catches at locations A and B were significantly different than C and D. For bag seine collections, four of the 47 species varied by location (Table 4). During Phase II, eight species for light traps and 10 species for bag seine varied when comparing catches by location (Tables 5 and 6).

Total catch by light traps and bag seine for Phase I was also compared spatially using PCA. Two factors were extracted for location that explained most of the variance. For light traps, Gulf menhaden and brown shrimp were extracted as Factor 1 representing 7.9% of the spatial variance; whereas southern flounder and silver perch *Bairdiella chrysura* were extracted as Factor 2 representing 6.8% of the variance (Figure 4). No factors could be determined for bag seine collections due to the absence of significant variance. For Phase II, total catch by light traps and bag seine were also compared using PCA. Two factors were extracted that explained the variance in biota: Factor 1, red drum (17.2%) and Factor 2 white shrimp (14.1%) (Figure 5). For bag seine, Factor 1, bay anchovy, explained 17.3% of the variance, and factor 2, southern flounder, explained 13.8% of the variance (Figure 6).

Shannnon's Diversity Index and Simpson's Dominance Index were used to compare mean species diversity and dominance by location and between sampling gears. For Phase I, all four sampling locations and both sampling gears showed similar results (Table 7); therefore, diversity and dominance were calculated combining all locations and both gears. These figures were correlated with physicochemical data collected at times of light trap deployment and retrieval and bag seine utilization, as well as with total fish and crustacean collections for both gears. Significant correlations were made between diversity, dominance, and total catch of fishes and crustaceans to physicochemical parameters (Table 8). Physicochemical data taken at times of light trap retrieval yielded the greatest number of significant correlations (10 out of 11) while physicochemical data collected at times of bag seine utilization showed the fewest (three of 11) significant correlations.

Shannon's Diversity Index and Simpson's Dominance Index were also used to compare species diversity and dominance by location for all sampling dates during Phase II (Tables 9-10). These figures were correlated with physicochemical data collected at the time of light trap and bag seine utilization, as well as total fish and crustacean collections for each gear (Table 11). Physicochemical data collected during bag seine utilization on 3 March 1998 yielded the highest number of correlations (five of 15); whereas, no correlations were made on 25 June 1997.

Discussion

Physicochemical Alterations from Weir Placement and Closure

Overall, physicochemical conditions of the semi-impounded system were consistent with conditions of the open system during the Phase I study. The weir was not

TABLE 4.---Species collected by bag seine that significantly ($P \leq 0.05$) varied in catch by location during Phase I (July 1995 to July 1996) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Underlining indicates locations that are not significantly different. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Species	Common Name	P	Locations
Cynoscion arenarius	Sand trout	0.048	A C B D
Fundulus similus	Longnose killifish	0.036	D A B C
Paralichthys lethostigma	Southern flounder	0.028	A B C D
Symphurus plagiusa	Black cheek tonguefish	0.042	A B C D

TABLE 5.---Species collected by light traps that significantly ($P \leq 0.05$) varied in catch by location for Phase II (May 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Underlining indicates locations that are not significantly different. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Date	Species	Common Name	*P*	Locations
25 Jun 1997	*Penaeus aztecus*	Brown shrimp	0.021	<u>ACD</u> B
26 Aug 1997	*Lagodon rhomboides*	Pinfish	0.044	<u>AB</u> <u>CD</u>
30 Sep 1997	*Anchoa mitchilli*	Bay anchovy	0.050	A <u>BCD</u>
	Gobiosoma robustum	Code goby	0.013	<u>ACD</u> B
	Menidia beryllina	Tidewater silverside	0.041	<u>ACD</u> B
	Paralichthys lethostigma	Southern flounder	0.002	A <u>CD</u> B
	Penaeus setiferus	White shrimp	0.025	<u>ABD</u> C
03 Mar 1998	*Mugil cephalus*	Striped mullet	0.033	<u>ABC</u> D

