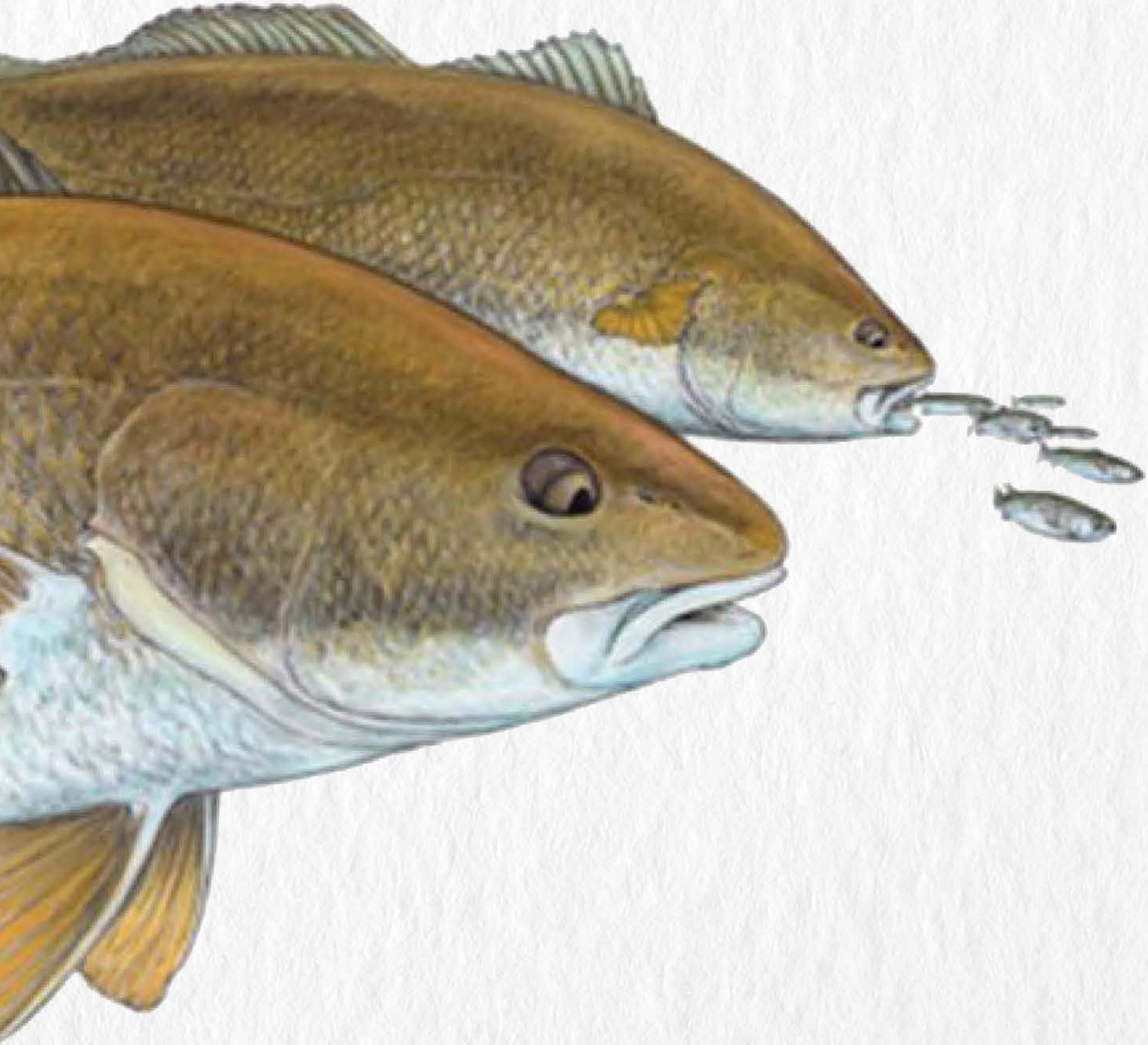
# Management Profile for Gulf of Mexico Red Drum

January 2023



Gulf States Marine Fisheries Commission

Pub Number 317.1

## Commissioners and Proxies

**ALABAMA**
Chris Blankenship
AL Department of Conservation and Natural Resources
Montgomery, AL
Proxy:
Scott Bannon, Director
AL Department of Conservation and Natural Resources/Marine Resources Division
Dauphin Island, AL

Representative Chris Pringle
Mobile, Alabama

Chris Nelson
Bon Secour Fisheries, Inc.
Bon Secour, AL

**FLORIDA**
Eric Sutton
FL Fish and Wildlife Conservation Commission
Tallahassee, FL
Proxy:
Dan Ellinor
FL Fish and Wildlife Conservation Commission
Tallahassee, FL

Representative Jay Trumbull
Tallahassee, FL

TBD

**LOUISIANA**
Jack Montoucet, Secretary
LA Department of Wildlife and Fisheries
Baton Rouge, LA
Proxy:
Patrick Banks
LA Deptartment of Wildlife and Fisheries
Baton Rouge, LA

TBD

John Roussel
Zachary, LA

**MISSISSIPPI**
Joe Spraggins, Executive Director
MS Department of Marine Resources
Biloxi, MS
Proxy:
Rick Burris
MS Department of Marine Resources
Biloxi, MS

TBD

Read Hendon
Ocean Springs, MS

**TEXAS**
Carter Smith, Executive Director
TX Parks and Wildlife Department
Austin, TX
Proxy:
Robin Riechers
TX Parks and Wildlife Department
Austin, TX

TBD

Doug Boyd
Boerne, Texas

# Management Profile for Gulf of Mexico Red Drum

by the

Red Drum Technical Task Force

edited by

Steven J. VanderKooy
and
Jeffrey M. Rester

published by the

Gulf States Marine Fisheries Commission
2404 Government St.
Ocean Springs, Mississippi 39564

January 2023 Publication Number 317.1

A publication of the Gulf States Marine Fisheries Commission pursuant to National Oceanic and Atmospheric Administration Award Number NA10NMF4070006 and FNA15NMF4070076. This publication is funded by a grant from the National Oceanic and Atmospheric Administration. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of its sub-agencies.

# Gulf States Marine Fisheries Commission
## Interjurisdictional Fisheries Management Program

### Red Drum Technical Task Force


Gina Alvarez
Florida Fish and Wildlife Conservation Commission
3911 Hwy. 2321
Panama City, Florida 32409

John Mareska
Alabama Department of Conservation
and Natural Resources/Marine Resources Division
P.O. Box 189
Dauphin Island, Alabama 36528

Wade Hardy
Mississippi Department of Marine Resources
1141 Bayview Avenue
Biloxi, Mississippi 39530

Brian Bartram
Texas Parks and Wildlife Department
Coastal Fisheries Division
702 Navigation Circle
Rockport, Texas 78382

Jason Adriance
Louisiana Dept. of Wildlife and
Fisheries
2021 Lakeshore Drive, Suite 407
New Orleans, Louisiana 70122

Scott Pearce
Florida Fish and Wildlife Conservation Commission
620 South Meridian Street
Tallahassee, Florida 32399

Andrew Ropicki
Florida Sea Grant College Program
P.O. Box 110240
Gainesville, Florida 32611

Sarah Gibbs
USA/Dauphin Island Sea Lab
600 Clinic Drive
Mobile, Alabama 36688

Harlon H. Pearce Jr.
Harlon’s LA Fish
P.O. Box 486
Kenner, Louisiana 70063

Jeff Rester
Gulf States Marine Fisheries Commission
2404 Government St.
Ocean Springs, Mississippi 39564


### Commission Staff


David M. Donaldson
Executive Director

Steven J. VanderKooy
IJF Program Coordinator

Debora K. McIntyre
IJF Staff Assistant

Jeffrey M. Rester
Task Force Specialist

## Acknowledgments

The Gulf States Marine Fisheries Commission (Commission) would like to thank the members of the Red Drum Technical Task Force (TTF) for their many hours of work and dedication in developing the *Management Profile for Gulf of Mexico Red Drum*. The TTF gratefully acknowledges the assistance in collection and assimilation of fishery-dependent and independent data provided by the various state agencies as well as the commercial and recreational data provided by the NOAA Office of Science and Technology and the NOAA Southeast Fisheries Science Center. The TTF would also like to thank Ms. Stephanie Link (formerly FWC) who served as the Florida representative on the TTF originally, Dr. Ava Lasseter (Gulf of Mexico Fishery Management Council), and Dr. Steven Scyphers (Northeastern University Marine Science Center and University of South Alabama) for their assistance with the Sociology chapter.

The Red Drum TTF would not be able to complete the profile without the support of the various academic libraries and library staff across the five Gulf states and the libraries of our federal partners. We would especially like to thank Ms. Joyce Shaw, Ms. Maryanne Anthony, and Ms. Martha Brown at the Gulf Coast Research Laboratory's Gunter Library in Ocean Springs, Mississippi.

Finally, TTF members would like to express their appreciation to Ms. Debora K. McIntyre (Commission) for her support and editorial reviews of the draft profile.

## Preface

The Gulf States Marine Fisheries Commission (Commission) was established by the Gulf States Marine Fisheries Compact under Public Law 81-66 approved May 19, 1949. Its charge is to promote better management and utilization of marine resources in the Gulf of Mexico.

The Commission is composed of three members from each of the five Gulf States. The head of the marine resource agency of each state is an ex officio member. The second is a member of the legislature. The third is a governor-appointed citizen with knowledge of or interest in marine fisheries. The offices of the chairman and vice chairmen are rotated annually from state to state.

The Commission is empowered to recommend to the governor and legislature of the respective states action on programs helpful to the management of marine fisheries. The states, however, do not relinquish any of their rights or responsibilities to regulate their own fisheries as a result of being members of the Commission.

One of the most important functions of the Commission is to serve as a forum for the discussion of various problems and needs of marine management authorities, the commercial and recreational industries, researchers, and others. The Commission also plays a key role in the implementation of the Interjurisdictional Fisheries (IJF) Act. Paramount to this role are the Commission's activities to develop and maintain regional profiles and plans for important Gulf species.

The *Management Profile for Gulf of Mexico Red Drum* is a cooperative planning effort of the five Gulf states under the IJF Act. Members of the task force contributed by drafting individually-assigned sections. In addition, each member contributed his/her expertise to discussions that resulted in revisions and led to the final draft of the profile.

The Commission made all necessary arrangements for task force workshops. Under contract with the National Marine Fisheries Service (NMFS), the Commission funded travel for state agency representatives and consultants other than federal employees.

Throughout this document, metric equivalents are used wherever possible with the exceptions of reported landings data and size limits which, by convention, are reported in English units. Recreational landings in this document are Type-A and Type-B1 and actually represent total harvest, as designated by the NMFS. Type-A catch are fish that are brought back to the dock in a form that can be identified by trained interviewers and Type-B1 catch are fish that are used for bait, released dead, or filleted – i.e., they are killed, but identification is by individual anglers. Type-B2 catch are fish that are released alive – again, identifications are by individual anglers and are excluded from the values in this profile.

# Abbreviations and Symbols

| | |
|---|---|
| ADCNR/MRD | Alabama Department of Conservation Natural Resources/Marine Resources Division |
| B | Billions |
| BRD | Bycatch Reduction Device |
| ˚C | degrees Celsius |
| DO | Dissolved Oxygen |
| DMS | Data Management Subcommittee |
| EEZ | Exclusive Economic Zone |
| EFH | Essential Fish Habitat |
| FWC/FMRI/FWRI | Florida Fish and Wildlife Conservation Commission/Florida Marine Research Institute/Florida Fish and Wildlife Research Institute |
| FMP | Fishery Management Plan |
| ft | feet |
| g | gram |
| GSI | Gonadal Somatic Index |
| C | Gulf States Marine Fisheries Commission |
| hr(s) | hour(s) |
| ha | hectare |
| IJF | interjurisdictional fisheries |
| kg | kilogram |
| km | kilometer |
| lbs | pounds |
| LDWF | Louisiana Department of Wildlife and Fisheries |
| m | meter |
| M | Millions |
| mm | millimeters |
| min(s) | minute(s) |
| MDMR | Mississippi Department of Marine Resources |
| MRFSS/MRIP | Marine Recreational Fisheries Statistical Survey/Marine Recreational Information Program |
| mt | metric ton |
| n | number |
| NL | Notocord Length |
| NMFS | National Marine Fisheries Service |
| ppm | parts per million |
| ‰ | parts per thousand |
| PPI | producer price index |
| SAT | Stock Assessment Team |
| SD | Standard Deviation |
| SE | Standard Error |
| sec(s) | second(s) |
| SL | Standard Length |
| S-FFMC | State-Federal Fisheries Management Committee |
| SPR | Spawning Potential Ratio |
| TCC | Technical Coordinating Committee |
| TED | Turtle Exclusion Device |
| TL | Total Length |
| TPWD | Texas Parks and Wildlife Department |
| TTF | Technical Task Force |
| TTS | Texas Territorial Sea |
| TW | Total Weight |
| YOY | Young-of-the-Year |
| yr(s) | year(s) |

# Table of Contents

## Chapter 4
## DESCRIPTION OF THE HABITAT OF THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

## Chapter 6
## DESCRIPTION OF THE FISHERY

## Chapter 7
## ECONOMIC CHARACTERISTICS OF THE COMMERCIAL AND RECREATIONAL FISHERIES



## Chapter 8
## SOCIAL AND CULTURAL DIMENSIONS OF RED DRUM

## Chapter 9
## RESEARCH AND DATA NEEDS



## Chapter 10

# List of Tables

**Page**

# List of Figures

**Page**

# Chapter 1
# SUMMARY

Red Drum (*Sciaenops ocellatus*) occur from northern Mexico all along the Gulf Coast, around peninsular Florida and up to Massachusetts and are one of the largest and most popular nearshore fisheries in the southeastern United States. Red Drum support both recreational and commercial fisheries throughout much of its geographic range; however, due to severe overfishing in the 1980s, sale of wild Red Drum are now prohibited in most of the Gulf states. In the U.S., Red Drum stocks are generally split for management purposes between the Gulf and the Atlantic Coast. This management profile will focus on Red Drum occurring in the Gulf of Mexico.

Although Red Drum can be found alone as individuals, they are typically a schooling fish and can be found ranging from a few individuals to hundreds. These large schools are most often sexually mature adults that aggregate near Gulf passes and along beachfront habitats, as well as open water. Juvenile Red Drum prefer to occupy the warm, shallow waters of inshore bays. In late summer and early fall, recently matured Red Drum will move out of the estuary and join large schools nearshore in preparation for spawning, and older, mature fish will return from offshore for spawning. As their name implies, Red Drum have the ability to produce drumming sounds. This behavior is associated with spawning activity when males form large spawning aggregations and actively drum to attract females.

In the Gulf of Mexico, Red Drum have long been commercially harvested as food fish, however, declines in overall abundances in the 1980s resulted in a number of regulatory actions intended to protect Red Drum populations and begin to rebuild the stocks across their range. At the height of the fishery, the landings in the Gulf reached 13.7M lbs causing Congress to pass the Redfish Conservation and Management Act of 1986. As a result, the commercial and recreational catches changed significantly as tighter bag and size limits were put in place and all Red Drum fishing in the EEZ was eliminated. Today, only Mississippi has a commercial quota for Red Drum allowed from state waters which is capped at 60,000 lbs annually. With the closure of the commercial Red Drum fisheries in most states, the recreational fishery became the primary emphasis of management of the population. The rebuilding plan for Red Drum hinged on the escapement rates from state waters and the five Gulf states regulated their waters accordingly.

In the Gulf, Red Drum are one of the most sought-after species targeted by recreational anglers and combined with Spotted Seatrout (*Cynoscion nebulosus*), and flounder, make up the trifecta for inshore fishing. They are easily taken by hook-and-line with minimal skill required and are great table fare. Red Drum could be considered an 'every person' fish in that anyone can catch them with no restrictions to access. They can be targeted from shore or dock anywhere along the estuary as well as by boat, and anyone with access to sand beaches and barrier islands can surf fish, wade fish, or float and find Red Drum. The total recreational harvest of Red Drum in Florida, Alabama, Mississippi, and Louisiana totaled around 30M lbs by the early 2010s. Texas reports numbers of fish rather than by weight and estimated the recreational take during the same period to be close to Alabama and Mississippi's annual recreational harvest by numbers. Louisiana topped all the other states at around 24M lbs.

The most recent assessment for Red Drum in the Gulf of Mexico was SEDAR 49 (SEDAR 2016) as a data-limited species. This is in part due to the fact that there are no data available on the offshore, adult spawning population. However, based on escapement rates, the states have exceeded the goals set by NOAA by the rebuilding plan but a stock status has yet to be determined. Despite the success and total closure of the EEZ, the stock status determination requires significantly more data.

There has been a number of efforts in the Gulf to produce Red Drum for stock enhancement and restoration. The state of Texas released nearly 252M Red Drum by 1993 and then targeted 25M annually through the 2000s and 15M since 2010. The aquaculture industry has yet to fully develop an economical market for Red Drum, but there is growing interest. Globally, Red Drum are a significant species under production throughout Asia, with China being the largest producer at around 70,000 MT (154M lbs) by 2018. In the U.S., aquacultured Red Drum are primarily derived from China and Vietnam, and less significant imports originating from Mexico, Argentina, Ecuador, and Central America.

# Chapter 2
# INTRODUCTION

Red Drum in the Gulf of Mexico are managed by NOAA and the Secretary of Commerce through the Gulf of Mexico Fishery Management Council under the Red Drum Fishery Management Plan (FMP) which was implemented in 1986 and prohibited any directed commercial harvest from the EEZ (GMFMC 1986). As part of the rebuilding plan for the fishery, NOAA requested the five Gulf states manage their respective waters for escapement rates of 20% SSB (spawning stock biomass) which was later increased to 30% SSB. Since that time, the states have managed to exceed the target rates, but the stock remains unassessed due to a lack of data related to the offshore population, a direct result of the complete EEZ closure. Despite Red Drum being a "a data-limited species" in SEDAR 49, the population had reasonable likelihood of not being overfished, but a stock status was not actually determined (SEDAR 2016).

At the October 2018 meeting of the Gulf States Marine Fisheries Commission, the State-Federal Fisheries Management Committee directed staff to begin development of a Management Profile for Gulf of Mexico Red Drum. The Red Drum TTF was established in the Spring of 2019 and included representation from each of the state marine resource agencies and others as needed. The introductory meeting of the Red Drum TTF took place in Mobile, Alabama in June 2019. The TTF met again in November 2019 in St. Petersburg, Florida and reported on the progress drafting the various sections of the Profile. The remaining members of the TTF which included the recreational and commercial reps and the social and economic seats were filled. The TTF was scheduled to meet again in mid-March 2020 in Texas but the COVID pandemic necessitated the canceling of the meeting. The TTF held a few conference calls throughout 2020 and 2021, but with most of the state agencies shutdown and under stay at home orders, progress was slow. The TTF finally met in person in December 2021 in Gulf Shores, Alabama and again, in person, in May 2022 in Pensacola, Florida for their last meeting. Most of the sections were complete and under review and the TTF set a goal of August 2022 to provide the Management Profile to the Commission's Technical Coordinating Committee (TCC) in anticipation of their review of the draft for action in October 2022. The final draft was sent to the TCC by the Red Drum TTF in early October, but review was extended until later in the year and a final vote was taken via email in early December.

## IJF Program and Management Process

The Interjurisdictional Fisheries Act (IFA) of 1986 (Title III, Public Law 99-659) was approved by Congress to: (1) promote and encourage state activities in support of the management of interjurisdictional fishery resources and (2) promote and encourage management of interjurisdictional fishery resources throughout their range. Congress also authorized federal funding to support state research and management projects that were consistent with these purposes. Additional funds were authorized to support the development of interstate management plans by the marine fishery commissions.

After passage of the IFA, the Commission initiated the development of a planning and approval process for the management profiles and plans. Since the Gulf Commission has no regulatory authority, all authority resides with the state agencies. Three options exist for profiles or plans within the Commission's IJF Program depending on the needs identified by the state management agencies:

(1) Biological Profile
    A Biological Profile contains the elements related to the species itself (biology and habitat) and a brief overview of the fisheries that exist in each state (landings, effort, economics, and a description of participation). This option is provided when biological or fisheries data is limited or unavailable to provide any type of evaluation of the fishery or population. Research and data needs will be highlighted and presented for state agency consideration.

(2) Management Profile
A Management Profile contains the same elements as the Biological Profile plus the addition of any state information related to the stock status but not a regional stock assessment. The Management Profile will identify research and data needs as well as management considerations which are optional for the states should a need arise to change existing management scenarios or to conduct a stock assessment for the resource in the future.

(3) Fishery Management Plan
A Fishery Management Plan is the final option should a state or particular sector within the fishing community request a formal stock assessment be facilitated by the Commission. This may be useful only to the states who do not already have their own state-derived management plans or stock assessments and need a traditional FMP for certification or other purposes. Along with a regional assessment will be recommendations on management goals and objectives as well as a suite of potential biological reference points for management which are available to the state as options. The Commission's Fishery Management Plans continue to have no authority over the states in how they manage their fisheries and participation in development does not obligate any agency to implement the goals, objectives, or reference points for management.

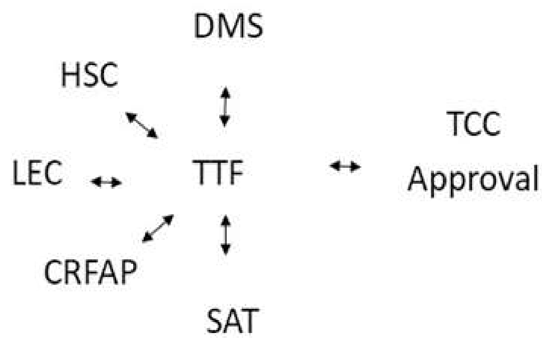
Regardless of which document type, once the profile or plan has received final approval from either the TCC or the Commissioners, the document will be published electronically and made available on the Commission webpage.

The TTF is composed of a core group of scientists from each Gulf state and is appointed by the respective state directors who serve on the Commission. Also, a TTF member from each of the Commission's standing committees (Law Enforcement, Habitat Advisory, Commercial Fisheries Advisory, and Recreational Fisheries Advisory) is appointed by the respective committee. In addition, the TTF may include other experts in economics, socio-anthropology, population dynamics, and other specialty areas when needed. The TTF is responsible for development of the management plan/profile and receives input in the form of data and other information from the DMS and the SAT.