TABLE 6.---Species collected by bag seine that significantly ($P \leq 0.05$) varied in catch by location during Phase II (May 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Underlining indcates locations that are not significantly different. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Date	Species	Common Name	*P*	Locations
15 May 1997	*Brevoortia patronus*	Gulf menhaden	0.023	<u>ACD</u> B
	Lagodon rhomboides	Pinfish	0.041	<u>CD</u> A B
	Menidia beryllina	Tidewater silverside	0.033	<u>ABD</u> C
	Polydactylus octonemus	Eightfingered threadfin	0.001	<u>AB</u> C D
25 Jun 1997	*Anchoa mitchilli*	Bay anchovy	0.026	<u>ACD</u> B
	Bairdiella chrysura	Silver perch	0.010	<u>ACD</u> B
	Mugil cephalus	Striped mullet	0.003	<u>ABD</u> C
26 Aug 1997	*Lagodon rhomboides*	Pinfish	0.002	<u>ACD</u> B
30 Sep 1997	*Arius felis*	Hardhead catfish	0.036	<u>ABD</u> C
	Penaeus setiferus	White shrimp	0.020	<u>BC</u> A D
03 Mar 1998	*Brevoortia patronus*	Gulf menhaden	0.010	<u>ACD</u> B

TABLE 7.---Diversity and dominance means for light trap and bag seine gears for all sampling locations during Phase I (July 1995 to July 1996) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control outside the refuge boundary.

Location	Diversity	Dominance
Light Trap		
A	0.601	0.411
B	0.574	0.422
C	0.511	0.408
D	0.565	0.430
Bag Seine		
A	0.583	0.415
B	0.558	0.407
C	0.561	0.417
D	0.572	0.422

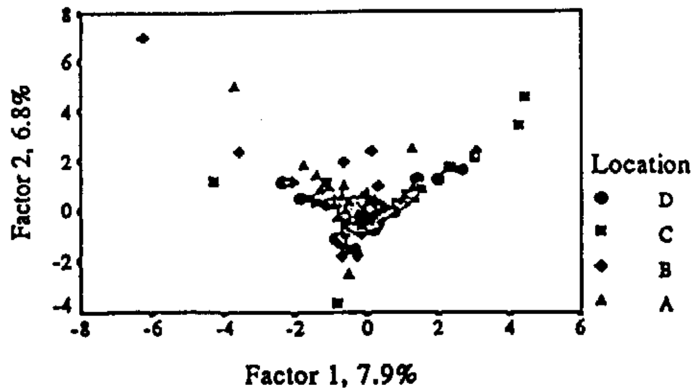

FIGURE 4.—Principal component analysis scatter plot showing light trap catch spatial variation in Salt Lake in the Brazoria National Wildlife Refuge, Texas between July 1995 and July 1996. Factor 1 represents Gulf menhaden *Brevoortia patronus* and brown shrimp *Penaeus aztecus*; whereas, Factor 2 represents silver perch *Bairdiella chrysura* and southern flounder *Paralichthys lethostigma*. Location A is located in front of the weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

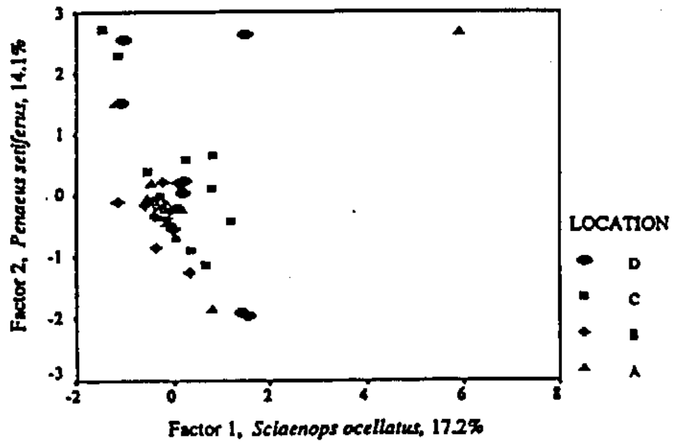

FIGURE 5.—Principal component analysis scatter plot showing light trap catch spatial variation in Salt Lake in the Brazoria National Wildlife Refuge, Texas between May 1997 and February 1998. Location A is located in front of the weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

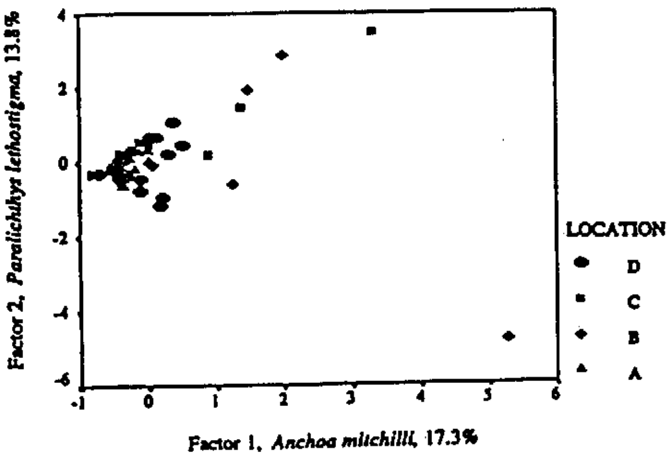

FIGURE 6.—Principal component analysis scatter plot showing bag seine catch spatial variation in Salt Lake in the Brazoria National Wildlife Refuge, Texas between May 1997 and February 1998. Location A is located in front of the weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

TABLE 8.---Significant correlations ($P \leq 0.05$) between diversity, dominance, and catch to physicochemical parameters during Phase I (July 1995 to July 1996) in Salt Lake in the Brazoria National Wildlife Refuge, Texas.

Correlation	Time of Light Trap Deployment	Time of Light Trap Retrieval	Time of Bag Seine Sampling
Diversity/ Salinity	r = 0.4662	r = 0.4282	
Diversity/Temperature		r = 0.5210	
Dominance/Conductivity	r = -0.5079	r = -0.5026	
Dominance/Salinity	r = -0.4967	r = -0.5015	
Dominance/Temperature	r = -0.8649	r = -0.5926	
Dominance/Dissolved Oxygen		r = 0.4663	
Dominance/Crust.			r = 0.4890
Crustaceans/Dissolved Oxygen	r = -0.5204	r = -0.5902	r = -0.5730
Crustaceans/pH		r = -0.5883	r = -0.5247
Crustaceans/Fishes	r = 0.5342	r = 0.5342	
Fishes/pH		r = -0.4921	

TABLE 9.---Diversity (H') and dominance (DI) figures for light trap catch for all sampling locations and dates during Phase II (February 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Date	Location A		Location B		Location C		Location D	
	H'	DI	H'	DI	H'	DI	H'	DI
15 May 1997	0.323	0.612	0.234	0.727	0.388	0.537	0.371	0.462
25 Jun 1997	0.539	0.383	0.194	0.778	0.302	0.644	0.495	0.465
29 July 1997	0.497	0.365	0.398	0.431	0.303	0.684	0.268	0.731
26 Aug 1997	0.500	0.449	0.361	0.622	0.621	0.291	0.505	0.419
30 Sep 1997	0.194	0.782	0.560	0.318	0.388	0.566	0.506	0.320
21 Jan 1998	0.368	0.444	0.244	0.500	0.475	0.393	0.410	0.431
03 Mar 1998	0.489	0.405	0.001	0.990	0.405	0.488	0.112	0.900

TABLE 10.---Diversity (H') and dominance (DI) figures for bag seine catch for all sampling locations and dates during Phase II (May 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas. Location A is in front of weir, B is behind the weir, C is a control site within the refuge boundary, and D is a control site outside the refuge boundary.