Once the TTF completes a profile or plan, it enters the Commission's review process and, at any point, may be returned to the TTF for modification or further revision. In the case of a management plan, the document will be released for a voluntary public review and comment. After public review, the document and all comments are considered by the Commission who may accept the existing draft, accept the draft with modification, or reject the draft and return it to the TCC or the TTF for further revision. Once approved by the Commission, the plan is submitted to the Gulf states for consideration as potential measures for research or management in their respective states.

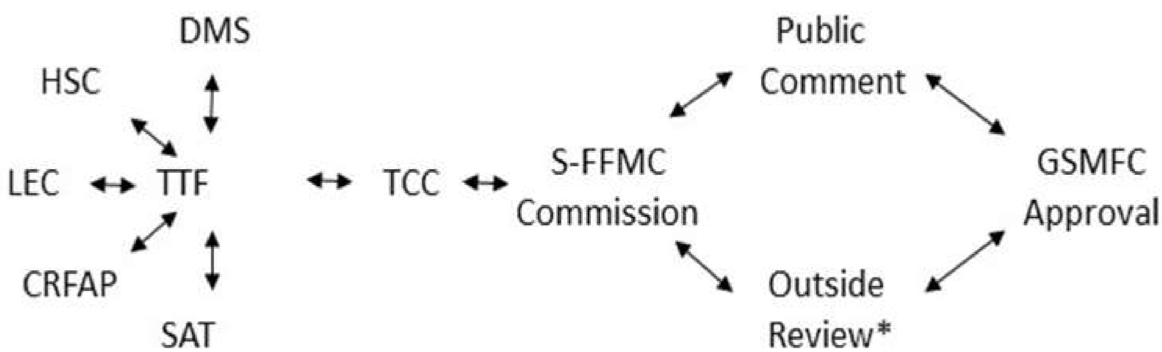
The profile/plan process has evolved to its current form as outlined below:

Biological Profile and Management Profile Review




DMS = Data Management Subcommittee
SAT = Stock Assessment Team
HSC = Habitat Subcommittee
LEC = Law Enforcement Committee
CRFAP = Comm/Rec Fishery Advisory Committee
TTF = Technical Task Force
TCC = Technical Coordinating Committee

Fishery Management Plan Review




DMS = Data Management Subcommittee
SAT = Stock Assessment Team
HSC = Habitat Subcommittee
LEC = Law Enforcement Committee
CRFAP = Comm/Rec Fishery Advisory Committee
TTF = Technical Task Force

TCC = Technical Coordinating Committee
S-FFMC = State-Federal Fisheries Management Committee
GSMFC = Gulf States Marine Fisheries Commission
*Outside Review = standing committees, trade associations, general public

## Management Profile Objectives

The objectives of the *Management Profile for Gulf of Mexico Red Drum* are:

1. To summarize, reference, and discuss relevant scientific information and studies regarding the management of Red Drum in order to provide an understanding of past, present, and future efforts.

2. To describe the biological, social, and economic aspects of the Gulf of Mexico Red Drum fisheries.

3. To review state and federal management authorities and their jurisdictions, laws, regulations, and policies affecting Red Drum.

4. To ascertain optimum benefits of the Red Drum fisheries of the U.S. Gulf of Mexico to the region while perpetuating these benefits for future generations.

5. To identify gaps in the knowledge regarding the species or the fisheries and suggest to the states research needs or improvements in fishery-dependent and fishery-independent data collection to enhance management strategies for Red Drum in the future.

# Chapter 3
# DESCRIPTION OF STOCK(S) COMPRISING THE MANAGEMENT UNIT

## Introduction

Red Drum (*Sciaenops ocellatus*) is one of the largest and most popular nearshore fisheries in the southeastern United States. Red Drum support both recreational and commercial fisheries throughout much of its geographic range; however, due to severe overfishing in the 1980s, sale of wild Red Drum is now prohibited in most of the Gulf states. While most adult Red Drum are typically found in offshore waters, the adult stock also inhabits estuaries and nearshore state waters along with the juvenile and sub-adult populations. Red Drum can be found all along the U.S. Atlantic Coast and Gulf of Mexico. This management profile will focus on Red Drum occurring in the Gulf of Mexico.

## Geographic Distribution

Red Drum occur from around Tuxpan in central Mexico (Simmons and Breuer 1962, Yokel 1966, Castro-Aguirre 1978) all along the Gulf Coast, around peninsular Florida and up to Massachusetts (Matlock 1980, Murphy and Taylor 1990, Porch et al. 2002; Figure 3.1) and were introduced into several Caribbean countries including Martinique and the Bahamas (Chakalall 1993). This species has also been introduced outside the Atlantic where they have established populations off Reunion (Letourneur et al. 2004), Israel (Golani and Mires 2000, Galil 2007, Golani et al. 2015), and Singapore (Sasaki 2000). There are reports of some commercial landings from the southeastern Mexican states of Campeche and Yucatan but it is unclear if these were in the native range or introduced/escaped fish (CONPESCA 2013).

In the U.S., Red Drum stocks are generally split for management purposes between the Gulf and the Atlantic Coast. Genetic studies suggested that the Gulf population exhibits high heterozygosity (Ramsey and Wakeman 1987) and is effectively one stock (see Genetics). Further work by Gold et al. (1993) and (1999) indicated a weak differentiation of subpopulations across the northern Gulf of Mexico and the

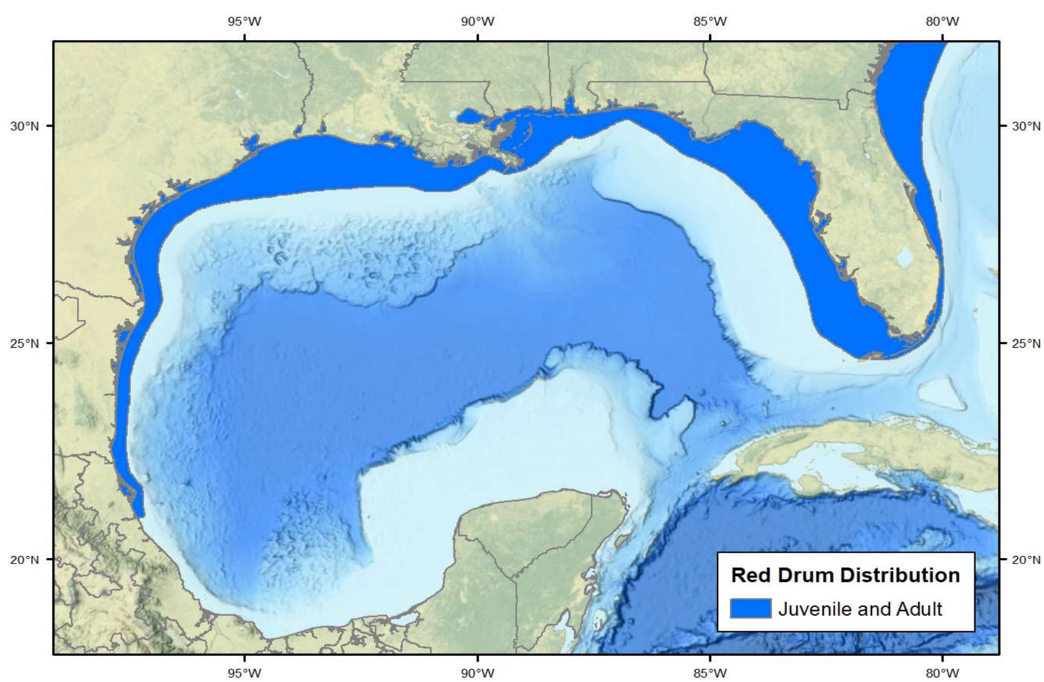



Figure 3.1 Distribution of *Sciaenops ocellatus* native range in the western Atlantic basin from the South Atlantic to Tuxpan, Veracruz, Mexico.

southeastern Atlantic Ocean. More recent studies indicate slight divergence across the specific regions along the Gulf, but until more definitive work is completed on the offshore population, the Gulf remains a single stock. Additionally, conventional tagging studies of Red Drum in the Gulf have not reported individuals mixing across regions from the Gulf into the Atlantic (see Migration and Movement).

## Biological Description

Red Drum are characterized by their elongated bodies, general bronze coloring, and a distinctive ocellated black spot at the base of the caudal fin. Although several similar spots (or none) may occur, one on both sides of the body is typically present. Red Drum coloration can range from a dark copper to a silvery-red that fades to a lighter cream or white on the ventral side of the fish (Wenner 1992). Their coloration likely helps them blend into the shallow water mud and sand bottoms where they forage.

Red Drum are primarily estuarine and have a slightly subterminal mouth lacking barbels. Their subterminal mouth allows them to feel the bottom while foraging. They have long, pointed pharyngeal teeth which aid Red Drum in consuming prey such as shrimp and crabs (Grubich 2000).

## Classification

The following classification is a complete outline of the species according to ITIS (Linnaeus 1766).

- Kingdom Animalia
  - Subkingdom Bilateria
    - Infrakingdom Deuterostomia
      - Phylum Chordata
        - Subphylum Vertebrata
          - Infraphylum Gnathostomata
            - Superclass Actinopterygii
              - Class Teleostei
                - Superorder Acanthopterygii
                  - Order Perciformes
                    - Suborder Percoidei
                      - Family Sciaenidae
                        - Genus *Sciaenops*
                          - Species *Sciaenops ocellatus*

The current scientific name for Red Drum is *Sciaenops ocellatus* (Linnaeus 1766); *Sciaenops* (Greek *skiaina* or *skion* + *ops* = a fish) and *oceallatus* (Latin *ocellātus* = having small eyes). Synonyms include the previous name *Perca ocellate* (Linnaeus 1766) which was changed to *Sciaenops ocellate* (Linnaeus 1766), the misspelling *Sciaenops ocellata*, and the incorrect name *Lutjanus triangulum* (Lacepède 1802).

Many common names exist for *S. ocellatus*; however, the accepted common name in the U.S. is 'Red Drum' (Page et al. 2013). Other local names include redfish, reds, bull red, channel bass, and spot tail. Puppy red and rat red are also common names usually referring to juvenile Red Drum. The complete list of common and market names from around the world can be found in Table 3.1.

## Morphology

Descriptions of Red Drum early life stages have been described based on wild collections and laboratory reared fish (Welsh and Breder 1923, Pearson 1929, Fowler 1952, Jannke 1971, Holt et al.

Table 3.1 Common and market names of *Sciaenops ocellatus* used around the world (Froese and Pauly 2022).

| Common Name | Country of Origin | Language (Dialect) | Type | Official Trade Name |
|---|---|---|---|---|
| Rød trommefisk | Denmark | Danish | Vernacular | No |
| Channel bass | UK | English | Vernacular | No |
| Channel bass | U.S. | English | Vernacular | No |
| Red Drum | Taiwan | English | Vernacular | No |
| Red Drum | Mexico | English | AFS | No |
| Red Drum | UK | English | FAO | No |
| Red Drum | U.S. | English | AFS | No |
| Redfish | U.S. | English | Vernacular | No |
| Spotted bass | UK | English | Vernacular | No |
| Tropical sea bass | Australia | English | Vernacular | No |
| Tropical sea bass | UK | English | Vernacular | No |
| Punarumpukala | Finland | Finnish | Vernacular | No |
| Tambour rouge | France | French | FAO | No |
| Red Drum | Germany | German | Vernacular | Yes |
| Roter Trommler | Germany | German | Vernacular | Yes |
| Roter Umberfisch | Germany | German | Vernacular | Yes |
| Tambour Rouge | Germany | German | Vernacular | Yes |
| 眼斑拟石首鱼 | China | Mandarin Chinese | FAO | No |
| Rødhavgjørs | Norway | Norwegian | Vernacular | No |
| Corvinão-de-pintas | Portugal | Portuguese | Vernacular | No |
| Corvina | Mexico | Spanish | Vernacular | No |
| Corvineta ocelada | Mexico | Spanish | AFS | No |
| Corvinón ocelado | Mexico | Spanish | Vernacular | No |
| Corvinón ocelado | Spain | Spanish | FAO | No |
| Röd havsgös | Sweden | Swedish | Vernacular | No |
| Röd trumfisk | Sweden | Swedish | Vernacular | No |

1981) and were compiled by Johnson (1978) but did not include egg descriptions. The majority of this material is borrowed heavily from Johnson (1978) unless otherwise noted. In personal communications, several hatchery managers that work with Red Drum often refer to fish as larvae as long as they have a notochord and most consider larvae as not able to feed on zooplankton. After the development of the caudal peduncle they may refer to them as post-metamorphic, postlarvae, or fry, however, each had a different juvenile definition. For many, complete mouth and digestive system allows fish to feed on live food and makes them juveniles.

For the purposes of this document, we are using a combination of life history stage descriptions which include information published by Pearson (1929), Yokel (1966), Johnson (1978), and Holt et al. (1981a) which are divided into the following categories. Length ranges are not provided due to variation in physical length estimates in the literature for each stage (Table 3.2).

1. **Embryo** - Developmental stages [in the egg] to the moment of hatching or birth.
2. **Prolarvae** - A larval fish still bearing yolk.

Table 3.2 Summary of published designation for Red Drum life stages from ecological and hatchery work.

| Authors | Location | Larvae | | Juvenile | Subadult | Adult |
|---|---|---|---|---|---|---|
| | | Prolarvae | Postlarvae | | | |
| Pearson 1929 | Texas | < 7 mm[1] | | > 40 mm[1] | | 750 mm[1] |
| Welsh and Breder 1923 | Atl Coast | < 58 mm[1] | | > 120 mm[1] | | |
| Yokel 1966 | South Florida | < 7 mm SL | 7-42 mm SL | > 42 mm SL | | |
| Johnson 1978 | NE to Gulf | 4.0-7.9 mm[2] | | 25-150 mm[2] | | 400-800 mm[2] |
| Peters and McMichael 1987 | Florida | < 8 mm SL | | ≥ 8 mm SL | >200 mm (enter the fishery) | |
| Rooker et al. 1997 | Texas | | | > 20 mm SL | | |
| Krebs and Turingan 2003 | East Florida | < 4.5 mm SL | | > 4.5 mm SL | | |
| Smith and Fuiman 2003 | Texas | 2.7-25.0 mm TL | | | | |

[1]Lengths were only reported as 'length'
[2]Lengths were summarized for various authors so measurements were mixed SL and TL.

3. **Postlarvae** - A larval fish following absorption of yolk.
4. **Larvae** – A more general description of recently hatched fish that haven't fully developed their gut; includes pro- and postlarvae.
5. **Fry** – Early fish that have a complete mouth, gut, and anus and can feed on zooplankton.
6. **Juvenile (Fingerling)/Subadult** - Young fish look similar to adult.
7. **Adult** - Mature fish with developing or developed gonads, or spent fish, or one which has spawned.

### Eggs

Holt et al. (1981a) described the eggs of Red Drum raised in the laboratory (Figure 3.2). Their descriptions are as follows:

> "Fertilized eggs of Red Drum were buoyant and usually contained one oil globule; about one-fourth contained 2-6 oil globules. Eggs were spherical with a clear and unsculptured chorion. Oil globules were yellow to amber in preserved samples but clear and colorless in live specimens. The perivitelline space varied in size but was generally less than 2% of the egg diameter.
>
> Diameters of 75 live eggs averaged 0.93 mm (0.86-0.98 mm) and those of 50 preserved eggs averaged 0.95 mm (0.86-1.07 mm). Diameters of oil globules averaged 0.27 mm (0.24-0.31 mm) in live eggs and averaged 0.30 mm (0.22-0.36 mm) in preserved eggs. The number of oil globules decreased with embryonic development, indicating coalescence."

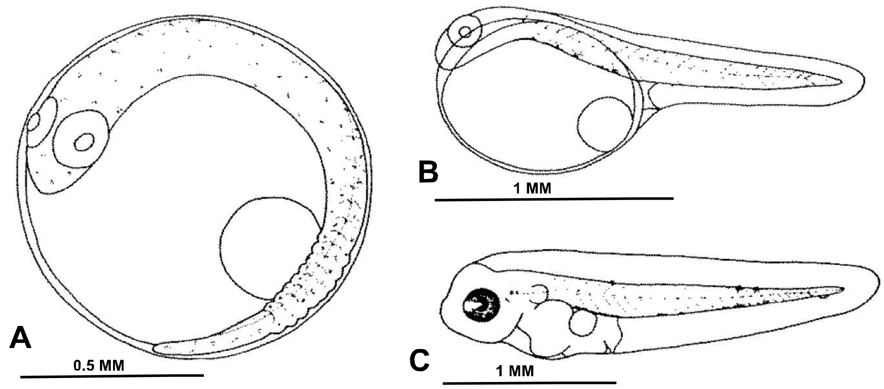



Figure 3.2 A). Late stage egg of Red Drum. B). 1-hr posthatch larvae (2.37 mm SL). C). 36-hr larvae (2.37 mm SL). (Figure 1 *from* Holt et al. 1981a

The authors further reported three stages of eggs; early (0-12 hr), middle (12-24 hr), and late (24-29 hr). The stages describe the changes to the oil globules and development of the embryo until the point of hatching. More information can be found in detail in Holt et al. (1981a).

## Larvae

Red Drum larvae ranging from 4.0-4.9 mm TL were summarized in Johnson (1978) (Figures 3.3 and 3.4).

> "At 4-5 mm finfold well developed, dorsal and anal fins not distinct; pectoral present throughout development and pelvic fins not evident. At about 7 mm only a small membrane between anus and anal fin remaining on finfold [Pearson 1929].

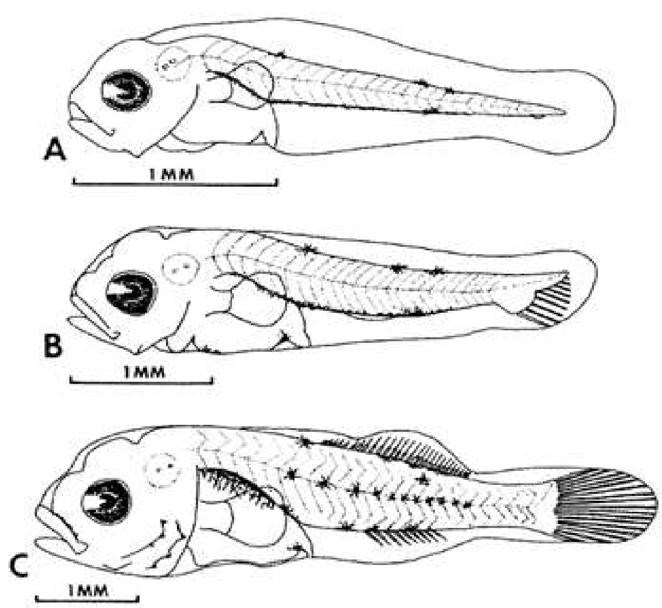



Figure 3.3 A). Four-day old larva of Red Drum (2.49 mm SL). B). Eight-day old larva (3.46 mm SL). C). Thirteen-day old larva (5.11 mm SL). Scale = l mm. (Fig 2 *from* Holt et al. 1981a).

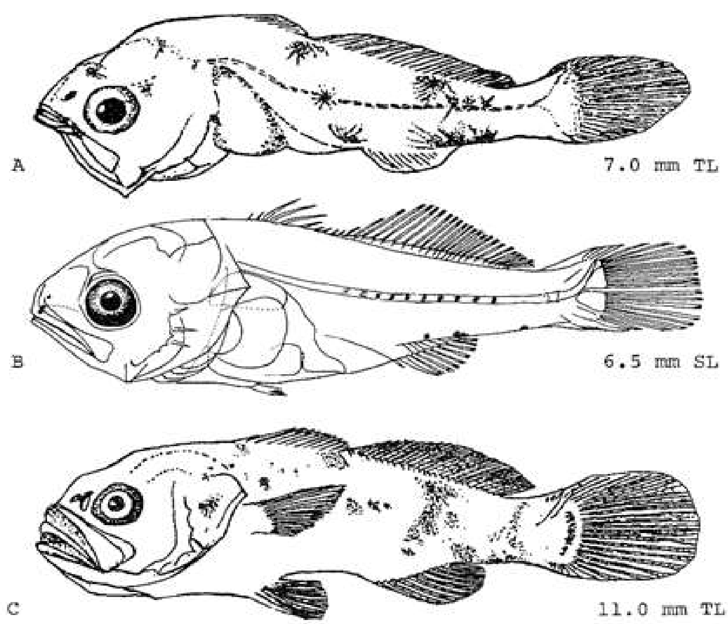



Figure 3.4 Red drum. A). Larva, 7.0 mm TL, preopercular spines not shown (HWP). B). Larva, 6.5 mm SL, note notochord pigment spots. C. Juvenile, 11.0 mm TL. (A and C: figs. 4-5 *from* Pearson 1929; B: fig. 24B *from* Jannke 1971) (Reproduced from Fig. 144 *from* Johnson 1978).

Pigmentation: At 4-5 mm one or several prominent groups of melanophores or pigment patches present, one ventrally along posterior end of anal fin base, one at origin of the second dorsal fin, and one ventral, slightly posterior to anus [Pearson 1929]. Internal pigment along notochord, suggested in several drawings, often pronounced in specimens 4.1-7.9 mm; about 10 marks from anus to caudal peduncle providing a good character for identification ([H.W. Powles personal communication] HWP)."

## Juveniles

Johnson (1978) summarized juvenile descriptions of Red Drum (Figure 3.5) from 25-150 mm as follows:

"At 25 mm scales and teeth evident [Pearson 1929].

Pigmentation: At 25-40 mm color pattern quite distinctive; ground color pale brown, somewhat silvery in fresh specimens; a distinct row of 5-7 brown blotches, usually smaller than eye, along lateral line, one on opercle, one behind, 2 or 3 under dorsal fin, and one on caudal peduncle; a fainter row of these blotches along back from nape to caudal peduncle, the number varying; series of dark brown pigment dots along base of caudal fin, and a series of chromatophores along base of anal fin; membrane of spinous dorsal punctulate with dark brown; soft dorsal with similar, less distinct markings [Welsh and Breder 1923, Pearson 1929]. At 36 mm a pronounced chromatophore enlargement occurs dorso-laterally at base of caudal fin, which is the first appearance of the ocellated black spot characteristic of the adult (however, it is elsewhere reported that this spot is not evident until 50-60 mm). Brown lateral blotches generally remain to about 150 mm but becoming less distinct by 120 mm and may be lost earlier [Pearson 1929, Hildebrand and Schroeder 1928].