Date	Location A		Location B		Location C		Location D	
	H'	DI	H'	DI	H'	DI	H'	DI
15 May 1997	0.583	0.364	0.361	0.597	0.598	0.382	0.526	0.400
25 Jun 1997	0.279	0.742	0.565	0.453	0.165	0.867	0.588	0.349
29 July 1997	0.514	0.451	0.808	0.151	0.201	0.816	0.689	0.252
26 Aug 1997	0.254	0.760	0.464	0.387	0.680	0.387	0.520	0.436
30 Sep 1997	0.278	0.681	0.636	0.285	0.356	0.643	0.375	0.561
21 Jan 1998	0.380	0.472	0.151	0.777	0.415	0.450	0.456	0.497
03 Mar 1998	0.217	0.778	0.002	0.998	0.710	0.231	0.422	0.537

TABLE 11.---Significant correlations ($P \leq 0.05$) between diversity, dominance, and catch to physicochemical parameters for light trap (L.T.) and bag seine (B.S.) catches and corresponding water quality parameters during Phase II (May 1997 to March 1998) in Salt Lake in the Brazoria National Wildlife Refuge, Texas.

Correlation	15 May 1997 B.S.	29 Jul 1997 L.T	29 Jul 1997 B.S.	26 Aug 1997 L.T	26 Aug 1997 B.S.	30 Sep 1997 L.T	30 Sep 1997 B.S.	21 Jan 1998 B.S.	03 Mar1998 B.S.
Crustaceans/pH								r = 0.960	r = -0.969
Crustaceans/Salinity								r = -0.975	
Diversity/Crustaceans			r =-0.962						
Diversity/Dissolved Oxygen									r = -0.984
Diversity/Dominance	r =-0.979	r =-0.967				r = -0.985	r = -0.989		
Diversity/pH									r = -0.954
Dominance/Crustaceans		r =-0.988	r = 0.971		r = 0.953				
Dominance/Dissolved Oxygen									r = 0.980
Dominance/pH									r = 0.951
Dominance/Salinity		r = 0.986							
Fishes/Dissolved Oxygen				r = -0.952		r = -0.979			
Fishes/Diversity	r = -0.955				r = 0.974				
Fishes/pH					r = -0.977				
Fishes/Salinity								r = -0.972	
Fishes/Temperature		r =-0.955							

actively managed during the study period, and the dam and/or permanent fittings did not significantly affect physicochemical conditions upstream or downstream of the structure. Significant physicochemical variations that did occur (Table 1) were the result of factors other than the weir structure.

During Phase II, the physicochemical conditions of all sampling locations varied significantly from one another throughout the entire study period (Table 2). As in the Phase I study, environmental conditions, especially rain, caused most of the variation. Although the water control structure was closed, there was only one sampling event, 29 July 1997, when water was not moving over the dam allowing for water circulation. However, the weir had some adverse affects on water quality which were evident during the summer sampling events when the water level was low and a more accurate assessment of the effects on water quality could be made. For example, dissolved oxygen measured in location B (behind the weir) was always lower than the other sampling locations, and pH was generally higher.

All dates during Phase I on which salinity and conductivity were significantly different among locations followed rainfall events in the area. The open marsh had lower salinities than the semi-impounded site, which can be attributed to the control site being at the mouth of Salt Bayou. Salt Bayou is channelized and approximately 8 km in length and extends west from Salt Lake receiving freshwater runoff from all surrounding upland areas (Figure 1). This freshwater then flows down the bayou eventually emptying into Salt Lake. Behind the semi-impounded site are open, shallow pond or marsh areas that are not channelized to facilitate the movement of freshwater through the system. Subsequently, rainwater or freshwater that is collected in this site is more indicative of actual rainfall totals, unlike the control site, that has freshwater inflow from adjacent areas via the channelized bayou. Salinity also showed the greatest difference in measurements among sampling locations throughout the Phase II study period, with the open marsh having lower salinities than the impounded site, due to the same reasons explained above.

The date of the greatest pH variation during Phase I (18 November 1995) (Table 1) followed the heaviest rainfall in the area. pH typically remains stable in saline waters; however, when freshwater is introduced into a saline system, the ratio of carbonate and borate buffers decreases allowing for declines in pH (Tait 1980). Two other dates during which pH significantly varied among locations were at times when large amounts of algae were observed in the marshes, especially at location C. The presence of algae causes fluctuations in pH in surface waters because the algae can withdraw carbon dioxide from surface waters which in turn raises pH (Tait 1980).