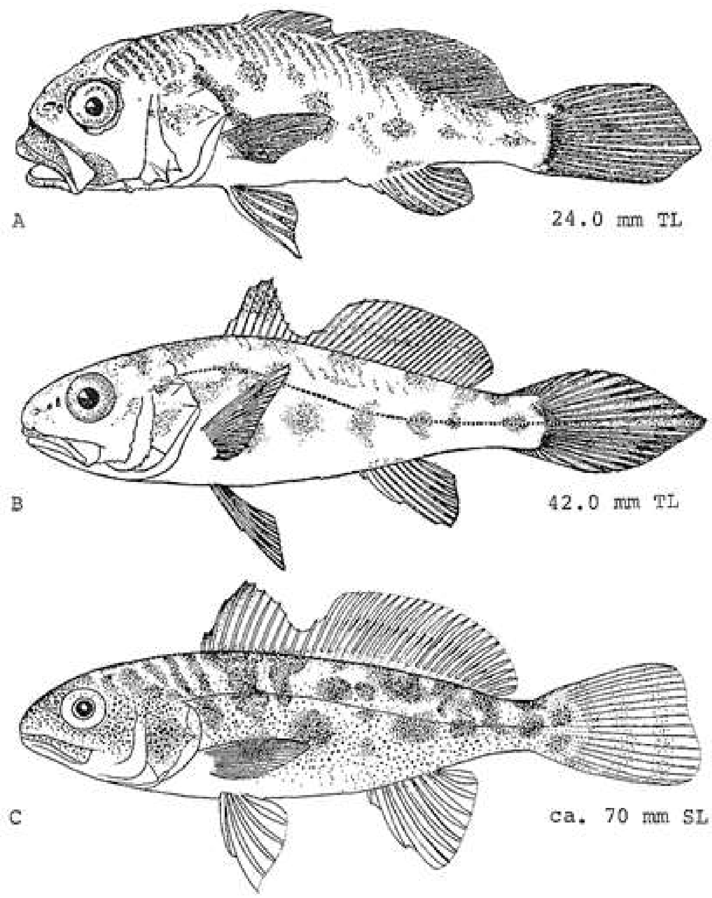



Figure 3.5 *Sciaenops ocellata*, Red drum. A). Juvenile, 24.0 mm TL. B). Juvenile, 42.0 mm TL. C). Juvenile, ca. 70 mm SL. (A and B: figs. 6-7 *from* Pearson 1929; C: fig 21 *from* Fowler 1945[1]) (Reproduced from Fig. 145 *from* Johnson 1978). [1]Fowler cite should be Fowler 1940.

> Characterized by absence of chin barbels and presence of one or more spots at base of upper part of caudal fin [Hildebrand and Schroeder 1928] pectoral fin more pointed than that of *Micropogonias undulatus*, caudal fin less pointed [Simmons and Breuer 1962]."

## Adults

Adult Red Drum are quite distinct and vary greatly in their color and spot patterns. They may be dark brown to olive or golden, even silvery depending on the time of year and area they are taken from (estuarine vs offshore). Male Red Drum can become "dark red to bluish-gray" above the lateral line and pale white below during courtship and spawning in the hatchery (Arnold et al. 1977). Unusual color and patterns of Red Drum are described in detail in Anomalies and Abnormalities.

Johnson (1978) summarized the adult Red Drum descriptions which follow:

> "D. X-I, 23-25 [Hildebrand Schroeder 1928, Miller and Jorgenson 1973]; A, II, 7-8 [Topp and Cole 1968, Miller and Jorgenson 1973, Hildebrand Schroeder 1928, Miller and Jorgenson 1973]; C. 9 + 8, procurrent rays 8-10 + 7-10 [Miller and Jorgenson 1973, Topp and Cole 1968]; V. I, 5 [Topp and Cole 1968]; scales 40-45 in a lateral series [Hildebrand Schroeder 1928]; vertebrae 10 + 15 [Topp and Cole 1968, Miller and Jorgenson 1973], pleural ribs 8, epipleural ribs 7 [Topp and Cole 1968]; gills rakers 4-5 + 7-9 [Chao 1976]; branchiostegals 7

[Hildebrand Schroeder 1928]; teeth small conical in jaws, set in bands, outer row teeth of upper jaw slightly enlarged; lower jaw teeth subequal ([L.N. Chao personal communication] LNC); no teeth on vomer, palatines, or tongue [Jordan and Evermann 1896-1900].

Head 2.8-3.3, depth 3.3-3.9 in SL; snout 3.3-3.8, eye 3.1-4.7 [Hildebrand Schroeder 1928], maxillary 2.5 [Jordan and Evermann 1896-1900], interorbital 3.7-4.6, pectoral fin 1.5-1.8 in head [Hildebrand Schroeder 1928].

Body elongate [Hildebrand Schroeder 1928], and rather robust, not much compressed [Jordan and Evermann 1896-1900]; back moderately arched; ventral outline nearly straight; head rather long and low; snout conical; mouth horizontal, lower jaw included [Hildebrand and Schroeder 1928]; lower jaw with five pores, without barbels; maxillary almost reaching below posterior margin of eye (LNC). Scales rather large, strongly ctenoid [Hildebrand and Schroeder 1928]; no scales on soft dorsal fin [Hildebrand and Schroeder 1928, Jordan and Evermann 1896-1900]; scales of breast embedded, cycloid [Jordan and Evermann 1896-1900]. Dorsal fin continuous, with a deep notch between the spinous and soft portions ([L.N. Chao personal communication] LNC); dorsal spines rather stiff, pungent; second anal spine thick, much shorter than longest soft rays; posterior margin of caudal fin straight to slightly concave; pectoral fin as long as pelvic fin. Preopercular margin serrate in smaller specimens, becoming entire in specimens of about 9-13 kg [Jordan and Evermann 1896-1900].

Pigmentation: May be silvery, grayish, bronze, coppery, yellow, and sometimes almost black; often silvery or copperish in Gulf, darker in muddy bays; each scale with a dark center, forming rather obscure, irregular, undulating brown stripes along scale rows [Hildebrand and Schroeder 1928, Jordan and Evermann 1896-1900]; one to several (most frequently 1) jet black spots at base of caudal and below the soft dorsal fin above lateral line [Simmons 1969, Hildebrand and Schroeder 1928, Jordan and Evermann 1896-1900]; dorsal and caudal fins dusky; anal and pelvic fins white; outer part of pectoral fin bright rusty [Hildebrand and Schroeder 1928]."

## General Behavior

Adult Red Drum can be found singly or in schools (Overstreet 1983). They can be found in schools ranging from a few individuals to schools numbering in the hundreds. These large schools are most often sexually mature adults that can be found in aggregations near Gulf passes and along beachfront habitats, as well as open water. Juvenile Red Drum prefer to occupy shorelines, shallow water, and seagrass meadows (Matlock 1987), typical of inshore bays. They will forage for invertebrates in and on the substrate using their subterminal mouths to find prey. When they engage in this behavior in very shallow water, this can result in a behavior known as "tailing" (Matlock 1987), during which their heads are down near the substrate (Yokel 1980) and their bodies and tails are extended upwards with their tails breaching the surface of the water. Anglers fishing shallow water habitat will often observe this behavior from schools of feeding Red Drum. In seagrass habitats, small schools of Red Drum can be found in open areas within the seagrass meadows. Red Drum will use these unvegetated areas as points of ambush for prey using this edge habitat. They are worthy opponents for anglers and will put up a dogged fight on rod and reel. Although they rarely breach the surface during a fight, they will make determined runs on medium tackle before coming to hand.

In late summer and early fall, recently matured Red Drum will move out of the estuary and join large schools nearshore in preparation for spawning (Pearson 1929). Anglers know this phenomenon as the fall "Redfish Run", and many anglers take advantage of the opportunity to catch these mature spawning fish. Anglers can find schools of recently matured Red Drum schooling up on grass flats, foraging before exiting to the Gulf. The fish do not venture far into offshore waters and stay relatively close compared to pelagic species that may travel many kilometers offshore (Migration and Movement). Mature Red Drum will return from offshore waters to nearshore habitats for the annual spawning event.

As their name implies, Red Drum have the ability to produce drumming sounds (Guest and Lasswell 1978). Specialized musculature in their abdomen allows them to produce a deep, hollow drum with their air bladders. This behavior is associated with spawning activity when males form large spawning aggregations and actively drum to attract females. Holt (2008) identified two classes of sounds produced, one being a low frequency rumble and the other a call made by individuals or small groups of Red Drum.

## Anomalies and Abnormalities

Occasionally, Red Drum that exhibit some type of abnormality are captured by recreational anglers. These can range from skeletal deformations that can have a significant effect on the ability of the animal to swim and survive to abnormal colorations that likely have no effect on survival. While these fish are occasionally documented in peer-reviewed literature, many abnormal fish are found on the internet through fishing message boards or social media platforms.

An iconic characteristic of the Red Drum is the "spot", or the black dot found near the tail of most Red Drum. This spot is typically round in shape, black in coloration, and near the top of the caudal peduncle on both sides of the fish. A commonly held belief is that this spot is an adaptation for survival, a "false eye" that might fool a predator into attacking the tail rather than the head, thereby increasing chances of survival if attacked (Wenner 1992). In some specimens, this spot can be out of place, absent, an odd size

Figure 3.6 Leopard pigmentation example captured by Capt. Eddie Berthelot Jr. from Golden Meadow, Louisiana (courtesy Berthelot).

or shape, or a specimen may have multiple spots on its body numbering from two or three extra spots to hundreds of spots all over the body. Although rare, the latter of these occurrences can produce what is called a "leopard" Red Drum in which hundreds of spots are distributed across the sides of the body and tail (Figure 3.6).

Red Drum raised in aquaculture may be susceptible to abnormalities as a result of dietary deficiencies that would not otherwise occur in the natural environment. Browning et al. (2012) reported that captive-raised Red Drum were observed with physical abnormalities, including deformities of the spine, jaw, and cephalic region, that were consistent with vitamin C deficiency during the larval stage. Deformities do occur in wild fish, although rare, and can be the result of injury during developmental stages or injuries sustained from a failed attempt by a predatory bird. Schwartz and Francesconi (1998) documented a Red Drum suffering from kyphosis (humped) scoliosis, ankylosis (side-wise bends), and lordosis (forward curvature) of the skeletal column (Figure 3.7). Deformities can also occur as the result of human activities or interaction. Post-release wounds can result from mishandling of fish by anglers and can cause wounds or scars to the lips, mouth, and eyes. The scientific community was greatly concerned about developmental and sub-lethal effects following the BP Deepwater Horizon disaster in 2010 in the northern Gulf. Khursigara

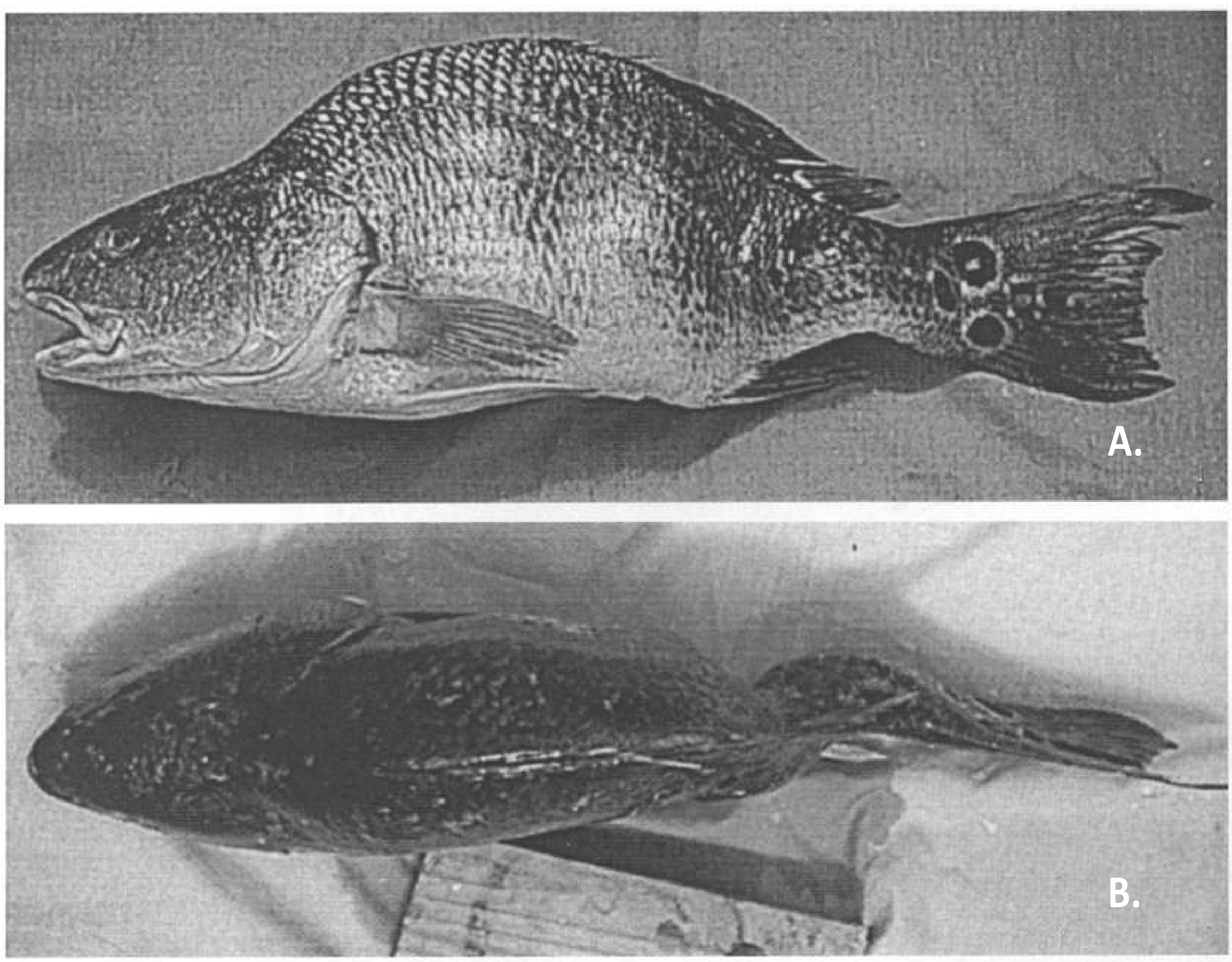



Figure 3.7 A). Lateral view of 'humped' Red Drum illustrating kyphosis scoliosis. B). Dorsal view exhibiting radical body bends (scoliosis and ankylosis) (Figs 1a and 1b *from* Schwartz and Francesconi 1998).

Figure 3.8 Spinal curvature in larval Red Drum after exposure to weathered oil from the 2010 BP Deepwater Horizon disaster (Figure 2 *from* Khursigara et al. 2017).

et al. (2017) observed craniofacial and spinal curvature after larval Red Drum were exposed to weathered oil collected from the disaster (Figure 3.8).

Another less common abnormality is mandibular macrognathia, also referred to as pugheadedness, an abnormality in which the upper jaw is shortened relative to the lower jaw, which can lead to an inability to completely close the mouth. The severity of the deformity determines how much of an effect it has on the fish (Hickey 1972). There are not many reported occurrences in the literature for Red Drum, however, they have been reported online by anglers who capture them (Figure 3.9).

Figure 3.9 Example of mandibular macrognathia or 'pughead' in Red Drum captured by Brent Dupre from Cocodrie, Louisiana (Bonin 2017).

## Physiologic Requirements

### Temperature

According to Crocker et al. (1981), Red Drum eggs and newly hatched larvae are only able to tolerate a small temperature range but are able to withstand wider temperature ranges after 10 days. Red Drum eggs and larvae develop over a temperature range of 10-34°C (Holt et al. 1981b, Rooker et al. 1999, Perez-Dominguez et al. 2006, Stewart and Scharf 2008) but grow optimally at 25-26°C (Holt et al. 1981b, Rooker et al. 1999). Holt et al. (1981b) theorized that spawning success was adversely impacted when water temperatures dropped below 20°C since they observed inactive larvae that did not attempt to capture prey when temperatures were lower than 20°C and the larvae therefore grew very slowly. Conversely, higher temperatures between 30-35°C were associated with poor survival of larvae (Holt et al. 1981b, Overstreet 1983, Lee et al. 1984). Larvae and postlarvae have been collected in the wild from 18.3-31.6°C (Yokel 1966, Perret et al. 1980, Peters and McMichael 1987, Rooker et al. 1999).

Tolerating a wide range of temperatures, juvenile Red Drum have been found in waters ranging in temperature from 2.0-34.9°C (Perret et al. 1971, Peters and McMichael 1987, Baltz et al. 1998, Dance and Rooker 2016). Ward and Armstrong (1980) found that juveniles preferred temperatures ranging from 10-30°C, while Dance and Rooker (2016) found juveniles were most abundant in water temperatures between 15 and 25°C. They rarely caught juveniles in areas with water temperatures were less than 15°C. Molina et al. (2016) held juvenile Red Drum between 30-34°C in water recirculating systems for four to five weeks with no detrimental effects. McDonald et al. (2015) examined the effect of salinity and the upper lethal temperature tolerance of juvenile Red Drum. They found that the lethal temperature that killed 50% of the juvenile Red Drum ranged from 36.1-37.7°C. While most Red Drum will move into deeper waters during extreme low temperatures, large numbers have been killed in sudden severe cold spells (Simmons and Breuer 1962, Adkins et al. 1979). Miranda and Sonski (1985) found that juveniles stopped feeding between 7-9°C and that most juveniles died when temperatures fell lower than 4°C.

Like juveniles, adult Red Drum are also eurythermal and have been collected over a wide temperature range from 2-33°C (Perret et al. 1980, Ward and Armstrong 1980). When winter cold fronts drop the water temperature, adults normally move into deep water refuges (Simmons and Breuer 1962). Adult Red Drum are considered more susceptible to lower water temperatures than juveniles (Yokel 1966).

### Salinity

While examining the impact of high salinity on the survival, growth and development of Red Drum eggs and larvae, Kesaulya and Vega (2019) found that egg hatch-out rates and larvae growth were reduced at the lowest (28 ppt) and highest (48 ppt) salinity treatments. They reported that Red Drum eggs can hatch within a wide range of salinities with best hatch-out and growth rates occurring between 33-43 ppt. Holt et al. (1981b) stated that the best conditions for hatching and 24-hour larval survival were 30 ppt salinity. Red Drum larvae and post-larvae collected in the Gulf were found over a salinity range of 8.0-36.6 ppt (Yokel 1966, Peters and McMichael 1987, Lyczkowski-Shultz et al. 1988). Dance and Rooker (2016) found that larval abundance in three Texas estuaries peaked at salinities near 20 ppt but were also abundant from 0-25 ppt in Galveston Bay.

Juvenile and adult Red Drum have been collected over a wide range of salinities from 0-55 ppt (Peters and McMichael 1987, Molina et al. 2016) since salinity induced osmoregulation costs in Red Drum are relatively minor (Ern and Esbaugh 2018). Red Drum are efficient osmoregulators and can tolerate abrupt changes in salinity which is especially important to estuarine juveniles. Juvenile Red Drum can tolerate freshwater (Crocker et al. 1981) but also tolerate warm, hypersaline conditions for several weeks with no apparent detrimental effects (Molina et al. 2016). Adults can also tolerate high salinity. In Louisiana, Peterson (1986) found that juveniles preferred salinities between 16 and 25 ppt.

### Dissolved Oxygen

When dissolved oxygen levels were fluctuated between 2.4-6.1 ppm as part of a 22-day experiment, larval Red Drum were found to grow significantly less than larvae at a constant 6.4 ppm, but survival was not affected (Perez-Dominguez and Holt 2002). Large juveniles have been reported in waters with oxygen concentrations of 5.2 and 8.4 ppm (Barret et al. 1978). Baltz et al. (1998) found daytime dissolved oxygen concentrations ranged from 3.7-10.2 ppm during their three-month study of juvenile Red Drum along marsh edges in the Barataria Basin of Louisiana. Thomas (1991) found that juvenile Red Drum survived low dissolved oxygen (0.34 ppm) when dissolved oxygen was gradually reduced over several hours. Thomas (1991) also found that Red Drum fed poorly or not at all when dissolved oxygen values fell below 1.5 ppm.

## Reproduction

After reaching sexual maturity, Red Drum typically spawn multiple times per season throughout their lifetime. They spawn in coastal waters, where larvae are then recruited into protected estuarine habitats for development. Older studies regarding Red Drum reproduction include: Craig et al. (2000) on seasonal changes in reproductive condition; Luczkovich et al. (1998) on spawning behavior; Rooker and Holt (1997) on habitat use of newly settled Red Drum; Wilson and Nieland (1994) on the reproductive biology of Red Drum in the northern Gulf of Mexico; Murphy and Taylor (1990) on reproduction, growth and mortality in Florida waters; Peters and McMichael (1987) on early life history; Overstreet (1983) on the biology of Red Drum; and Guest and Lasswell (1978) on courtship behavior and sound production.

Recent research on Red Drum reproduction in the Gulf of Mexico includes: Bennetts et al. (2019) on sex-specific growth and reproduction (Table 3.3); Bennetts (2018) on life history characteristics and fishery dynamics; Lowerre-Barbieri et al. (2016b) on reproductive behavior of Red Drum and its implications for fisheries management; Nakayama et al. (2011) on the effects of batch spawning on resource competition; Rooker et al. (2010) on population connectivity in the northern Gulf of Mexico; and Holt (2008) on spawning sites determined by towed hydrophone array.

### Size and Age at Maturity

Sexual maturity has been found to have less relation to size in Red Drum when compared to other fishes throughout the Gulf (Table 3.3). However, findings indicate there is still a correlation that can be observed between the two. Wilson and Nieland (1994) reported that in the northern Gulf, 50% maturity is achieved at 690-700 mm and 4.0-4.1 kg for females and 660-670 mm and 4.0-4.1 kg for males. 100% maturity was found in all females larger than 810 mm and 6.1 kg and in all males larger than 810 mm and 5.4 kg (Table 3.4). In Mississippi, signs of gonad development were observed in both male and female samples beginning around 300-549 mm SL. Although, 50% maturity was not reached in either sex until after surpassing a length of 700 mm SL (Overstreet 1983).

Bennetts et al. (2019) had similar findings in his study of the northern Gulf indicating a 50% maturity rate at 639 mm and 638 mm for males and females respectively. However, a larger difference was found in the length of 100% maturity, as it was found to be 788 mm in males and 865 mm in females. Murphy and Taylor (1990), during their study off the coast of Florida showed a 50% maturity rate at the lengths of 529 mm for males and 825 mm for females. This study also showed the largest difference in size at 100%

Table 3.3 Comparison of Red Drum reproductive characteristics across multiple studies in the Gulf of Mexico. The sample size (n) is reported when known. Mean length at 50% maturity ($L_{50}$) and age at 50% maturity ($A_{50}$) parameter estimates are given with 95% confidence intervals in parentheses (Table 5 *modified from* Bennetts et al. 2019).

| Study | Length | Location | Sex | n | Size Range (mm) | $L_{50}$ (mm) | $L_{100}$ (mm) | $A_{50}$ (years) | Spawning Season |
|---|---|---|---|---|---|---|---|---|---|
| Bennetts et al. 2019 | TL | Northern Gulf | M | 318 | 105–996 | 673 (654–695) | 839 | 3.4 (3.0–4.0) | Aug and Sep |
| | | | F | 353 | 353–1,115 | 672 (659–687) | 924 | 3.1 (2.8–3.3) | |
| | FL | | M | | 128–930[1] | 639 (622–659)[1] | 788[1] | | |
| | | | F | | 351–1,037[1] | 638 (626–651)[1] | 865[1] | | |
| Wilson and Nieland 1994 | FL | Northern Gulf | M | 1,337 (1,137)[2] | 399–1,115 | 665 | 850 (810)[2] | 4 | Mid-Aug to early Sep |
| | | | F | 1,262 | | 695 | 850 (810)[2] | 4 | |
| Overstreet 1983 | FL | Mississippi | M | 323 | | 792 | | | Late Sep and Oct |
| | | | F | 159 | | 792 | | | |
| Murphy and Taylor 1990 | FL | Florida | M | 265 | 250–999 | 529 | 700 | 1–2 | Sep to Oct |
| | | | F | 260 | 200–1,049 | 825 | 850 | 3–5 | |

Table 3.4 Percent maturity and numbers samples (in parentheses) of Red Drum at age, fork length, and total weight. Specimens included were collected during the windows of August-October 1986-1991 and August-September 1992. Total sample sizes are 1,262 females and 1,137 males (Table 2 *from* Wilson and Nieland 1994).

| Class | Female | Male | Class | Female | Male |
|---|---|---|---|---|---|
| Age (years) | | | Fork length (mm) | | |
| 1 | 0 (0) | 0 (0) | 750-799 | 95 (129) | 97 (178) |
| 2 | 0 (8) | 13 (24) | 800-849 | 99 (216) | 99 (280) |
| 3 | 28 (81) | 30 (148) | ≥850 | 100 (764) | 100 (391) |
| 4 | 71 (75) | 73 (88) | | | |
| 5 | 88 (68) | 100 (77) | Total weight (kg) | | |
| ≥ 6 | 100 (1,011) | 100 (787) | < 3.00 | 0 (45) | 13 (96) |
| | | | 3.00-3.49 | 8 (24) | 35 (54) |
| | | | 3.50-3.99 | 33 (18) | 60 (40) |
| Fork length (mm) | | | 4.00-4.49 | 75 (28) | 84 (31) |
| < 550 | 0 (7) | 0 (15) | 4.50-4.99 | 83 (23) | 90 (52) |
| 550-599 | 8 (13) | 8 (25) | 5.00-5.49 | 94 (33) | 97 (39) |
| 600-649 | 0 (26) | 22 (68) | 5.50-5.99 | 95 (60) | 100 (55) |
| 650-699 | 24 (42) | 48 (82) | 6.00-6.49 | 98 (59) | 100 (79) |
| 700-749 | 82 (65) | 91 (98) | ≥ 6.50 | 100 (963) | 100 (678) |

maturity between the sexes with males reaching this point at 700 mm while females did not do the same until the length of 850 mm.

### Gonadal Development

While the onset of sexual maturity in Red Drum differs slightly throughout the Gulf of Mexico, the study performed by Wilson and Nieland (1994) showed the development of Red Drum in the northern Gulf from Mobile Bay, Alabama to Galveston Bay, Texas. A maturity of more than 50% was found to be achieved by both sexes by age-4. All male specimens collected at age-5 and older were found to be sexually mature, while females did not reach 100% sexual maturity until age-6. The researchers also did not observe any signs of reproductive regression in the samples collected, thus indicating that both sexes retain their reproductive abilities from the time of sexual maturity until their death.

The gonadosomatic index (GSI) is the calculation of gonad weight as a percentage of total body weight. The formula used to determine the GSI is

$$GSI = (\text{gonad weight}/\text{body weight}) \times 100.$$

GSI is commonly used to determine the investment of energy in reproduction, allowing one to determine when spawning is most likely to occur. Wilson and Nieland (1994) found a sudden escalation in both male and female Red Drum GSI values in the month of August in all regions that they sampled. The maximum GSI values were achieved in September and were followed by a steep decline, reaching minimum values in October.

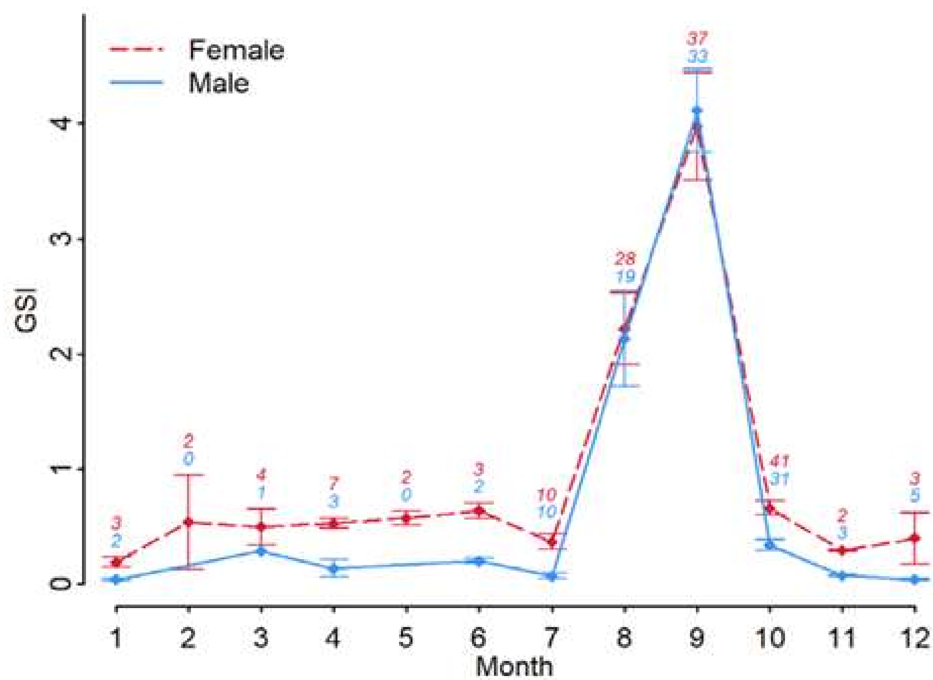



Figure 3.10 Mean (±SE) monthly gonadosomatic indices (GSI) of sexually mature Red Drum females (red dashed line) and males (blue solid line). Specimens included were collected from September 2016-October 2017 in the northern Gulf of Mexico. Numbers above data points indicate their respective sample sizes (Figure 5 *from* Bennetts et al. 2019).

In a more recent study, Bennetts et al. (2019) also used GSI calculations in his determination of a Red Drum spawning season (Figure 3.10). In this study, an increase in the GSI values were observed in both male and female Red Drum during the months of August and September. These values showed a significant difference when compared to the much lower values of each sex during the months of July and October. This significant variation in the values indicated an August and September spawning season for the Red Drum sampled throughout this study. Sexually mature Red Drum younger than 5 years old were also collected throughout the study, but the GSI values of these fish showed little to no variance throughout the spawning months when compared to older specimens.

### Gonadal Histology

As presented by Craig et al. (2000), histological examination has shown to be a more accurate examination method than that of the GSI values when assessing gonadal development in Red Drum. This was indicated by histological examination showing clear signs of spawning preparation in both sexes of Red Drum, despite low GSI values still being observed in the samples collected. Furthermore, while there are many different representations of maturity used in histological examinations, the definition as stated by Wilson and Nieland (1994) will be used here. This definition states that female Red Drum will be considered mature when oocytes develop to the stage of vitellogenesis. Males, however, will be considered mature when milt can be produced from the central lumen of the testes as a result of light squeezing.

### Males

Craig et al. (2000), by use of histological examination on male specimens off the coast of Texas, showed clear signs of testicular development that preceded the noticeable changes in GSI values. Histological examination of males showed tubules in a regressive, inactive state during the months spanning from November through July. However, spermatogonial proliferation in the tubules was first observed in the month of March and continued through June. A small number of males collected during the months of July, August, and September also histologically demonstrated all stages of spermiogenesis. All males collected during the month of August showed signs of active spermatogenesis, while in the month of October, nearly all collected males showed post spawning testes regression.

Bennetts et al. (2019) showed similar results, with some slight variations, during his more recent study. Individuals collected under age-5 were shown to be physiologically mature but did not yet show any gonadal enlargement. All spawning-capable males collected in this study during the month of October showed signs of spermatogenic activity in the testes. However, early developing males were also captured immediately following the spawning season from the month of October through April. These precocious males, while still physically mature, did not contribute to spawning, likely due to missing the spawning window.

### Females

Craig et al. (2000) showed a similar trend in the histological examination of females. Samples collected during the months of November through June showed unproductive ovaries that were small and pale. The first appearance of more vascularized ovaries was observed in late July, with a small number of samples collected showing oocytes in the cortical granule stage (Wallace and Selman 1981). During the following month of August, half of the female Red Drum collected showed ovaries comprised of primary oocytes, some even showing signs of vitellogenesis. Lastly, in the months of September and October, all female Red Drum histologically examined were found to be in the primary oocyte stage. As sampling for this study concluded during the month of October, no post-ovulatory females were observed.

Just as with the male samples, more recent histological examinations by Bennetts et al. (2019) showed similar results to those of Craig et al. (2000) but with some slight deviations. One of which was the capture of regenerating females during the regular spawning season. Many of these females were well over average maturity length (larger than 900 mm TL) and should have contributed to spawning. However, the appearance of these large regenerating females during this time suggests the existence of skipped spawning. This response was hypothesized to be the result of hormone changes, poor nutritional conditions, or a combination of the two.

Bennetts et al. (2019) also reported the presence of all stages of oocyte development during their histological examinations. Additionally, certain specimens taken from spawning capable females were found to have all stages of oocyte development present concurrently. Thus, indicating the existence of batch spawning with asynchronous oocyte development in Red Drum. Despite this, no samples taken from actively spawning females were found to have the presence of postovulatory follicles, substantiating the lack of daily spawning patterns in female Red Drum.

### Fecundity

Red Drum are highly fecund, pelagic spawners. They are somewhat long-lived, living to >30 years old, with some over 40 years old having been observed (Winner et al. 2014). They typically produce multiple batches of eggs per season and are capable of producing upwards of 3 million eggs per batch (Wilson and Nieland 1994; Table 3.5). However, marine species as fecund as Red Drum often display relatively poor recruitment in relation to stock size (Lowerre-Barbieri et al. 2016a). Many factors aside from fecundity, like competition for resources and environmental conditions, affect reproductive success.

Throughout the spawning season each year, Red Drum typically spawn numerous times in batches. Batch spawning often can increase reproductive success. With temporal spacing, if one batch exhibits low survival rates due to poor environmental conditions, later batches may be more successful if conditions improve (Nakayama et al. 2011). If batch spawning was not utilized and a single spawning event occurred shortly before environmental conditions became detrimental, reproductive success that season could be nonexistent. However, batch spawning can have other negative side effects, like asymmetry in competition

Table 3.5 Comparison of age, fork length (FL) and batch fecundity (BF) ranges of Red Drum collected in the northern Gulf of Mexico by year of capture. The number of specimens collected each year is represented by (n) (Table 4 *from* Wilson and Nieland 1994).

| Year | n | Age range (yr) | FL range (mm) | BF range (ova x $10^6$) |
|---|---|---|---|---|
| 1986 | 8 | 6-21 | 800-964 | 0.75-2.54 |
| 1987 | 2 | 20-33 | 933-1005 | 1.65-1.67 |
| 1988 | 6 | 9-30 | 820-950 | 1.87-3.22 |
| 1989 | 23 | 3-24 | 697-999 | 0.16-3.27 |
| 1990 | 0 | | | |
| 1991 | 12 | 5-25 | 760--924 | 0.57-3.13 |
| 1992 | 0 | | | |
| Total | 51 | 3-33 | 697-1005 | 0.16-3.27 |

for resources. Later batches may experience a disadvantage when competing with larger individuals from earlier batches from the same season (Nakayama et al. 2011).

Bennetts et al. (2019) also noted the capture of regenerating females throughout the typical spawning season. The existence of these large regenerating females during this period seems to suggest the existence of skipped spawning in Red Drum. Red Drum are a long-lived species and Secor (2007) indicated a positive correlation between skipped spawning and longevity in several other species. However, due to their indeterminate fecundity, definitive identification of skipped spawning is difficult in Red Drum as there is potential to recruit oocytes by the end of the spawning season despite their absence during the peak of spawning activity (Rideout and Tomkiewicz 2011).

### Spawning Season

Throughout the years, the spawning season of Red Drum has been assessed using a wide variety of scientific analyses. These methods include the documentation of gonad histology, the observation of gonad development, and the collection and examination of juveniles by both size and abundance. These studies, performed throughout the Gulf have shown a late summer to autumn spawning season that is slightly varied based on location.

Wilson and Nieland (1994) assessed the spawning season of Red Drum across the coasts of Texas, Louisiana, Mississippi, and Alabama by way of gonad histological and GSI examination. The specimens collected for these examinations were largely collected by purse seine throughout a period of seven spawning seasons spanning from March 1986 through September 1992. The results of this multi-year study were the identification of an 8-9-week spawning period beginning in mid-August and extending into October.

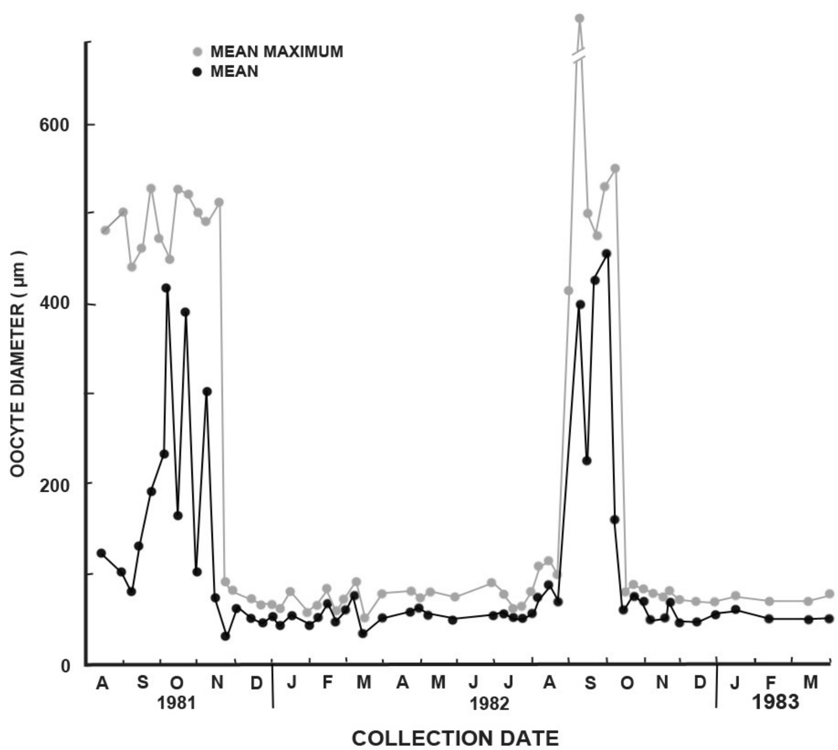



Figure 3.11 Mean and mean maximum oocyte diameters (µm) for Red Drum sampled from both the Gulf and Atlantic coasts of Florida (recreated from Figure 1 *from* Murphy and Taylor 1990).

Similar findings were reported by Murphy and Taylor (1990) in Tampa Bay and Mosquito/upper Indian River Lagoon in Florida. Throughout the period of August 1981 through March 1983, monthly samples were collected from both commercial and recreational catches obtained through a wide variety of gears (Figure 3.11). These researchers reported peak spawning activity of the Red Drum collected from both Florida coasts ranged from early September through the end of October.

Bennetts et al. (2019) collected Red Drum along the coasts of Mississippi, Louisiana, and western Alabama from September 2016 to October 2017. Sampling included both fishery-dependent (fishing tournaments and for-hire vessels) and fishery-independent (gill nets, cast nets, and purse-seine) sources and were all examined to determine their reproductive phase and GSI values. Based on the information obtained from this analysis, August and September were determined to be the peak reproductive months for Red Drum collected from the northern Gulf.

These studies confirm a late summer to early fall peak in Red Drum spawning activity with variation which could be based on a variety of factors. Overstreet (1983) reported that both lengths and dates of peak spawning activity almost certainly had some amount of variance based on changes in temperature, photoperiod, or salinity. Bennetts et al. (2019) stated that their findings were also subject to change based on factors that could have affected growth rates, such as food availability, population dynamics, and even parasitism.

### Spawning Frequency

Mature Red Drum typically spawn multiple times per season, each year from late summer into the fall. Earlier studies suggested that females spawn four or five times per season (Wilson and Nieland 1994) at about a two-week interval (Peters and McMichael 1987). However, more recent studies suggest that spawning may be more frequent than previously stated. Bennetts et al. (2019) suggested a Red Drum spawning season in the northern Gulf of Mexico in August and September of 2017. Based on the reproductive stages of female Red Drum collected, they estimated the mean spawning interval to be every 3.7 days rather than every two weeks. Collections of these spawning-capable females were over a 39-day period, suggesting an average of 10.5 spawning events per individual in the 2017 season. Furthermore, nearly 20% of fish collected during this spawning season were sexually mature but reproductively inactive (Bennetts et al. 2019). In all, the majority of sexually mature Red Drum spawn numerous times throughout the season, often in synchronous batches (Nakayama et al. 2011). However, a percentage of sexually mature Red Drum do not spawn throughout the entire spawning season every year, and some may not spawn at all in a given season (Bennetts et al. 2019).

### Spawning Location

While adult Red Drum use a wide range of habitats (coastal and offshore), it appears that they return to nearshore locations to spawn in the summer/fall (Overstreet 1983). Much of the research regarding Red Drum spawning locations specifies estuarine habitats near the mouths of large embayments or other tidal inlets as their primary spawning grounds (Overstreet 1983, Rooker et al. 2010, Lowerre-Barbieri et al. 2016a).

However, in the eastern Gulf of Mexico, Lowerre-Barbieri et al. (2019) found that spawning aggregations consistently occurred in Tampa Bay and Charlotte Harbor, Florida. They also noted that strong spawning site-fidelity occurred in these locations on both population and individual scales. Lowerre-Barbieri et al. (2016a) suggest that, while adult Red Drum have a large range throughout the year, they cluster in relatively small and consistently used estuarine spawning sites, with roughly two-thirds of adults returning to previously used grounds and first-time spawners exhibiting natal homing. They also found that while Red Drum display spawning site fidelity, they may spawn at multiple sites in the same spawning season. This spatial distribution of spawning in one season may demonstrate similar "bet-hedging" strategies to that of the temporal distribution resulting from batch spawning (Lowerre-Barbieri et al. 2016b).

While Lowerre-Barbieri et al. (2019) and others found that Red Drum spawn in concentrated aggregations, returning to the same sites each year to spawn (Figure 3.12), Holt (2008) suggests that this may not always be the case. Using a towed hydrophone to detect Red Drum mating calls in the western Gulf of Mexico, Holt (2008) found that Red Drum spawning was spread all along the nearshore region of the central Texas Coast and was not concentrated at inlets as earlier researchers suggested (Simmons and Breuer 1962, Jannke 1971). Holt (2008) found relatively intense drumming activity all along the coastline,

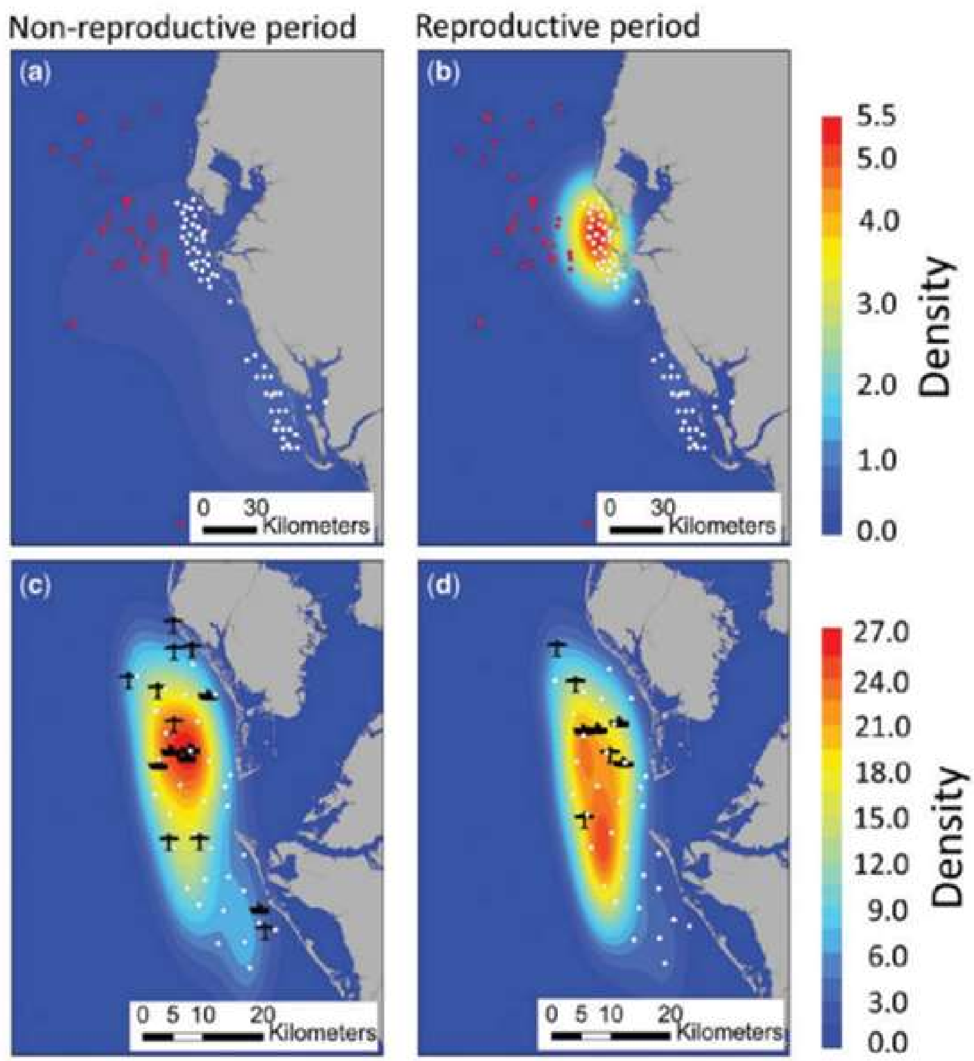



Figure 3.12 Comparison of kernel density estimates based on acoustic tag detections of Red Drum during non-reproductive (a) and reproductive (b) periods from data collected over 2013 and 2014, as well as kernel density at the Tampa Bay fish aggregation site during the spawning seasons of 2013 (c) and 2014 (d). Purse seine locations (boat markers) and aggregation locations (plane markers) are also shown. White dots are receivers in the study array and red dots are receivers in other researchers' arrays. Relative densities of tagged fish are indicated by the colored bar to the right (Figure 3 *from* Lowerre-Barbieri et al. 2019).

confirming that spawning may occur over the nearshore continental shelf, as Murphy and Taylor (1990) had previously suggested.