Temperature during Phase II typically significantly varied among all locations (Table 2), which may be attributed to water depth. Both location B and D were deeper than locations A and C causing the water to stay colder or warmer depending on environmental conditions. In addition, locations C and D were unprotected, facing the prevailing southeast winds, therefore, more susceptible to the affects of winds.

The PCA indicated that there were slight physicochemical differences among all sampling locations during Phase I, with the greatest variance among locations observed during the morning hours at light trap retrieval (Figure 2b), because temperature and dissolved oxygen are typically at their lowest levels in early morning hours. Water quality parameters at times of bag seine utilization showed the least variation among locations (Figure 2c). This may be attributed to the fact that both surface and bottom measurements taken at bag seine deployment were combined (because there was no significant difference) for the analysis. Surface waters are more susceptible to change than deeper waters, therefore, by combining the two values the variation was masked.

For Phase II, the PCA indicated that not only were there differences in water quality among sampling locations, but also between sampling dates (Figures 3a, 3b, and 3c). Temperature was again extracted as Factor 1 by the PCA; however, in this study, temperature was a much higher percent of the variation than the first study, 65.1% and 45.6%, respectively. Unlike Phase I, salinity was extracted as Factor 2 in this study for all times of physicochemical measurement. The combined percent of variance explained in this study by all scatter plots averaged 90%, while only 69% in the first study. Therefore, it is evident that these two parameters fluctuated more among sampling locations during the second study period.

Physicochemcial Effects on Biota

Fishes and crustaceans search for and select a certain optimum combination of physical conditions in the environment which are conducive to growth, reproductive development, and feeding. When these conditions are altered, organisms either adapt or migrate to more suitable areas.

In Phase I, temperature was a determining factor in species diversity and dominance (Table 8). Water temperatures ranged from a winter low of 8.1°C to a summer maximum of 33.65°C. The varying catch rates observed over this temperature range may reflect an organism's tolerance of these widely fluctuating temperatures and/or the number of species spawning during each season. During extreme low temperatures, catch rates for light traps averaged 1.36 individuals/h, while catch rates for bag seine averaged 0.54 individuals/m. In contrast, during higher water temperatures, light trap catch rates averaged 11.41 individuals/h, and bag seine catch rates averaged 32.05 individuals/m. These numbers indicate that extreme cold temperatures cause juvenile fishes and crustaceans to move to deeper, warmer water, and that more organisms are capable of withstanding the higher temperatures encountered in this study. In addition, more species spawn in the warmer months which is reflected in the higher catch rates by the light traps.

Temperature, for Phase II, was negatively correlated with fish catch on 29 July 1997 (Table 11). Temperature was actually highest on 25 June 1997, however, the sustained warm water temperatures, which affect fishes as described above, cause fishes to seek deeper, cooler water, which may explain the lower catch rates during this sampling event.

All organisms inhabiting saltmarshes must contend with fluctuating salinities. These organisms are affected not only by the magnitude of the salinity change, but also by the rate of change (Green, 1968). The rate of change is determined by such factors as freshwater inflow, evaporation, and tidal influence. Salinities during Phase I, ranging from 9.93 to 33.59 ppt and played an important role in species diversity and dominance in this study (Table 8). At both high and low salinities, a reduction in number of individuals collected was observed. At the lowest salinity, (19 November 1995) light traps averaged 5.29 individual/h, while bag seine collections averaged 6.14 individuals/m. At the highest salinity (30 June 1996) light traps averaged 4.82 individuals/h and bag seine collections averaged 4.56 individuals/m. Neither salinity measurement is considered an extreme condition; however, the reduced number of individuals, especially during the summer when there was an increase in abundance and diversity of species, suggests an intolerance or movement to more suitable conditions by organisms.

For Phase II, salinity was negatively correlated with dominance and crustacean and fish catches (Table 11). Salinity measurements ranged from a high of 37.90 ppt to a low of 1.20 ppt, both readings considered extreme for a coastal marsh. However, these extreme salinity readings did not last for extended periods of time, which would be necessary to create fatal conditions for biota. The correlation between salinity and crustacean and fish catches may have been made because of the mobility of these organisms. Being mobile, fishes and crustaceans can move to more favorable conditions to alleviate undo stress, which may explain why catches were lower associated with these extreme salinity measurements.