Lowerre-Barbieri et al. (2019) and Holt (2008) conducted surveys on opposite sides of the Gulf of Mexico (Florida versus Texas) and used different survey methods (aerial surveys and acoustic tags versus a towed hydrophone). These differences in methods and environments may be the cause of their differing results. It is likely that Red Drum often spawn in aggregations with fidelity to certain sites but may also spread out and spawn along other nearshore locations.

### Time of Spawning

The observations of multiple researchers found that spawning occurs primarily in the evening. In the field setting, Holt's (2008) towed hydrophone array recorded the highest levels of drumming activity, which is associated with spawning, between 6:30 and 9:30pm, with little activity after 9:30pm. Activity was randomly distributed throughout this time period without any temporal pattern (Holt 2008). Guest and Lasswell (1978), in an observation of captive Red Drum, noted consistent drumming by males from dusk (around 7:00pm) until sometime after spawning (around 9:45pm), with short quiet periods during actual spawning. Both surveys found that Red Drum spawning occurs in the evenings, detectable by behavioral patterns and mating calls, the "drumming" sound made by males.

Lowerre-Barbieri et al. (2008) indicated spawning in Florida waters occurred between 4:00 and 9:00pm based on drumming behavior in field and tank observations.

### Courtship and Spawning Behavior

As indicated by their common name, Red Drum are known for the "drumming" sound that the males produce by flexing the muscles on either side of their swim bladders (Holt 2008). They produce low-frequency sounds previously described as "knocks" by Fish and Mowbray (1970) or "drumming" by Guest and Lasswell (1978) and others. Sounds are only made by male Red Drum as the females do not have the sound producing apparatus (Parmentier et al. 2014). Males have a sonic muscle that lays lateral to the swim bladder and are absent in female Red Drum. These calls made by male Red Drum are associated with courtship and spawning and, as such, can be regularly observed during the formation of spawning aggregations throughout the spawning season (Guest and Lasswell 1978, Lowerre-Barbieri et al. 2016b). Each mating call consists of multiple pulses repeated at various rates and patterns (Guest and Lasswell 1978, Holt 2008). It is unknown whether specific call patterns are associated with particular spawning behaviors. However, the particular noise made and the consistency of frequency make the mating calls easily recognizable by ear, with the frequency of Red Drum calls in the field consistently measured to be around 140-160 Hz (Holt 2008, Luczkovich et al. 1998). In an observation of the spawning of captive Red Drum, Guest and Lasswell (1978) found that males drummed constantly from dusk until shortly after spawning, except for brief periods of quiet when the males were observed nudging a female's urogenital opening to induce the release of eggs. Arnold et al. (1977) reported that tank spawning by Red Drum was predictable, noting that drumming could be heard 3-4 hrs before a spawn and the males would chase and 'butt' the females. Males changed color with stronger contrast as courtship intensified. Male Red Drum would release milt just before or just after dusk in the hatchery causing the water to become cloudy. Females would release eggs into the sperm cloud at mid-water and fertilized eggs would begin to float 10-20 minutes later.

## Larval Transport

Red Drum eggs are spawned in nearshore waters, primarily around the mouths of estuaries (Pattillo et al. 1997). The larvae typically remain pelagic for two or three weeks, reaching approximately 7 mm SL (Peters and McMichael 1987, Brown et al. 2000). They are then transported to inshore habitats by tidal currents (Peters and McMichael 1987, Brown et al. 2000). Upon hatching, juvenile Red Drum tend to remain at their natal estuaries throughout much of their early life. Only after reaching sub-adulthood will the Red Drum then leave these estuaries in search of spawning aggregation sites where they will remain until fully matured (Porch 2000).

## Genetics

Red Drum is a popular sportfish that inhabits the Atlantic Ocean and the Gulf of Mexico. Management has had the species under a no-take moratorium in federal waters since Amendment 2 to the Federal Fishery Management Plan for Red Drum (GMFMC 1998) and stocks of Red Drum in the Gulf of Mexico and along the Atlantic Ocean are managed separately. Refining the genetic boundaries has not been a priority for federal management since the federal fishery has remained closed to this date. Genetic concerns were raised by the Gulf states as they undertook restoration efforts through supplemental stocking (Chapter 6 – Stock Enhancement). Early work by Ramsey and Wakeman (1987) found that Red Drum exhibit high heterozygosity as a result of Gulf-wide panmixia. Due to overfishing in the 1980s, concerns of genetic viability were addressed by Gold et al. (1993) who determined that the genetic variability of the species had not been affected by the intense fishing pressure.

As Texas began supplemental stocking efforts to facilitate recovery efforts of Red Drum stocks, questions arose related to the genetic diversity of the stock with large-scale supplemental stocking efforts. There was concern over the potential loss of genetic heterozygosity due to inbreeding and a reduction in the effective population size in a combined natural and captive population which is known as the Ryman-Laikre effect (Ryman and Laikre 1991). If the survivorship of hatchery raised fish exceeded natural survival, then the genetic heterozygosity of future stocks would be reduced with the limited crosses conducted within the hatchery. King et al. (1995) isolated a gene marker with an allele frequency that would be rare in wild populations that could be used for direct estimation of stocking success, abundance, natural mortality, movement and recruitment into natural populations. Genetic evidence from King et al. (1995) suggested that biological and physical processes are not present to form discrete stocks in Texas waters. Five geographic Texas subpopulations of Red Drum exhibited an effective absence of genetic subdivision, high degree of genetic similarity, and homogenous allele frequencies (King et al. 1995). Carson et al. (2009) also found no significant differences in genetic diversity among four Texas bay systems and the genetic diversity within the bays was equal to other bay systems in the southeastern U.S. that had not been stocked with hatchery-raised Red Drum.

Even though the genetic diversity of the wild stock is not diminished by supplemental stocking, allele richness of hatchery released Red Drum was significantly lower than their broodfish or wild Red Drum (Karlsson et al. 2008, Carson et al. 2014). Karlsson et al. (2008) discusses the Ryman-Laikre effect which is a possibility in Texas waters due to non-random survival of individual releases, unequal contributions among dam x sire combinations, or physiological conditions of time or season of release sites.

Gold et al. (1993) and (1999) indicated a weak differentiation of subpopulations across the northern Gulf of Mexico and the U.S. Atlantic coast. Red Drum had positive autocorrelations of mtDNA haplotypes at proximal localities and negative for distal localities for which the overall gene flow may be sufficient to neutralize genetic differentiation (Gold and Richardson 1994). Genetic differentiation in Red Drum is due to isolation by increasing distance (Gold and Richardson 1994, Gold and Turner 2002), thus no evidence of phylogeographic cohesion. Gold et al. (1999) speculated that genetic divergence stems from environmental barriers, suitable habitat, current patterns and perhaps behavioral factors. In addition to physical isolation by distance, isolation may also be facilitated by female philopatry and limited movements by females.

Work by Seyoum et al. (2000) found, through mtDNA linkages showing a neighbor-joining tree based on nucleotide divergences, that cohesion among Atlantic Ocean Red Drum was greater than that of Gulf of Mexico Red Drum. They describe the area from Mosquito Lagoon, Florida (Atlantic coast) to Sarasota Bay (Gulf coast) as an area of differentiation in which two semi-isolated population exist. Additionally, Seyoum et al. (2000) indicated that the Red Drum from Apalachicola Bay is genetically divergent and it was recommended that Gulf and Atlantic stocks be managed separately.

The modified stepping-stone model (Gold et al. 2001) of Red Drum population structure from the northern Gulf of Mexico hypothesizes that gene flow is restricted to adjacent estuaries. Because of the nearshore migrations and mixing of adjacent estuaries, management should consider wider geographic context for management. These conclusions were further supported by mtDNA results indicating small but significant genetic divergence among geographic samples represented overlapping populations (Gold and Turner 2002). Hollenbeck et al. (2019) using restricted site-associated DNA (RAD) sequencing for the analysis of neutral and divergence loci indicated three genetically distinct regions; Atlantic, northeast Gulf and northwest Gulf. The Atlantic samples came from Charleston, SC south to Indian River, Florida. Northeast Gulf samples were from Apalachicola to Charlotte Harbor, Florida. Northwest Gulf samples were from Lower Laguna Madre, Texas to Biloxi, Mississippi. Hollenbeck et al. (2019) concluded that isolation by distance and differences in basic habitat, oceanic, and atmospheric forces, interacting with the geomorphology of the Gulf of Mexico, was the source of the differentiation. Hollenbeck et al. (2019) did not indicate the Apalachicola stock as divergent, as samples were also collected from nearby Cedar Key, Florida. Seyoum et al. (2000) was comparing samples from Apalachicola to samples from Tampa and south in their study. The division of Red Drum north in the Big Bend region compared to off Tampa Bay and Charlotte Harbor is supported by Lowerre-Barbieri et al. (2016b) who found spawning site fidelity among aggregations off Tampa and Charlotte Harbor.

If future fishing for Red Drum is allowed in federal waters, more work needs to be conducted to identify regional philopatry for management as effort from different regions will not be uniform. Regions from Louisiana to Apalachicola in the northcentral Gulf and the area of differentiation from Mosquito Lagoon, Florida (Atlantic coast) to Sarasota Bay (Gulf coast) as described by Seyoum et al. (2000) needs study.

## Age and Growth

Red Drum in the Gulf of Mexico grow rapidly as juveniles and tend to slow after age five when both sexes attain full maturity (Beckman 1989, Ross et al. 1995). However, few studies report length-at-age much past 10 years (Table 3.6). Like many estuarine species in the Gulf, Red Drum exhibit exponential growth during the first year and reach the asymptote around age-10 (Figures 3.13A and 3.13B). Studies have shown that Red Drum generally grow to around 300-350 mm TL during their first year with larger fish reported in the more southern regions of the Gulf (Aransas Bay, Texas and southwestern Florida; Table 3.6). Beckman (1989) estimated growth rates of around 0.57 mm/day in a Louisiana impoundment which was similar to rates reported for non-impoundment fish estimated at 0.48 mm/day. Other previously

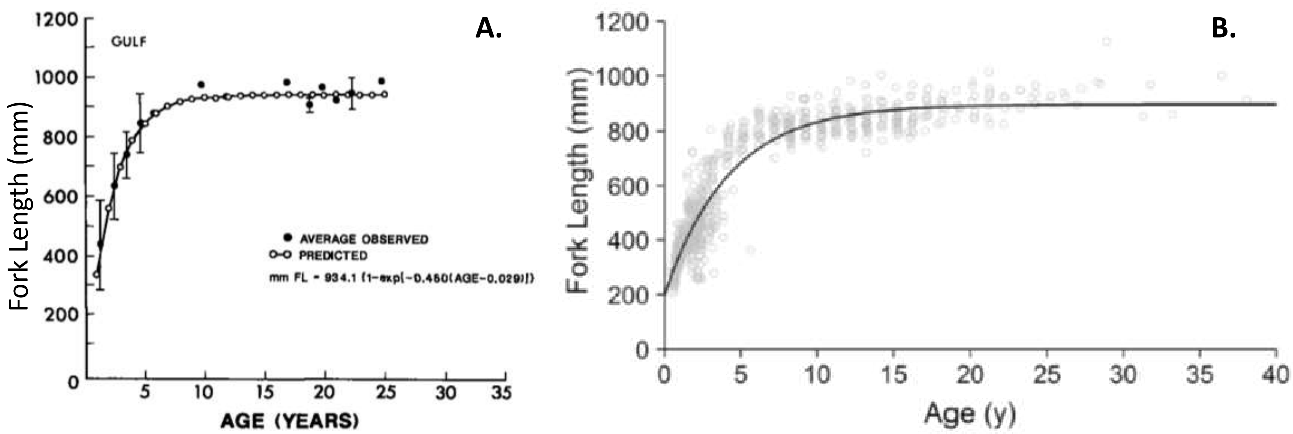



Figure 3.13 A). Average observed (±2SD or range if n = 2) and predicted mean lengths of Red Drum in Florida waters (Figure 5A *from* Murphy and Taylor 1990). B). Age and fork length of Red Drum caught in Mississippi waters fit with a three parameter von Bertalanffy growth function. The line represents the model using median parameter estimates obtained through Bayesian analysis (Figure 1.1 *from* Bennetts 2018).

published studies reported similar daily rates to Beckman (0.54 mm/day, Pearson 1929; 0.59 mm/day, Simmons and Breuer 1962; 0.6 mm/day, Scharf and Schlight 2000).

Porch et al. (2002) indicated a strong seasonal pattern in juveniles with most growth occurring during the warm summer months where they calculated the highest growth rate coefficients in fish before age-5 or age-6 (Figure 3.14).

In addition, there is strong sexual dimorphism in growth (Table 3.7), with female Red Drum growing much larger than males after reaching maturity (Bennetts et al. 2019). Similar patterns for larger females

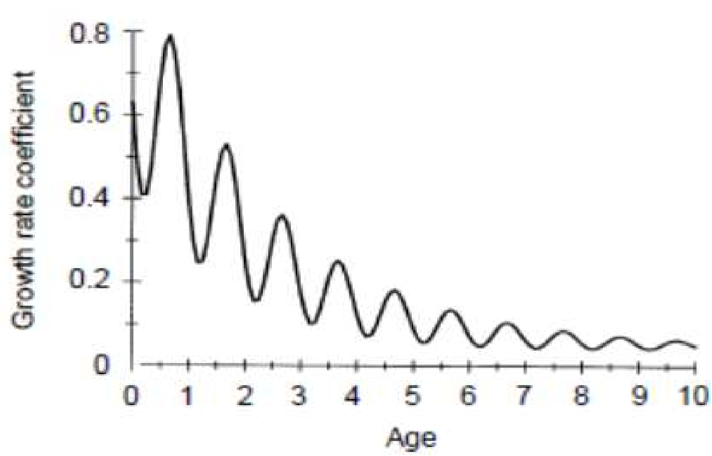



Figure 3.14 Growth rate coefficient from seasonal model as a function of age (Figure 2 *from* Porch et al. 2002).

Table 3.6 Literature accounts of mean length-at-age (FL mm) for Red Drum. Fork lengths were converted from TL or SL, if necessary, using the relationships in text.

| Area | Age (yr) | | | | | | | | | | Technique | Authors |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| **Texas** | | | | | | | | | | | | |
| Aransas/Corpus Christi Bays | 300 | 530 | 630 | 750 | 840 | | | | | | length frequency | Pearson (1929) |
| Aransas Bay | 380-423 | 575 | 630-684 | | | 826 | 871* | 917-940 | | | otoliths | Miles (1951) |
| Lower coast | 322 | 519 | 693 | | | | | | | | tag recapture | Simmons and Breuer (1962) |
| Lower Laguna Madre | 290 | 447 | 542 | | | | | | | | scales | Wakefield and Colura (1983) |
| Matagorda Bay | 255 | 399 | 526 | 605 | 660 | | | | | | scales | |
| Galveston Bay | 275 | 439 | 547 | 619 | | | | | | | scales | |
| **Mississippi** | | | | | | | | | | | | |
| | 356 | 522 | 638 | 717 | 772 | 810 | 839 | 853 | 867 | 875 | otoliths** | Rohr (1980) |
| **Florida** | | | | | | | | | | | | |
| Gulf Coast | 337 | 557 | 696 | 784 | 839 | 874 | 896 | 910 | 919 | 925 | otoliths | Murphy and Taylor (1990) |
| Northwest*** | 315 | 465 | 554 | 607 | 639 | 657 | 668 | 675 | 678 | 681 | otoliths | Addis (2020) |
| Southwest*** | 374 | 511 | 612 | 687 | 743 | 784 | 815 | 838 | 855 | 867 | otoliths | |

*A mixture of fish age seven and eight.
**Average size for age group from June through November.
***TL converted to FL using (tlcm=-1. 604+(1. 08*flcm) from Addis 2020

Table 3.7 von Bertalanffy growth parameters reported in various studies using scales, otoliths, or other techniques and by region over time.

| Location | Sex | Technique | $L_{inf}$ (mm FL) | K (years$^{-1}$) | $t_0$ (years) | Reference |
|---|---|---|---|---|---|---|
| Florida Gulf | Comb | Otoliths | 934 | 0.460 | 0.029 | Murphy and Taylor (1990) |
| Florida Northwest | Comb | Otoliths | 693** | 0.52 | -0.17 | Addis (2020) |
| Florida Southwest | Comb | Otoliths | 912** | 0.30 | -0.79 | |
| Alabama | Male | Otoliths | 928 | 0.31 | -1.4 | Hightower (2013) |
| | Female | Otoliths | 953 | 0.32 | -1.4 | |
| Mississippi/Louisiana | Comb | Otoliths | 894 | 0.37 | -0.30 | Rohr (1980) |
| Mississippi | Comb | Otoliths | 901* | 0.26 | -1.17 | Bennetts (2018) |
| | Male | Otoliths | 875* | 0.26 | -1.39 | |
| | Female | Otoliths | 924* | 0.26 | -1.22 | |
| Texas-Alabama | Male | Otoliths | 909 | 0.137 | -7.74 | Beckman (1989) |
| | Female | Otoliths | 1,013 | 0.088 | -11.29 | |
| Texas | Comb | Tag Recapture | 865 | 0.422 | - | Doerzbacher et al. (1988) |
| Texas - Lower Laguna Madre | Comb | Scales | 680 | 0.52 | -0.01 | Wakefield and Colura (1983) |
| Texas - Matagorda | Comb | Scales | 789 | 0.35 | -0.02 | |
| Texas - Galveston | Comb | Scales | 760 | 0.41 | -0.01 | |
| Texas | Comb | Published Data | 1,002 | 0.295 | 0.144 | Matlock (1984) |

*TL converted using [FL mm = (0. 90*TL mm) + 33.14] from Bennetts (2018).
** converted using [FL cm = -1. 604 + (1. 08*FL cm)] from Addis (2020).

were also reported by Beckman (1989) and Hightower (2013). Hightower (2013) did report higher $L_\infty$ from their von Bertalanffy parameters for female than male Red Drum off Alabama.

Red Drum maximum sizes vary substantially across the Gulf. The largest fish recorded in the Gulf was 61.0 lbs caught off Louisiana by a recreational angler in 1992 and is the current Gulf and Louisiana record (Table 3.8). There is no length associated with that fish. A very large Red Drum was caught off Venice, Louisiana in 2015 that would have potentially broken the current record, but it was released alive and never certified. That fish was 53½ inches long and estimated to weigh 65 lbs (Bonin 2015). The world record Red Drum however, was caught off North Carolina in 1984 and weighed 94.125 lbs (Figure 3.15). In the published literature, the largest Red Drum sampled were a 1,156 mm TL female encountered by Powers et al. (2012) and a 1,150 mm TL female reported by Beckman et al. (1989).

### Life Span

Red Drum have been documented to live to around 60-years-old along the north Atlantic and roughly 40-years-old in the South Atlantic and Gulf. Powers et al. (2012) found that in the early 2000s, there were very few Red Drum in the Gulf older than about age-24 due to fish not surviving prior to the regulatory

Table 3.8 Current Red Drum state recreational saltwater records for the Gulf of Mexico and the current IGFA World Record (IGFA 2018).

| City, State | Year | Record Holder | Weight |
|---|---|---|---|
| Cocoa, Florida | 1996 | George E. Hogan, Jr. | 52lb 5oz |
| Theodore, Alabama | 2013 | Al Mead | 45lb 9oz |
| *unknown*, Mississippi | 2016 | Antonio Rubio | 52lb 2oz |
| *unknown*, Louisiana | 1992 | David Weber | 61lb 0oz |
| *Gulf of Mexico*, Texas | 2000 | Artie Longron | 59lb 8oz |
| IGFA World Record<br>Hatteras, North Carolina | 1984 | David Deuel | 94lb 2oz |

actions by NOAA to restrict harvest to recreational anglers and the closing of the EEZ. Subsequently, Hightower (2013) reported the oldest fish in her thesis work in Alabama was a fish aged at 40-years-old.

## Migration and Movement

Fish swim to feed, locate habitat, avoid predators, locate or avoid environmental conditions, spawn, and migrate, but migration is usually tied to seasonal components and often associated with spawning. Overstreet and Heard (1978) postulated that Red Drum movements were regulated by optimal abundance

Figure 3.15 North Carolina world record Red Drum caught November 7, 1984 by David Deuel from shore off Hatteras.

of specific prey items on a seasonal basis. Dresser (2003) found that tide limited access to foraging grounds and movements coincided with tide stage for juvenile Red Drum. Movements of juveniles were also influenced by daylight as Red Drum tended to stay in the deeper channel when high tide occurred at night (Dresser 2003). Powers et al. (2012) documented that local increases in water temperatures decreased catch rates during May to October. In 2012, Lowerre-Barbieri et al. (2016a) indicated that a lack of schools of Red Drum was due to the presence of a strong red tide off Charlotte Harbor.

Red Drum grow quickly in the estuaries of the Gulf of Mexico and begin an ontogenetic shift to the nearshore waters as young adults. Van Hoose (1987) speculated that Red Drum in Mobile Bay must begin to emigrate by their second summer (>400 mm TL) to justify their decrease in local abundances. Walters Burnsed et al. (2020) reported that Red Drum migrated out of Tampa Bay and Charlotte Harbor to the nearshore environment at different rates. Red Drum left Charlotte Harbor in smaller pulses across years, while 74% of Red Drum left Tampa in a single year. Wilson and Nieland (1994) reported that a numerical dominance of immature males in the aggregations of nearshore waters may indicate a male predisposition for an earlier emigration from estuarine habitats.

Once offshore, movements of adult Red Drum tend to be along the coastlines (Nichols 1988). Red Drum tagged by Overstreet (1983) off Mississippi were recaptured 778 km off Texas and another was recaptured 120 km away six days later. During a mark-recapture study, Nichols (1988) noted movements of Red Drum from angler recaptures demonstrated inshore movements.

It is generally held that large schools of adult Red Drum are related to spawning migrations or activity (Overstreet 1983, Mullin et al. 1996). However, surface schools of Red Drum were reported outside of the spawning season (Lohefener et al. 1987, Wilson and Nieland 1994, Mullin et al. 1996, Powers et al. 2012, Lowerre-Barbieri et al. 2016a).

Extensive work has been put into locating and estimating the size and abundance of Red Drum aggregations. Lohoefener et al. (1987) evaluated the feasibility of aerial surveys and found 90% of the sightings were in waters less than 22 m where the commercial fishery had been operating. Mitchell and Henwood (1999) during a large mark and recapture study tagged over 9,500 Red Drum and the average depth of capture was 5.4 m. Holt (2008) indicated that spawning activities of Red Drum off the coast of Texas were most frequently observed at the 10-m isobath. Powers et al. (2012) sampled out to a depth of 60 m but reported most catches and aerial observations were in water depths less than 20 m. Lowerre-Barbieri et al. (2016a) indicated that Red Drum schools during the reproductive period were fairly common to 3.7 and 7.4 km offshore according to aerial transects which corresponds approximately to the 10-m isobath. In spite of these studies, the transmigration of these schools along the nearshore or offshore environment have not been well documented. In great contrast, the GMFMC's (2016) essential fish habitat report listed depth out to 70 m as essential fish habitat for Red Drum. A common notion is that schools of Red Drum further offshore (deeper) do not surface and are not being captured or included in estimates of abundance or biomass from aerial surveys. Recent studies indicate that this may not be the case and the majority of the Red Drum aggregations may reside in waters less than 20 m across the Gulf of Mexico (Lohoefener et al. 1987, Mitchell and Henwood 1999, Holt 2008, Powers and Hightower 2018, Lowerre-Barbieri et al. 2019, Hightower et al. 2021).

Most of the work on locating and estimating the size and abundance of Red Drum aggregations has been centered around the spawning season and spawning aggregations. Mullin et al. (1996) postulated that surface school sightings of Red Drum across the Gulf of Mexico were representative of transitory behavior, which was related to spawning. Lohoefener et al. (1987) reported surface aggregations off

Florida were more dominant in the morning hours and the remainder of the Gulf of Mexico surface aggregations were more dominant between 10am and 4pm. These results suggest a vertical component to Red Drum movements on a daily basis. Lowerre-Barbieri et al. (2008) reported spawning was most likely occurring between the hours of 4pm and 9pm but did not indicate a depth component to this behavior. While a few fish have been reported as moving across the northern Gulf, no reports have been located indicating movements in either direction around the Florida peninsula or to and from the Mexican region of the Gulf of Mexico.

### Gulf of Mexico Tagging

Tagging of Red Drum within the Gulf of Mexico proper is limited, and most recaptured tags are from inshore tagging programs where the fish have emigrated. Texas began tagging Red Drum in the 1950s. In 1951, 134 Red Drum were tagged at the entrance to Cedar Bayou Pass. Multiple recaptures noted regional movements 48 km to the south and 64 km north of the pass (Simmons and Breuer 1976). One Red Drum tagged in Aransas Bay in 1951 was recaptured 12 years later at the Big Shell rig in the Gulf of Mexico. Another Red Drum (410 mm) was tagged in San Antonio Bay and then the recovered tag was verified 273 days later in Tampa Bay, Florida. While these returns were rare, they highlight the range and longevity of the information that can be obtained from a passive tag in the Gulf of Mexico versus the data rich but short lived and short ranged acoustic tags.

Overstreet (1983) tagged 360 Red Drum near the Mississippi barrier islands with 13 reported recaptures. Four larger fish (650-850 mm TL) were recaptured in the first 4 days and had moved a few kilometers. In contrast, one fish moved 16 km in a single day. Five fish had migrated 24-63 km westward after 160 days at large. Two longer returns were reported: one off Texas, 778 km after 746 days at liberty and one off Florida, 316 km away after 399 days.

Nichols (1988) tagged Red Drum offshore collected in purse seines (1986-1987) from Mobile to Galveston Bays using internal anchors or dart tags to estimate population size. The marking phase ended in May 1987 (N=15,349) and recapture began in July 1987. Recaptured Red Drum within a purse seine set were comprised of fish from multiple sets during the marking phase indicating substantial mixing. Alongshore motion was noted, but public angler recaptures tended to indicate inshore movements.

In an attempt to repeat the Nichols study, Mitchel and Henwood (1999) marked Red Drum captured from purse seines, June to October 1997 and the recapture phase was from July to November 1998. Fish were sampled from Mobile Bay to Sabine Lake and 4,289 Red Drum were released to the east and 5,380 to the west of the Mississippi River. During the recapture phase, 5,392 were examined for tags east and 4,158 to the west of the Mississippi River. Average water depth for purse seine deployments was 5.4 m. All 29 recaptures were east of the Mississippi River and direction, or distance moved was not reported. From 125 public recoveries, 27 recaptures were east, and 98 were west of the Mississippi River.

### Florida

Florida's 'Schlitz Tagging Program' of inshore and nearshore Red Drum reported 91.3% of returns moved less than 8 km and 87.3% of returns moved less than 32 km (Ingle et al. 1962). The greatest distance moved was 180 km over 186 days. Beaumariage and Wittich (1966) reviewed tagging and recapture results on a regional basis for north Atlantic, south Atlantic, Florida panhandle and the central west coast of Florida, and 85.7% of Red Drum (310-575 mm) showed no significant movements (<9.2 km). In the Everglades National Park, Bryant et al. (1989) indicated most tagged Red Drum moved less than 8 km, but fish larger than 750 mm moved greater distances. Lowerre-Barbieri et al. (2016a) conducted a three-year study of adults along the nearshore habitats and, due to multiple recaptures within a season, they were able to conclude that mixing among schools within the spawning site was occurring. Unlike conventional tagging, acoustic tagging showed individual fish moving a distance of ~150 km along the coast and 90 km offshore (Lowerre-Barbieri et al., 2019).

Lowerre-Barbieri et al. 2019 acoustically tagged 122 Red Drum from a nearshore spawning site off Tampa Bay during 2012 and 2013. Fish concentrated at the Tampa Bay fish spawning aggregation site during the reproductive period and then dispersing over a much larger area in the non-reproductive period.

### Alabama

Alabama has conducted one inshore tagging study of Red Drum between October 1987 – August 1989 (Minton and Van Hoose 1989). The study used hatchery raised as well as wild caught fish for the study. Over twenty thousand hatchery raised Red Drum were tagged with 12 mm anchor tags. Two hundred sixty-eight fish were recaptured during 1988 and 1989. Twenty-two percent of the Red Drum were characterized as having little movement (<9 km) within the estuary. Hatchery Red Drum were least likely to move in a southerly direction (10%) but were more distributed among north (28%), east (18%), and western (22%) movements.

Two hundred sixty-two wild Red Drum were caught by hook-and-line, tagged, and released. Fifty-eight wild Red Drum were recaptured and 46% exhibited little movement (<9 km). Wild Red Drum movements were approximately split among north (16%), east (14%), and south (17%), and were least likely to move to the west (7%).

Red Drum were tagged in Dog River (n=36) and Fowl River (n=43) of Mobile Bay to estimate mortality and residency. Fish ranged from 291-667 mm TL and were estimated to be 1-2 years of age. Dog River monthly residency for Red Drum ranged from 0.917-0.99 and annual residency was 0.724 (Nelson 2019). Fowl River monthly residency for Red Drum ranged from 0.942-0.99 and annual residency was 0.638 (Nelson 2019). Most fish emigrated during August with an escapement rate from the rivers combined of 36.3% (Nelson and Powers 2020). Annual fishing mortality in the two rivers was estimated at 0.414 and 0.309 for Dog and Fowl rivers, respectively (Nelson and Powers 2020).

### Mississippi

Overstreet (1983) tagged 88 Red Drum in the inshore waters of Mississippi. Twenty fish were recaptured, of which ten were recaptured at the release site within a week post-release and up to 464 days post-release. Ten fish moved 4-33 km with a maximum days-at-large of 316.

In 2008, the Gulf Coast Research Lab (GCRL) in Mississippi began opportunistically tagging Red Drum from ongoing fishery independent surveys. Approximately 1,500 Red Drum have been tagged from 2008-2019. A total of 51 tagged Red Drum have been recaptured through 2019 (GCRL unpublished data). The majority of the fish remained near the release location in the Biloxi Bay. Red Drum were recaptured to the east as far as the Orange Beach fishing pier in Alabama and near Slidell, Louisiana to the west.

Grammer et al. (2019) tagged 25 (600-800 mm TL) Red Drum with acoustic transmitters in St. Louis Bay, Mississippi in 2017-2018. Results indicated that the presence of that size class within the acoustic array may have been seasonal, as seasonal swings in bottom water temperature were observed around the time many fish exited the Bay. In 2017, 14 Red Drum were detected more regularly near the mouth of the Bay. Seven individuals emigrated throughout the summer and all fish were absent from the array within St. Louis Bay October through November, though one fish returned after November. In 2018, eight Red Drum were detected and maintained a higher position in the Bay than those detected in 2017,

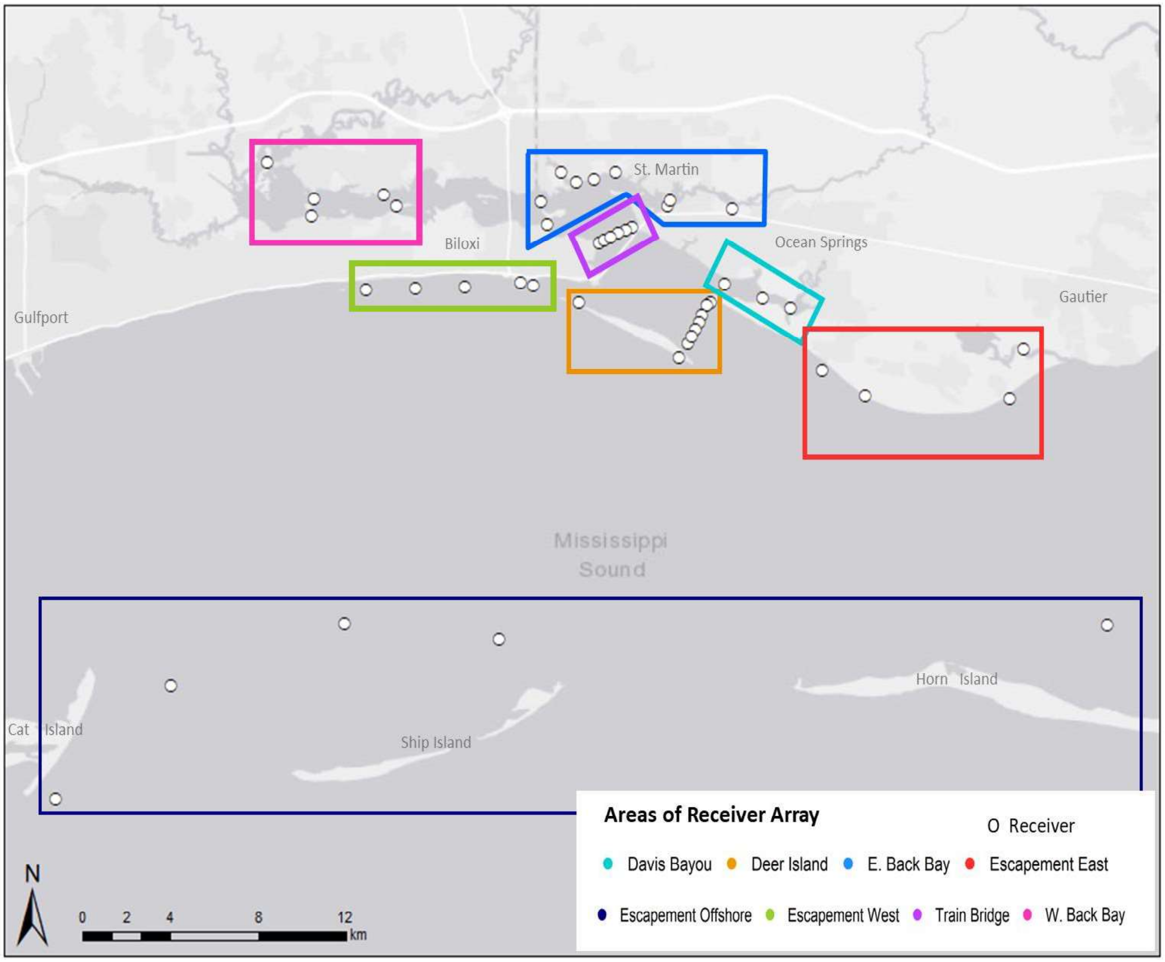



Figure 3.16 Map of the Back Bay of Biloxi and Mississippi Sound study area, south-central Mississippi. The Mississippi Department of Marine Resources passive acoustic receiver array comprised up to 40 receivers* from May 2017- April 2021. Boxes indicate groups of receivers categorized into general areas within the array. (*Offshore receivers were added September 2020.) (Figure 2 *from* Green and Hill 2021).

presumably in response to reduced fresh water input that year. Only two of the eight Red Drum were detected emigrating from the system during the summer/fall transitional period in 2018. Generally, the results of the study indicated use of the St. Louis Bay system by Red Drum in that size class may change seasonally and their latitudinal position within the Bay array is likely affected by freshwater inflow and salinity.

Green and Hill (2021) acoustically tagged 82 Red Drum from 2017-2019 in bays and tributaries of the Back Bay of Biloxi, Mississippi (Figure 3.16). Ages of tagged Red Drum based on length ranged from 1-6 years; nearly 50% of tagged fish were considered age-2. Red Drum tended to stay within the same areas as tagged during 2017 and 2018 with limited and brief movements. July and September of 2018 initial detections at Deer Island acoustic receiver indicated escapement from the Back Bay of Biloxi. In 2019, most detections were in the escapement east array and some in the Deer Island array also indicating escapement. By 2020, most detections were similar to previous years. The expanded study area included the Escapement Offshore array near Ship and Horn islands. Three fish were detected in the offshore array with one returning to the estuary and the other two were no longer detected in any of the study arrays.

## Louisiana

In the late 1980s, a member of the Coastal Conservation Association (CCA) took it upon himself to start tagging and collecting data. In 2010, the LDWF got involved, but it was to support the activities of the CCA program. In a subsequent analysis of the program by LDWF, it was determined that the information had limited benefit to the stock assessment or management of the species and state support of the program was ceased. No analysis or report of the cumulative data has been published by the LDWF.

Behringer (2019) monitored ages 0-1 year old Red Drum in Barataria Bay and reported high site fidelity and no movement between habitat types potentially due to division of habitats by deep expansive mud flats that would subject them to predation. Fine scale movements noted foraging at high tides in the marsh and retreating to channels at low tide (Behringer 2019).

## Texas

The TPWD began the tagging of several important species that supported local fisheries as early as 1950 and expanded and intensified tagging efforts in 1975 (Bowling and Sunley 2003). Results for recaptured inshore Red Drum indicated fine scale movements less than 3.2 km from Galveston Bay for Red Drum tagged in Christmas Bay (87%) and Moses Lake (83.3%), and Newcom Bend (60.2%) from Aransas Bay (Simmons and Breuer 1976). Texas coast-wide bay surveys indicated significant site fidelity within the bay systems (Matlock and Weaver 1979, Osburn et al. 1982, Marwitz 1989, Bowling and Marwitz 1991, Bowling 1996). Matlock and Weaver (1979) indicated that the percent of recaptures was inversely related to the distance from the original tagging site. Osburn et al. (1982) reported no relationship to distance moved by fish size or season and that no winter mass migration offshore occurred. However, Osburn et al. (1982) reported that Red Drum in Corpus Christi and Upper Laguna Madre left the bay systems to a greater extent when compared to other Texas bay systems. Green et al. (1985) reported a 15% survival rate for tagged Red Drum, summer had the lowest survival, and emigration did not affect survival estimates. From November 1975 to December 1999, approximately 55,091 Red Drum were tagged by the TPWD with 6,094 recaptures and of those, two Gulf-released fish were recaptured in the bays (Bowling and Sunley 2003).

In April 2022, a tagged Red Drum 889 mm in length was caught by an angler in Galveston Bay. The fish had been tagged and released by TPWD staff on May 6, 1998 in East Matagorda Bay. The fish was 607 mm when tagged and 889 mm when recaptured. Based on length-at-age when tagged, the fish was estimated to be age-27 at recapture and had grown 282 mm in 24 years (TPWD unpublished data).

Rooker et al. (2010) using stable carbon and oxygen ratios from otoliths reported four distinct regions along the Texas Coast for Red Drum young-of-the-year up to age-5+. Each region consisted of multiple bay systems except for the southern region (Laguna Madre). Mixing among regions was more pronounced in the northern regions where a percentage (35-42%) of individuals moved to adjacent regions to the south.

Dance and Rooker (2015) deployed an acoustic array in Christmas Bay to determine habitat preferences and bay-scale use for Red Drum. Red Drum exhibit a preference for shoal grass (*Halodule wrightii*), turtle grass (*Thalassia testudinum*), and sand habitats (Dance and Rooker 2015, Moulton et al. 2017). Movements over bare substrate was greatest during the day and greatest at night over grasses indicating movements between the habitat types (Moulton et al. 2017). The rate of movement across the different habitat types did not differ significantly for Red Drum with a mean of 8.4±0.5 m/minute (Dance and Rooker 2015). Similarly, mean distance traveled per day was 11.9±2.8 km (Moulton et al. 2017). Water temperature did not have a significant effect on the rate of movement by Red Drum. Maximum distance traveled in one day was 3.4±0.6 km (Dance and Rooker 2015). Moulton et al. (2017) found juvenile Red

Drum (223-537 mm TL) movements were restricted to the inner lagoon for foraging and protection from predators.

Hall et al. (2019) acoustically tagged maturing Red Drum from Mesquite Bay in proximity to the reopening of an inlet that was closed in 1979. The closing of the pass created a 55-mile barrier between inlets for emigration. Of eight tagged fish, only one Red Drum used Cedar Bayou in a 24-hr period prior to the reopening. After the reopening, numerous detections were made at several receivers. Most of the detections were during the spawning season and five of the last detections of Red Drum were made at the receiver closest to the Gulf of Mexico inlet. Based on their results, Hall et al. (2019) concluded that Red Drum choose migration corridors opportunistically and do not display natal homing in Texas waters.

## Parasites and Diseases

Red Drum carry numerous infections and parasites both internally and externally from a wide variety of vectors that lead to a broad spectrum of diseases. Infections may affect the brain, skin, fins, digestive tract, and other internal organs. Symptoms may include problems with orientation, hemorrhaging, eyeball protrusion, and lesions. In the wild, large mortality events are usually not observed as sickened fish are most likely removed by predators from the population. In aquaculture, many of these infections can be lethal and result from high stocking densities and life cycle of the vectors that lead to infections.

Infections can be caused by bacterial, viral or fungal vectors. Bacterial outbreaks regularly cause losses of cultured fish species including Sciaenidae (Blaylock and Whelan 2004). Red Drum parasites include numerous organisms including dinoflagellates, flat and round worms, copepods, and fish lice which are the most observed due to their presence on the skin, fins, and gills. Some species of louse do occur internally in the stomach or intestine (Nahhas and Short 1965).

### Infections

#### Bacterial

*Vibrio* was reported by Johnson (1990) to be the most encountered bacteria affecting marine fishes. Most lesions on fish in the marine and estuarine waters of the Gulf of Mexico involve *Vibrio* or a form of stress in the disease process (Overstreet and Hawkins 2017). Tao et al. (2012) reported three Red Drum from a sample of five sampled during a 2009-2011 study were positive for *Vibrio vulnificus* on their external surfaces throughout the northern Gulf but reported that 37% of all fish tested were also positive. Vibrio was present across all fish, but the positivity rate increased with water temperature.

Quang et al. (2020) reported on four *Vibrio* species found in association with Red Drum from culture locations within the Tua Thien Hue province of Vietnam (Table 3.9). The study indicated increased mortality events for seabasses, shrimp and Red Drum being cultured. Yen et al. (2021) identified 30 strains of *Vibrio* and the toxic genes causing vibriosis from the brains, hemorrhagic site and digestive tract of Red Drum in an aquaculture setting. Four species causing vibriosis are listed in Table 3.9. Four toxic genes were isolated and 25 out of 30 *Vibrio* strains contained at least one toxic gene. Five isolations carried three toxic genes, and none carried all four toxic genes. The digestive tract carried the most common strains of *Vibrio* (*alginolyticus* and *azureus*).