Fishes and crustaceans are sensitive to fluctuations in pH. Low pH conditions can be toxic to fishes and crustaceans by decreasing oxygen consumption while increasing ventilation rates, although low pH is not a common environmental stress factor in saline estuaries (Lagler et al. 1977; Dunson et al. 1993). During Phase I, both fish and crustacean catches were negatively correlated with pH (Table 8), and pH was extracted as the second factor explaining the spatial variance among locations during late morning sampling (Figure 2c). pH ranged from 7.62-9.30. pH in marine water remains relatively constant because of the presence of sufficient quantities of carbonates and borates acting as buffers; however, it can fluctuate depending upon the temperature, pressure, and salinity of the water (Hela and Laevastu 1961).

In Phase II, both fish and crustacean catches were negatively correlated with pH, as well as diversity (Table 11); however, dominance was positively correlated with pH. pH values were lower than in Phase I, ranging from 7.82-8.28 due to high levels of rainfall and the uneven distribution of freshwater among the sampling locations. pH varied significantly among locations for almost all sampling dates causing catch of fishes and crustaceans to be notably different depending upon pH. Dominance, on the other hand, increases with variation in pH because those organisms that can tolerate the change will stay while the other organisms migrate, causing a decrease in the diversity of the area.

During Phase I, dissolved oxygen ranged from 2.34 mg/L to 11.41 mg/L and significantly correlated with species dominance and total catch of crustaceans (Table 8). The lowest reading was observed at light trap retrieval at a relatively high temperature (29.51°C). Both the early morning hours and the warm water temperature supported conditions for low dissolved oxygen levels. Highest readings were observed during cold water temperatures (10.02°C) and during late-morning/early-afternoon hours. Low dissolved oxygen levels can cause reduced numbers of species and individuals in a given area, which may explain the positive correlation with dominance.

Dissolved oxygen ranged from 0.58 mg/L to 9.98 mg/L throughout Phase II. Dissolved oxygen was negatively correlated with species diversity and total catch of fishes and positively correlated with species dominance (Table 11). The lowest reading was recorded at light trap retrieval was on 29 July 1997 at a relatively high temperature (28.92°C). Both the early morning hours and the warm water temperature created conditions for low dissolved oxygen levels. In addition, this was the only sampling event during which no water exchange occurred across the weir and dam structure. Low dissolved oxygen levels can cause reduced numbers of individuals in a given area, which may explain the correlation with dominance.

Spatial Variability of Biota

Distribution, recruitment, and migration of individuals into and out of the semi-impounded marsh were not restricted during Phase I. The semi-impounded marsh, as well as the open marsh, produced collections that reflected normal distribution and times of marsh use by most resident and transient species. Only a few species were not collected equally between sites, however, the causes for unequal distribution and/or low numbers could not be attributed to an inability by organisms to negotiate the water-control structure. During Phase II, distribution, recruitment, and migration of individuals into and out of the impounded area were minimally restricted. Again, collections reflected normal distribution and times of marsh use by all species collected. Only a few species were unable to negotiate the water control structure and enter the impounded marsh. Several species collections, however, were much higher behind the weir than in other sampling locations, which is substantiated by the low species diversity and high species dominance in this sampling location (Tables 9-10).

The ANOVA for species collected in light traps during Phase II indicated that eight species varied in catch by location (Table 5), which is an increase from the initial study in which only two species varied in catch by location. Of these eight species, five were of recreational or commercial importance: brown shrimp, white shrimp, bay anchovy, southern flounder, and striped mullet *Mugil cephalus*. Brown shrimp were collected in higher numbers behind the weir than in all other sampling locations. Brown shrimp begin migration to deeper waters in the early summer months (Weaver and Holloway 1974; Zimmerman and Minello 1984), which explains their absence from the other sampling locations. Those individuals behind the weir may have been unable to leave the impounded marsh to migrate due to low water levels. Southern flounder were more abundant in the semi-impounded marsh than in the open marsh. One explanation is that the sediment at the semi-impounded site is siltier making it conducive to burrowing. Possible reasons for the difference in sediment between the two sites may be that the weir slows the rate of water flow allowing for the finer particulates in the water column to settle out, and that the weir site was more protected than the control site from the predominant southeast winds, allowing for calmer water. As for the other commercially-important species, the water control structure had no impact on their distribution and collection.