Other bacteria of concern within the Gulf of Mexico include *Mycobacterium* which is present in wild fish and a cause for concern for Red Drum aquaculture (Diamant et al. 2000, Mugetti et al. 2020). *Streptococcus* has been linked to chronic fish kills in the northern Gulf of Mexico (Plumb et al. 1974) and mortalities in cage culture in the Mediterranean (Eldar et al. 1999). Recently, Red Drum being farmed in

Table 3.9 Bacterial infections common in Red Drum.

| Site | Symptoms | Vector | Reference | Location | Source |
|---|---|---|---|---|---|
| Skin, Fins | Fins become frayed, necrotic and hyperemic. Reddish skin lesions, scale loss. | *Aeromonas hydrophila* | Plumb (1991) | U.S. | aquaculture |
| Brain | Eubacterium meningitis, twirling, uncoordinated swimming | *Eubacterium tarantellae* | Henley and Lewis (1976) | Texas | wild |
| Skin Organs | skin ulceration, lethargy, grey-white nodules in liver and kidney, abdominal distension | *Mycobacterium pseudoshottsii* | Mugetti et al. (2020) | Italy | aquaculture |
| Skin Organs | superficial ulcers, scale loss hemorrhagic lesions penetrating the musculature | *Mycrobacterium marinum* | Diamant et al. (2000) | Israel | aquaculture |
| Skin Organs | erratic swimming, cutaneous ulcers, loss of scales, nodular formations mainly in internal organs | *Nocardia seriolae* | del Rio-Rodriguez et al. (2021) | Campeche Bay | aquaculture |
| Brain Kidney Spleen. | lethargy, loss of orientation, skin lesions, protrusion of the eye, gill rot | *Streptococcus iniae* | Colorni and Diamant (2014), Eldar et al. (1999), Buller (2004) | Global | wild / aquaculture |
| Digestive tract | hemorrhagic disease | *Vibrio alginolyticus* (and strains) | Yen et al. (2021) | Vietnam | aquaculture |
| Kidney and liver | poor feeding activity | *Vibrio anquillarium* | Trimble (1980) | Alabama | aquaculture |
| Digestive tract | hemorrhagic disease | *Vibrio azureus* (and strains) | Yen et al. (2021) | Vietnam | aquaculture |
| Kidney | hemorrhage on body, fin erosion, tailless condition and protruding eyes | *Vibrio brasiliensis* | Quang et al. (2020) | Vietnam | aquaculture |
| Spleen | hemorrhage on body, fin erosion, tailless condition and protruding eyes | *Vibrio cholerae* | Quang et al. (2020) | Vietnam | aquaculture |
| Brain, blood, digestive tract | hemorrhagic disease | *Vibrio fluvialis* (and strains) | Yen et al. (2021) | Vietnam | aquaculture |
| Intestine | gastroenteritis | *Vibrio harveyi* | Liu et al. (2003) | Taiwan | aquaculture |
| Brain, blood, digestive | hemorrhagic disease | *Vibrio orientalis* (and strains) | Yen et al. (2021) | Vietnam | aquaculture |
| Stomach | hemorrhage on body, fin erosion, tailless condition and protruding eyes | *Vibrio parahaemolyticus* | Quang et al. (2020) | Vietnam | aquaculture |
| Fins, skin, liver | lethargy, necrosis of fins, skin, or internal organs | *Vibrio vulnificus* | Tao et al. (2012), Quang et al. (2020) | Gulf of Mexico, Vietnam | wild |

Table 3.10 Viral infections common in Red Drum.

| Site | Symptoms | Vector | Reference | Location | Source |
|---|---|---|---|---|---|
| Skin, Fins | wart-like clusters, skin lesions, rayed fins and tails | LCDV - lymphocytivirus* | Colorni and Diamant (1995) | Global | wild, aquaculture |
| Swim bladder | erratic swimming, hyperinflation | *Nodavirus* | FAO (2022) | | aquaculture |
| Nervous system | abnormal swimming, muscle tremors, hyperinflation of swim bladder | Viral Nervous Necrosis (VNN) | Yanong (2019) | Global | aquaculture |

pens within the Gulf of Mexico (Mexico) experienced outbreaks which have been linked to *Nocardia*. This report is the first known case of *Nocardia* in Mexico (del Rio-Rodriguez et al. 2021). In most cases the outbreaks are linked to reduced water quality that facilitates conditions for bacteria.

### Virus

Viruses exist worldwide and two are well known to affect Red Drum (Table 3.10). Viral Nervous Necrosis (Betanodavirus) is a concern for marine species and has been associated with significant mortality events (Yanong 2019). This virus attacks the nervous system and has no known treatment. Regions susceptible include tropical and sub-tropical with temperatures ranging from 20-25°C. Lymphocystis Disease Virus (LCDV) is a waterborne vector reported to affect the spleen and heart of Red Drum (Colorni and Diamant 1995). Red Drum transported from Texas for culture in Israel developed LCDV and exhibited lesions on the skin and fins. The virus did not spread to all fish suggesting the disease was caused by a group of closely related viruses (Colorni and Diamant 1995). Infections to the internal organs were more sporadic pointing to a more systemic condition of individual fish. FAO currently does not list a treatment for viruses in marine aquaculture.

### Fungal

Fungal infections in Red Drum appear to be rare in nature. Johnson (1990) reported *Saprolegnia* in wild fish when fish are weakened by extreme changes in temperature. The infection occurs on the skin as white or grey fibrous patches and has been found in the Gulf.

### Parasites

#### Protozoans

A summary of protozoan infections recorded in the literature is included in Table 3.11. The parasitic dinoflagellate, *Amyloodinium ocellatum*, can be found on numerous species within the Gulf of Mexico (Lawler 1980) and in general, do not cause mortality events for Red Drum. However, the farming of Red Drum does present risk of amplification or spread of disease due to the density of fish in ponds and the addition of water has the potential to input vectors. Birds and other wildlife visiting ponds also have the potential to spread pathogens, such as *Amyloodinium* (Francis-Floyd and Floyd 2011), thus presenting another disease-spreading risk associated with pond culture of Red Drum. In an aquaculture setting, *A. ocellatum* was responsible for a mass mortality of Red Drum (Trimble 1980) and serious outbreaks have occurred (Francis-Floyd and Floyd 2011). This parasite can be extremely problematic because of its simple life cycle (3-6 days) that only requires one host. *A. ocellatum* tolerates a wide range of temperature (16-30°C) and salinities (12-50 ppt) (Francis-Floyd and Floyd 2011). The parasite adult stage produces

Table 3.11 Protozoan infections common in Red Drum

| Site | Symptoms | Vector | Reference | Location | Source |
|---|---|---|---|---|---|
| Intestine | Spores in and inflammation of digestive tract, scale loss, skin ulcers | *Enteromyxum leei* | FAO Website | | aquaculture |
| Intestine, kidney | | *Henneguya ocellata* | Iversen and Yokel (1963), Landsberg (1993b) | Florida | wild, aquaculture |
| Kidney | pathological changes in renal tissue | *Parvicapsula renalis* | Landsberg (1993b) | Florida | wild |
| Gills Skin | white patches: rings of interlocking cytoskeletal denticles | *Trichodina* | Trimble (1980), Overstreet (1983) | Gulf of Mexico | wild, aquaculture |
| External | slow growth | *Ambiphyra* | Trimble (1980) | Alabama | aquaculture |
| Gills Skin | Powdery or velvet appearance | *Amyloodinium ocellatum* | Trimble (1980), Lawler (1980) | Gulf of Mexico | wild |
| Gills Body | white dusting of skin, respiratory distress | *Cryptocaryon irratans* | FAO Website | | aquaculture |
| Intestine | no apparent pathological effect | *Epieimeria ocellata* | Landsberg (1993a) | Florida | wild |
| Intestine | no apparent pathological effect | *Goussia floridana* | Landsberg (1993a) | Florida | wild |
| Liver | | *Pleistophora sp.* | Overstreet (1983) | Mississippi | wild |
| Gills | | *Paratrichodina obliqua* | Trimble (1980) | Alabama | aquaculture |

a powdery/velvety appearance which results in the common name of 'velvet disease'. The adult stage attaching to epithelial cells while feeding on surrounding cells causes hyperplasia, inflammation and necrosis which disrupts gas exchange in the gills (Blaylock and Whelan 2004). The free-swimming stage is the most susceptible to treatments for control of outbreaks (Francis-Floyd and Floyd 2011), so multiple treatments are required.

## Worms

Cestoda worms (*Poecilancistrium caryophyllum*) are easily seen in the muscle tissue and their length (17 cm) decreases the palatability of the tissue even with a common name of spaghetti worms. Simmons and Breuer (1962) noted spaghetti worms being the most common parasite for Red Drum. Bullard and Overstreet (2004) identified a new species, *Cardicola currani*, from the heart of Red Drum from the waters of Mississippi and Louisiana. Other reported worm infections are included in Table 3.12.

## Copepods

Copepods are the most abundant parasite on Red Drum from Florida (Yokel 1966) and observed on gills, skin, and fins. Causey (1953) reported four copepod species from Red Drum. Simmons and Breuer (1962) noted the lack of presence of copepods parasites in hypersaline waters but indicated spaghetti worms were the most common parasite for Red and Black Drum under those conditions. Landsberg et

Table 3.12 Worm infections common in Red Drum

| Site | Symptoms | Vector | Reference | Location | Source |
|---|---|---|---|---|---|
| Intestine | | *Bucephaloides megacirrus* | Sparks (1958), Nahhas and Short (1965) | Louisiana, Florida | wild |
| Heart | | *Cardicola currani* | Bullard and Overstreet (2004) | Mississippi, Louisiana | wild |
| Stomach | | *Lecithochirium mecosaccum* | Nahhas and Short (1965) | Florida | wild |
| Intestine | | *Distomum vitellosum* | Linton (1905) | North Carolina | wild |
| Intestine | | *Opecoeloides fimbriatus* | Nahhas and Short (1965) | Florida | wild |
| Muscle | White worm in muscle tissue (17 cm) | *Poecilancistrium caryophyllum* | Hutton (1964) | Florida | wild |
| Intestine | | *Prosorhynchoides megacirrus* | Riggin and Sparks (1962) | Florida, Louisiana | wild |
| Muscle | | *Scolex Müller* | Linton (1905) | North Carolina | wild |
| Intestine | | *Stephanochasmus tenuis* | Linton (1905) | North Carolina | wild |
| Intestine | coelomic cavity | *Stomachicola rubea* | Sinclair et al. (1972) | Georgia | wild |
| *unknown* | | *Ascaris sp.* | Linton (1901) | Massachusetts | wild |
| Kidney and liver | | *Contracaecum multipapillatum* | Overstreet (1983) | | |
| Intestine | | *Cucullanus fastigatus* | Chandler (1935) | Texas | wild |
| Intestine | | *Cucullanus stossichi* | Linton (1905) | North Carolina | wild |
| Intestine | | *Geozia pelagia* | Overstreet (1983) | | |
| Mesentery and Intestine | | *Hysterothylacium reliquens* | Deardorff and Overstreet (1981) | Gulf of Mexico | wild |
| Intestine | | *Spirocamallanus cricotus* | Overstreet (1983) | | |
| External | | *Myzobdella lugubris* | Sawyer et al. (1975) | Gulf of Mexico | wild |

al. (1991) demonstrated that Red Drum infested with *Caligus sp*. copepods can be treated successfully with a 20-minute freshwater dip. These results indicate copepods can be located within a broad range of salinities. A list of the common copepod infections is provided in Table 3.13.

In general, numerous bacterial vectors are omnipresent and pose risks to Red Drum as well as numerous other species. This risk becomes elevated as more fish species are being cultured in larger quantities. Biosecurity protocols and quarantine measures can be used to prevent the spread of pathogens between pens/ponds. Prevention of introduction of pathogens is important to successful farming operations and the Southern Regional Aquaculture Center has developed resources to aid aquaculturists in this regard (Francis-Floyd and Floyd 2011).

Table 3.13 Copepod infections common in Red Drum

| Site | Symptoms | Vector | Reference | Location | Source |
|---|---|---|---|---|---|
| Fins | fish louse | *Argulus bicolor* | Overstreet (1983) | Mississippi | wild |
| Body | disease outbreaks | *Caligus bonito bonito* | Simmons and Breuer (1962) | Texas | wild |
| Gills Body | lesions on epidermis | *Caligus elongatus* | Landsberg et al. (1991) | Florida | aquaculture |
| Gills | | *Caligus haemulonis* | Causey (1953), Yokel (1966) | Florida, Texas | wild |
| *unknown* | | *Caligus rapax* | Simmons and Breuer (1962) | Texas | wild |
| Gills | Damage to gills | *Echetus typicus* | Causey (1953) | Texas | wild |
| Gills | | *Lepeophtheirus longipes* | Overstreet (1983) | Mississippi | wild |
| Skin | external elongate worm | *Lernaeenicus radiatus* | Yokel (1966) | North Carolina | wild |
| Gills | | *Lernanthropus seriolii* | Causey (1953) | Texas | wild, |
| Gills, operculum | | *Neobrachiella gulosa* | Causey (1953), Yokel (1966) | Florida, Texas | wild |
| Operculum | | *Parabrachiella intermedia* | Yokel (1966) | Florida | wild |
| Gills | | *Sciaenophilus tenuis* | Overstreet (1983) | Mississippi | wild |
| Gills | | *Lironeca ovalis* | Overstreet (1983) | Mississippi | wild |
| Fins Dorsal | | *Nerocila acuminata* | Simmons and Breuer (1962) | Texas | wild |

## Feeding, Prey, and Predators

Several investigations have provided extensive data on food habits of Red Drum: Pearson (1929), Gunter (1945), Kemp (1949), Miles (1950), Knapp (1950), and Scharf and Schlight (2000) from Texas; Fontenot and Rogillio (1970), Boothby and Avault (1971), Bass and Avault (1975), and Guillory and Prejean (2001) from Louisiana; Yokel (1966), Llanso et al. (1998), and Camp et al. (2019) from Florida; Van Hoose (1987), and Kroetz et al. (2017) from Alabama; and Overstreet and Heard (1978) from Mississippi. Stomach analyses of Red Drum have also been recorded from Texas by Miles (1950) and Soto et al. (1998), from Florida by Odum (1971), Camp et al. (2019), and Malinowski et al. (2019); and from Louisiana by Bass and Avault (1975). Other less extensive data on feeding habits have been reported by Reid (1955), Reid et al. (1956), Simmons (1957), Breuer (1957), Darnell (1958), Inglis (1959), Springer and Woodburn (1960), Simmons and Breuer (1962). In general, crustaceans and fish account for most of the reported food items of Red Drum throughout the Gulf of Mexico and south Atlantic (Music and Pafford 1984, Facendola and Scharf 2012, Peacock 2014). The percentages of these various food types varied with geographic location, season and size of fish. Roessler (1967) attempted to correlate the abundance of forage fish families (*Gerreidae, Clupeidae* and *Eugraulidae*) with the abundance of Gray Snapper (*Lutjanus griseus*), Red Drum, Spotted Seatrout (*Cynoscion nebulosus*), and Snook (*Centropomus undecimalis*), but no correlation was found between Red Drum abundance and forage fish abundance. Boothby and Avault (1971) considered Red Drum to be omnivores.

Yokel (1966) observed feeding habits of Red Drum in Florida Bay and in tanks at Miami Seaquarium. He observed fish feeding both by visual and tactile stimulation and reported that Red Drum used extensions of the first pelvic fin ray to orient their body in murky water. Yokel (1966) also found that Red Drum took food into their mouth either by rapid expansion of the 8 branchial region (thereby sucking the prey into the mouth) or by biting the substrate. Red Drum frequently feed in very shallow water and at such times can be seen “tailing” at the surface. In deeper areas, they lie in sloughs behind sand bars or adjacent to grass flats and, during a falling tide, feed in the water running off the bar or flat. Red Drum can also be observed feeding on fish, frequently Gulf Menhaden (*Brevoortia patronus*), at the surface in nearshore coastal waters.

The feeding habits of juvenile Red Drum have been investigated by Odum (1971), Bass and Avault (1975), Colura et al. (1976), Peters and McMichael (1987), and Soto et al. (1998). Juveniles less than 25 mm long fed almost exclusively on copepods and copepod nauplii while Red Drum nearer 50 mm began to include mysid shrimp in their diets when available. Fish, gammarid amphipods, decapods (grass shrimp, penaeid shrimp, young blue crabs) and polychaetes are also included in the diets of juvenile Red Drum but become more important above 70 mm, but amphipods are relied on heavily by fish between 60 mm and 100 mm. Bass and Avault (1975) indicated there may be some difference in day versus night feeding habits of Red Drum between 90-115 mm with palaemonid shrimp being mostly consumed during the day and finfish at night.

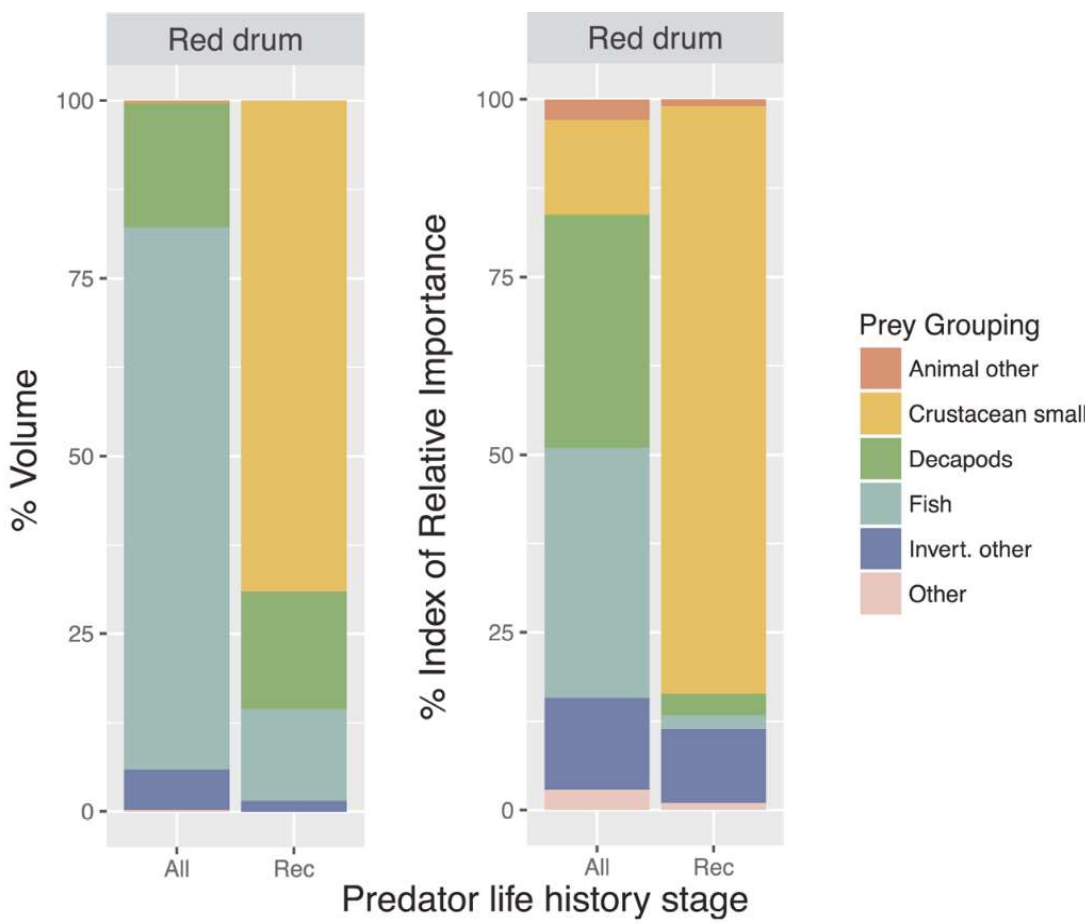



Figure 3.17 Comparison of contribution of major groups of diet items between recruiting predators (Rec) and all-sized predators (All), by A). % volume and B). % Index of Relative Importance (IRI). (modified Fig. 2. *from* Camp et al. 2019).

More recently, Camp et al. (2019) summarized the stomach data from four top predators along the West Florida coast (Gag Grouper, Gray Snapper, Red Drum, and Spotted Seatrout). They used stomachs collected by the FWC from 2005-2014 and grouped the prey consumption based on both volume (% volume) and Index of Relative Importance (% IRI). Camp et al. (2019) also broke prey consumption down by Red Drum life-history stages [recruitment predators (<160 mm) and all-sized predators combined (16-900 mm)]. Juvenile Red Drum relied heavily on small crustaceans (mysids and amphipods) with a significantly smaller amount of crabs and fish by volume and IRI (Figures 3.17A and B). In the combined all-sized Red Drum, the % IRI was equally split between crabs and fish although fish made up the largest prey group based on % volume.

Red Drum diets appear to be fairly diverse with a potential seasonal component (Pearson 1929), Gunter 1945, Knapp 1950, Miles 1950, and Scharf and Schlight 2000), especially for age-1 to age-4 Red Drum. Scharf and Schlight (2000) notes that diets in the fall were dominated by decapod crustaceans with finfish as a secondary component. However, in the spring, diets shifted with finfish comprising the majority of Red Drum diets and decapod crustaceans being of secondary importance but still occurring in 45% of Red Drum stomachs.

Pearson (1929), Gunter (1945), Simmons and Breuer (1962), Boothby and Avault (1971), and Overstreet and Heard (1978) agree that the primary foods of adult Red Drum are crustaceans (crab and shrimp) and fish. Bass and Avault (1975) found little overall difference between day and night feeding of adult Red Drum. Malinowski et al. (2019) reported crustaceans comprised five of the top food items in Red Drum diets year-round in South Florida.

Other food items reported in the literature include annelids, echinoderms, and bryozoans which were probably ingested passively while feeding on another organism (Overstreet and Heard 1978). Pearson (1929) reported that Red Drum feed both on the bottom and in the water column. Boothby and Avault (1971) suggested that Red Drum usually feed during late evening and early morning and described them as indiscriminate feeders, finding little difference in food habits among fish 250-930 mm SL and no difference for both males and females. However, they did find seasonal variation in food consumption with fish being generally more prevalent in the winter and spring while crustaceans become more prevalent in the spring and summer. Overstreet and Heard (1978) suggested that Red Drum migrations may be regulated by optimal abundance of specific types of food organisms.

# Chapter 4
# DESCRIPTION OF THE HABITAT OF THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

The Gulf is a semi-enclosed basin connected to the Atlantic Ocean and Caribbean Sea by the Straits of Florida and the Yucatan Channel, respectively. The Gulf of Mexico has a surface area of approximately 1,510,000 km$^2$ (Wiseman and Sturges 1999), a coastline measuring 2,609 km, one of the most extensive barrier island systems in the United States, and is the outlet for 33 rivers and 207 estuaries (Buff and Turner 1987). Water depths range from 3,000 to > 4,300 m with an average depth of 1,655 m (Turner 1999). Oceanographic conditions throughout the Gulf are influenced by the Loop Current and major episodic freshwater discharge events from the Mississippi/Atchafalaya Rivers. The Loop Current directly affects species dispersal throughout the Gulf while discharge from the Mississippi/Atchafalaya Rivers creates areas of high productivity that are used by many commercially and recreationally important marine species.