Of the non-commercial species collected by light traps, three were affected by the weir. Code gobies, *Gobiosoma robustum*, were collected in higher numbers behind the weir than in all other sampling locations. This species is epibenthic utilizing hard substrates, such as oyster reefs, for protection and food (Crabtree and Dean 1992). The varied catch of this species may have been attributed to the presence of oysters associated with the weir in the impounded site, and the lack of this hard substrate in the open marsh. Pinfish were also collected in higher numbers at the impounded site versus the open site in both studies. Pinfish are found more abundantly around wharves and pilings or over grassflats than open areas (Britton and Morton 1989; Hoese and Moore 1992); therefore, the difference in catch by location for this species may be the submerged structure of the weir providing the type of underwater structure that pinfish are commonly associated with. The tidewater silverside *Menidia beryllina* was only present behind the weir and not found in any other sampling locations. Again, this may be attributed to these individuals being unable to negotiate the weir and emigrate from the impounded location.

During Phase I, brown shrimp and Gulf menhaden were also extracted as Factor 1 by the PCA to explain spatial variation for light traps (Figure 4). The spatial variation for brown shrimp may be a result of a greater abundance of shrimp collected in the semi-impounded marsh associated with the weir. Inversely, Gulf menhaden school in large numbers as both postlarvals and juveniles, and rarely are individuals observed. Hence, the number of menhaden collected is dependent upon contact with schools. The variance for this species may be explained by their patchy distribution and possible occurrence of or encounter with a school at one sampling station and not another. Southern flounder was extracted as Factor 2 by the PCA (Figure 7). For reasons stated above, southern flounder were more abundant in the semi-impounded site than the open site.

For Phase II, the PCA extracted two commercially-important species red drum and white shrimp to explain 31.3% of the variance for biota among sampling locations for light trap collections (Figure 5). Both of these species utilize the marsh in very high numbers during certain seasons. Due to the sampling time frame and the inability to sample during October, November, and December for red drum and mid-March and April for white shrimp when the numbers are extremely high, the data reflects these two species as short term inhabitants with much higher numbers than other species collected simultaneously. Therefore, these two species were extracted to explain the variance in the system; however, it may not be an accurate assessment due to the gaps in data collection.

The ANOVA for species collected by bag seine during Phase II indicated nine species varied in catch by location (Table 6), which is an increase from the baseline study in which four species varied in catch by location (Table 3). Of these 13 species, six were of recreational or commercial importance: Gulf menhaden, bay anchovy, striped mullet, white shrimp, sand trout *Cynoscion arenarius*, and southern flounder. The water control structure appeared to cause a decrease in numbers of both bay anchovy and white shrimp. Both of these species were collected in relatively equal numbers among the sampling locations during Phase I, however, numbers were significantly lower in the impounded location during Phase II. Gulf menhaden were collected in higher numbers behind the weir than all other sampling locations. During Phase I, location B always had high numbers of Gulf menhaden during their time of marsh use; however, the collections were not significantly different than the other sampling locations (Dilworth *et al.* 1997). During Phase II, particularly the final sampling event on 3 March 1998, extremely high numbers of Gulf menhaden were collected behind the weir. This may be attributed to either an affinity by this species for this location, or an inability to exit the impounded location. Again, differences in catch for southern flounder are explained above.

Of the non-commercial species collected by bag seine that varied in catch by location, only three appeared to be impacted by the weir. Pinfish were collected in lower numbers behind the weir structure, unlike collections of this species in the light traps; however, this species was still collected in high numbers in front of the weir in location A. Silver perch were also collected in lower numbers behind the weir than in all other sampling locations. This species inhabited the marsh during the summer months when water levels were low, thus was unable to enter the impounded sampling location. Black cheek tonguefish, *Symphurus plagiusa*, is another benthic flat fish that burrows in the sediment. Catch of this species was higher at the impounded site than the open site, which again may be explained by siltier sediments at the impounded site.

The PCA extracted two commercially-important species, bay anchovy and southern flounder, to explain 31% of the variance in bag seine catch among locations for Phase II (Figure 6). The explanation for these two species creating the variance among locations is unclear. These two species were collected at different times throughout the study and in relatively low numbers, therefore not indicating any clear reasons for extraction by the analysis. Again, no PCA scatter plot could be derived for bag seine catches during Phase I due to lack of variation among locations.

Community Summary

Phase I results indicate the water-control structure did not impede the movement of organisms into or out of location B. This was evident from the diversity and dominance results, the principle component analysis results, as well as the collection of both nektonic and epibenthic species behind the weir. However, the submerged portion of the structure apparently provided a preferred habitat as indicated by variation in catch among locations for several species including brown shrimp, pinfish, and because of the associated oyster bed, both naked *Gobiosoma bosci* and code gobies. The seasonal patterns observed were indicative of the documented spawning and migration times of the marine transients. Only Gulf menhaden were collected in the marsh earlier than expected, arriving in October when the reported spawning period was during the winter months. The similarity of these two sites indicates that the open marsh can serve as an adequate control site when weir management is implemented.

During Phase II, the water-control structure impeded the movement of only a few organisms into or out of location B, which can be attributed to water movement across the dam. However, the results of the species diversity and dominance indices indicated that location B often had lower species diversity and higher species dominance than the other sampling locations (Tables 8-9). Therefore, even though only a few species' catches among locations were significantly different, the weir had some effect on the distribution, species composition, and migration of all species utilizing the marsh. If data collections could have been accomplished during the months of October, November, and December during very low water conditions, a more accurate assessment of the impacts of the weir could have been made; however, the data in this report clearly shows that the closed weir impeded species from freely utilizing the marsh.

Management Recommendations

Recommendations based on our studies are to close the weir from early fall (before low tides become prominent) through late winter. During this time, the number of species migrating is low, yet it does include the use of the marsh by red drum. Red drum prefer to migrate at bottom to mid-water depths, therefore, the crest of the weir should be adjusted several times during the closure, possibly once monthly coinciding with high tide events, to allow for migration and water circulation. The weir in turn should be opened in time to release the organisms behind it for migration from the marsh to deeper water for the summer. If a longer closure time is necessary, the weir should remain closed only until mid-spring, due to the migration and use of the marsh by both brown shrimp and Gulf menhaden. In addition, water level monitors could be installed to give refuge personnel a more accurate picture of water levels throughout the period of weir closure to help decide if the crest needs to be lowered more often than once a month or not manipulated at all in accordance with environmental conditions (i.e. extreme tide events, drought, etc.).

Acknowledgments

We thank T. Engelhard, K. Debault, B. Turner, F. Saenz, C. Longacre, and H. Hardaway for their help in the field. E. H. Smith, Q. R. Dokken, J. W. Tunnell, Jr., and D. A. McKee assisted in reviewing the manuscript. This research was supported by the U.S. Fish and Wildlife Service's Corpus Christi Fishery Resources Office and the Center for Coastal Studies at Texas A&M University-Corpus Christi.

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Acknowledgments

The contributions of the abstract authors, manuscript authors, and the Editorial Committee (Aaron Barkoh, Joe Fries, and Rebecca Hensley) towards the preparation of this Proceedings is gratefully acknowledged.

The entire Chapter is appreciative to the many contributors who donated auctionable and raffleable goods, money, and services for the 1997/1998 Meeting in Athens, Texas.

Citation:

Author(s). 1999. Title. Pages ___ *in* G. W. Linam, editor. Annual Proceedings of the Texas Chapter, American Fisheries Society, Volume 20. Texas Chapter, American Fisheries Society, Austin, Texas.