## *Sediments*

Two major sediment provinces exist in the Gulf of Mexico. Carbonate sediments predominate east of Desoto Canyon and along the Florida west coast while terrigenous sediments are commonly found west of Desoto Canyon and into Texas coastal waters (GMFMC 1998). Bottom sediments are coarse in nearshore waters extending northward from the Rio Grande River to central Louisiana and are the dominant bottom type in deeper waters of the central Gulf. Fine sediments are common in the northern and eastern Gulf and south of the Rio Grande due to riverine influence, particularly the Mississippi and Rio Grande Rivers. Fine sediments are also found in deeper shelf waters (> 80 m) (GMFMC 1998).

## *Circulation Patterns and Tides*

Hydrographic studies depicting general circulation patterns of the Gulf of Mexico include those of Parr (1935), Drummond and Austin (1958), Cochrane (1965), Jones et al. (1973), Ochoa et al. (2001). Circulation patterns in the Gulf are dominated by the influence of the upper-layer transport system of the western North Atlantic. Driven by the northeast trade winds, the Caribbean Current flows westward from the junction of the Equatorial and Guiana currents, crosses the Caribbean Sea, continues into the Gulf through the Yucatan Channel, and eventually becomes the eastern Gulf Loop Current (Figure 4.1). Upon entering the Gulf through the Yucatan Channel, the volume transported by the Loop Current is estimated to be between 2.38-2.8M m$^3$/sec (Johns et al. 2002, Sheinbaum et al. 2002).

Moving clockwise, the Loop Current dominates surface circulation in the northeast Gulf of Mexico. During late summer and fall, the progressive expansion and intrusion of the loop reaches as far north as the continental shelf off the Mississippi River Delta. High productivity associated with the discharge from the Mississippi/Atchafalaya River systems benefits numerous finfish and invertebrate species that use the northern Gulf as a nursery ground. Additionally, dispersal of tropical species from the Caribbean into the Gulf is accomplished via Loop Current transport. Nearshore currents are driven by the impingement of regional Gulf currents across the shelf, passage of tides, and local and regional wind systems. The orientation of the shoreline and bottom topography may also place constraints on speed and direction of shelf currents.

Gulf tides are small and noticeably less developed than along the Atlantic or Pacific coasts. Tides range from 0.5-1.0 m and are driven mostly by atmospheric pressure and wind direction (Solis and Powell

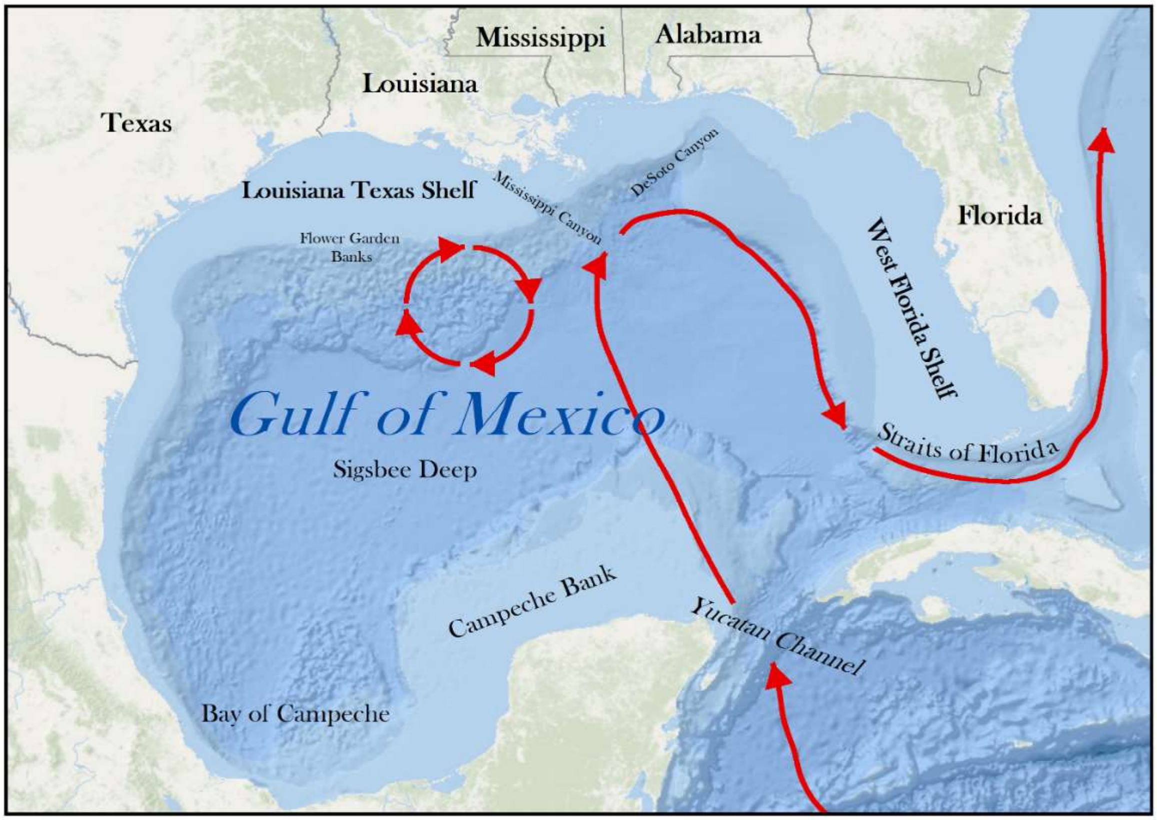



Figure 4.1 Generalized circulation pattern of the Loop Current in the Gulf of Mexico. Also included are some geologic features of the Gulf of Mexico, including shallower continental shelf regions and geologic breaks such as DeSoto Canyon off the Florida Panhandle and Mississippi Canyon off the Mississippi River Delta.

1999). Despite the small tidal range, tidal current velocities are occasionally high, especially near the constricted outlets that characterize many of the bays and lagoons. Tide type varies widely throughout the Gulf with diurnal tides (one high tide and one low tide each lunar day of 24.8 hrs) existing from St. Andrew's Bay, Florida, to western Louisiana. The tide is semi-diurnal in the Apalachicola Bay of Florida and mixed in western Louisiana and in Texas.

## *Salinity*

Runoff from precipitation on almost two-thirds of the land area of the United States eventually drains into the Gulf of Mexico via the Mississippi River. The combined discharge of the Mississippi and Atchafalaya Rivers is a major influence on salinity levels in coastal waters on the Louisiana/Texas continental shelf. The annual freshwater discharge of the Mississippi/Atchafalaya River system represents approximately 10% of the water volume of the entire Louisiana/Texas shelf to a depth of 90 m. The Loop Current and Mississippi/Atchafalaya River system, as well as anticyclonic Loop Current eddies, significantly affect oceanographic conditions throughout the Gulf of Mexico.

Surface salinities in the Gulf of Mexico vary seasonally. During months of low freshwater input, surface salinities near the coastline range between 29-32 ppt (MMS 1997). High freshwater input conditions during the spring and summer months result in strong horizontal salinity gradients with salinities less than 20 ppt on the inner shelf in the northern Gulf of Mexico. The waters in the open Gulf are characterized by salinities between 36.0-36.5 ppt (MMS 1997).

### *Temperature*

Surface water temperatures for the entire Gulf of Mexico were reported by NOAA (1985). Surface temperatures were measured in January and July. During January, temperatures ranged from 14-24°C. Minerals Management Service (MMS 1997) found surface temperatures in the Gulf of Mexico in January range from 25°C in the Loop current core to 14-15°C along the shallow northern coastal estuaries. The coldest water along the Louisiana/Texas border occurs on the upper shelf (NOAA 1985) and the warmest was found off the southwestern tip of Florida. Winter water temperatures gradually increased with distance from shore in the entire Gulf. Temperatures also increased southward on the Florida peninsula with temperatures ranging from 16-24°C.

Gulf surface water temperatures in July ranged from 28-30°C (NOAA 1985) with the coolest water found off the south Texas coast. The warmest water was found off the Mississippi/Alabama coast, the Big Bend area of Florida, and the southern tip of Florida. Summer water temperatures gradually decreased with distance from shore. Most of the Gulf had surface temperatures of 29°C. These temperatures agree closely with MMS (1997) data showing 29-30°C water throughout the Gulf during August.

While both of the references above are older, the temperature ranges correspond with recent 4 km sea surface temperature derived from measurements captured by Advanced Very High Resolution Radiometer (AVHRR) instruments aboard NOAA polar-orbiting satellites. Data from Saha et al. (2018) show that average sea surface winter temperatures in the northern Gulf of Mexico range from 14-24°C while summer temperatures range from 28-30°C.

### *Dissolved Oxygen (DO)*

Dissolved oxygen (DO) values in the Gulf of Mexico average about 5 ppm at 10 m below the surface during winter, with values averaging about 4.6 ppm during the summer months 10 m below the surface (Garcia et al. 2010). The surface layer in the northern Gulf of Mexico shows an oxygen surplus during February through July (Justic et al. 1993). The oxygen maximum that occurs during April and May coincides with the maximum flow of the Mississippi River. From January to July the oxygen in bottom waters decreases at an average rate of 0.7 ppm per month, and reaches its lowest value in July (Justic et al. 1993).

Areas of anoxic bottom water have not been reported from the eastern Gulf continental shelf. However, summer hypoxia of bottom water has been noted for Mobile Bay and Tampa Bay. Areas of excessively low bottom DO values (< 2.0 ppm) have long been known to occur off central Louisiana and Texas during periods of stratification in the warmer months. Oxygen-deficient conditions occur primarily from April through October each year with the location and extent varying annually (Rabalais et al. 1997). In 2002, the hypoxic zone was its largest ever at approximately 22,000 km$^2$, while the long-term average since mapping began in 1985 is 13,500 km$^2$ (Rabalais et al. 2007). Hypoxic waters can include 50-80% of the lower water column between 5-30 m water depth, and can extend as far as 130 km offshore to depths of 60 m (Rabalais and Turner 2001).

### *Submerged Vegetation*

Seagrass meadows are often populated by diverse and abundant fish faunas (Zieman and Zieman 1989). Both seagrasses and macroalgae have been found to be important nursery habitats for numerous fish species (Rydene and Matheson 2003). The seagrasses and their attendant epiphytic and benthic fauna and flora provide shelter and food to the fishes in several ways and are used by many species as nursery grounds for juveniles.

According to Handley et al. (2007), six distinct species of seagrasses have been identified in the bays, lagoons, and shallow coastal waters of the northern Gulf region. These species include paddle grass (*Halophila decipiens*), star grass (*Halophila engelmannii*), turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), and widgeon grass (*Ruppia maritima*). Widgeon grass and water celery (*Vallisneria americana*) are freshwater species capable of tolerating saline waters. Turtle grass is the most abundant seagrass found in the Gulf of Mexico. Shoal grass predominates in Mississippi and Alabama while widgeon grass is the dominant species found in Louisiana. Light, salinity, temperature, substrate type, and currents are important local factors that affect distributional patterns.

The structural components of seagrass leaves, rhizomes, and roots act to modify water currents and waves. Seagrasses trap and store both sediments and nutrients and filter nutrient inputs. This structure baffles waves, reduces erosion, and promotes water clarity while increasing bottom area and providing a surface upon which epiphytes and epibenthic organisms can live. Invertebrate abundance is much higher in seagrass beds than in adjacent unvegetated habitats (Pérez-Castañeda et al. 2010).

### *Emergent Vegetation*

Emergent vegetated wetlands provide essential habitat for many of the Gulf's managed fish species and their prey. Marshes and mangroves are integral parts of the estuarine system, serving as nursery areas for larval and juvenile invertebrates and fish, and as a source of detritus needed to supply organic matter to local estuarine and marine food webs.

In the Gulf of Mexico, salt marshes dominated by smooth cordgrass (*Spartina alterniflora*), needlerush (*Juncus roemarianus*), and marsh hay cordgrass (*Spartina patens*) are found in the temperate north. In southern areas, mangrove communities composed of red mangrove (*Rhizophora mangle*) or black mangrove (*Avicennia germinans*) are found. The vegetated wetlands found in estuaries are among the most productive ecosystems on earth (Teal and Teal 1969, Odum et al. 1982). Both marshes and mangroves require soft sediments, regular inundation from tides, freshwater, and low to moderate wave energy. Emergent wetlands may alter the sediment on which they grow and function as sediment builders through peat formation and their effect on local sedimentation patterns (Odum et al. 1982, Mitsch and Gosselink 1993). In addition, marshes and mangroves also act as filters by removing contaminants from water and recycling inorganic nutrients such as nitrogen and sulfur.

Salinity and tidal inundation control the zonation patterns of plant communities throughout Gulf estuaries. Salt marsh communities are dominated by salt tolerant smooth cordgrass in the intertidal zone, with marsh hay cordgrass or rushes in the upper intertidal zone. As elevation increases and tidal inundation decreases, cordgrass density declines and various other halophytic grasses and succulents replace cordgrass communities. The width and density of the cordgrass zone is greatest from Galveston Bay, Texas through the Big Bend region of Florida. This region of the Gulf has the largest amount of freshwater inflow.

The complex root system of red mangroves provides fish habitat by providing shelter and abundant detritus for local food webs on which fish and invertebrates depend (Zieman et al. 1984). Black mangrove roots do not have a well-developed invertebrate fauna. Black mangroves are the only mangrove species found in south Texas where the fauna consists of a few species of molluscs that are derived from other similar habitats such as salt marshes (Britton and Morton 1989) and fiddler crabs. During periods of high tide, this habitat also provides a refuge for fish and shrimp similar to that provided by salt marshes.

## *Estuaries*

The northern Gulf of Mexico contains 31 major estuarine systems extending from the Rio Grande River in Texas eastward to Florida Bay in Florida. Estuaries typically include wetlands and open bay waters in which nutrients from river inflows, adjacent runoff, and the sea support a productive community of plants and animals. Estuarine tidal mixing is limited by the small tidal ranges that occur within the Gulf of Mexico, but shallow estuarine depths tend to amplify the mixing effect. Estuaries in Florida and south Texas generally are clearer and have lower nutrient concentrations than those in other parts of the Gulf.

### Florida

McNulty et al. (1972), in conducting the Florida portion of the Gulf of Mexico Estuarine Inventory (GMEI), provided a comprehensive description of the natural and man-made features of the estuaries on the Florida Gulf Coast. The report covers some 40 estuarine areas from Perdido Bay at the Florida/ Alabama border south to Florida Bay.

The total area of Florida west coast estuaries is 12,154 km$^2$, including open water, tidal marsh, and mangroves (McNulty et al. 1972). Considerable changes occur in the type and area of submergent and emergent vegetation from south to north. While McNulty et al. (1972) reported that mangrove tidal flats were found from the Florida Keys to Naples, Snyder et al. (2021) found that robust stands of black mangrove, *Avicennia germinans*, and red mangrove, *Rhizophora mangle*, had expanded into the Apalachicola Bay region. Sandy beaches and barrier islands occur from Naples to Anclote Key and from Apalachicola Bay to Perdido Bay (McNulty et al. 1972). Tidal marshes are found from Escambia Bay to Florida Bay and cover 2,139 km$^2$ with the largest area occurring in the Suwannee Sound and Waccasassa Bay. The coast from west of Apalachee Bay to the Alabama border is characterized by wide sand beaches situated either on barrier islands or on the mainland itself. Beds of mixed seagrasses and/or algae occur throughout the eastern Gulf with the largest areas of submerged vegetation found from Apalachee Bay south to the Florida Keys.

Black needlerush predominates, but several species are locally abundant, among them smooth cordgrass, marsh hay cordgrass, seashore saltgrass (*Distichlis spicata*), *Salicornia perennias*, sea oxeye (*Borrichia frutescens*), *Batis marina*, and *Limonium carolinianum* FWC/FWRI (unpublished data). GIS mapping by FWC/FWRI (unpublished data) showed 2,192 km$^2$ of mangroves along Florida's Gulf coast. The three common mangroves in their order of abundance and zonation landward are the red (*Rhizophora mangle*), black (*Avicennia germinans*), and button wood (*Conocarpus erectus*). A fourth and less abundant species, the white mangrove (*Laguncularia racemosa*), generally grows landward of the black mangrove.

Approximately 6,794 km$^2$ of seagrass or submerged aquatic vegetation (SAV) occurs within the Gulf of Mexico off Florida and Florida's Gulf Coast bay systems (Handley et al. 2007). Handley and Lockwood (2020) found that six of the nine Florida bay systems along the Gulf Coast had increased seagrass coverage of between 24 and 60% from when they were originally sampled from 1992 through 2002. Handley and Lockwood (2020) reported that the Big Bend region has the largest total seagrass area of 3,717 km$^2$, followed by the Florida Bay area with 1,389 km$^2$. Charlotte Harbor had 292 km$^2$; Sarasota Bay contained 55 km$^2$; Tampa Bay had 169 km$^2$; St. Andrews Bay contained 50 km$^2$; Choctawhatchee Bay had 7.4 km$^2$; the Pensacola Bay system contained 15.4 km$^2$ while Florida's portion of Perdido Bay contained 1.4 km$^2$.

Shoal grass and widgeon grass are abundant intertidally, whereas turtle grass, manatee grass, paddle grass, and star grass are found only below low water levels. In most of Florida's estuaries, seagrasses are found at depths to about 2.1 m, except where water is exceptionally clear (e.g., portions of Pensacola Bay) where they are found to about 3.6 m (McNulty et al. 1972).

McNulty et al. (1972) found nearly 56.7 $km^2$ of live oyster beds (20.7 $km^2$ in private leases and 35.3 $km^2$ in public beds) in the panhandle estuaries of Apalachicola Bay and St. George Sound. GIS mapping by FWC/FWRI (unpublished data) showed 30.7 $km^2$ of oysters in Rookery Bay, Estero Bay, Tampa Bay, Big Bend, and Apalachicola Bay.

Coastal waters in the eastern Gulf may be characterized as clear, nutrient-poor, and highly saline. Rivers which empty into the eastern Gulf carry little sediment load. Stream discharge in north Florida estuaries is much greater than that in central and south Florida. Mean stream discharge for the west coast is 1,988 $m^3$/sec (70,251 CFS) (McNulty et al. 1972). More than 70% of the runoff is from the Apalachicola, Suwannee, Choctawhatchee, and Escambia rivers. The Apalachicola River accounts for about 35%, and the Suwannee River accounts for nearly 15%.

Primary production is generally low except in the immediate vicinity of estuaries or on the outer shelf when the nutrient rich Loop Current penetrates into the area. Presumably, high primary production in frontal waters is due to the mixing of turbid nutrient-rich plume water where photosynthesis is light-limited with clear, nutrient-poor, Gulf of Mexico water where photosynthesis is nutrient-limited creating good phytoplankton growth conditions (GMFMC 1998).

### Alabama

Crance (1971) divided the Alabama coastal zone into five estuarine systems: Mississippi Sound, Mobile Bay, Mobile Delta, Perdido Bay, and Little Lagoon. Combined, these estuaries contain an open-water surface area of 1,608 $km^2$. Mean tidal range is small, varying from about 0.3 m at the head of Mobile Bay to about 0.5 m at the entrance. Annual mean discharge of gauged streams in the Mobile River system is 1,659 $m^3$/sec (58,636 CFS). Salinity is highly variable with oceanic levels occurring at the Gulf passes at times, and freshwater at the upward end of the estuary is often present.

There were 10,614 ha of estuarine emergent wetlands, 17.6 $km^2$ of palustrine emergent wetlands, and a total of 123.7 $km^2$ of emergent wetlands in coastal Alabama in 2002 (Handley et al. 2013a). From 1955-2002, Alabama lost 147.6 $km^2$ (54.4%) of the emergent wetlands in the coastal area (Handley et al. 2013a).

In higher salinity areas, the major emergent species are black needlerush, smooth cordgrass, big cordgrass (*Spartina cynosuroides*), marsh hay cordgrass, and seashore saltgrass. Submerged vegetation includes patches of shoal grass, widgeon grass, and slender pondweed (*Potamogeton pusillus*) (Crance 1971).

In lower salinity areas, alligator weed (*Alternanthera philoxeroides*) and *Phragmites communis* are more abundant. The major species of submerged vegetation are southern naiad (*Najas guadalupenis*), wild celery, horned pondweed (*Zannichellia spiralis*), slender pondweed, and *Nitella* spp. (Crance 1971).

Vittor and Associates (2009) found shoal and widgeon grass were the dominant seagrass species in coastal Alabama in 2009 with ~2.0 $km^2$ of shoal grass, ~1.0 $km^2$ of widgeon grass, and ~1.0 $km^2$ of mixed shoal and widgeon grass. Since that time recent mapping has found 44.4 $km^2$ of submerged aquatic vegetation in coastal Alabama with the majority being freshwater species in upper Mobile Bay (Handley and Lockwood 2020). Mobile Bay has seen a 68.2% increase in SAV between 2002 and 2015 with most being exotic SAV species spreading in the shallow flats of upper Mobile Bay (Handley and Lockwood 2020).

There are some 203.9 $km^2$ of live oyster beds, with more than 121.4 $km^2$ of public beds and nearly 80.9 $km^2$ in private leases. More than 8.5 $km^2$ of estuarine habitat were filled for various purposes.

### Mississippi

Mississippi Sound is a relatively shallow estuary aligned in a generally east-west direction along Mississippi and Alabama bounded on the east by Mobile Bay and the west by Lake Borgne. Barrier islands form a partial boundary separating the sound from the Gulf of Mexico. Numerous marsh isles in southeast Louisiana completes the southern boundary. Unless otherwise noted, the following information on Mississippi estuaries was condensed from Christmas (1973) and Eleuterius (1976a, 1976b).

Mississippi Sound is a system of estuaries adjoining a lagoon. The sound, separated from the Gulf of Mexico by a chain of barrier islands, acts as a mixing basin for freshwater discharge from rivers and seawater entering through the barrier island passes. The complexity of the system does not readily lend itself to concise hydrological classification. Both north-south and east-west salinity gradients exist in addition to vertical gradients. Overall, positive salinity gradients exist from the mainland seaward and vertically, surface to bottom. In periods of peak river discharge, the water column may be homogeneous.

The salinity regime of eastern Mississippi Sound is determined largely by the influx of Gulf waters through Petit Bois, Horn, and Dog Keys passes and the outflow of waters from Mobile Bay, the Pascagoula River, and Biloxi Bay. Water from Mobile Bay appears to exit Mississippi Sound entirely through Petit Bois Pass; thus, the west branch of the Pascagoula River becomes the major source of freshwater into the Sound. The western end of Mississippi Sound is heavily influenced by drainage from the Pearl River, the Lake Borgne-Lake Pontchartrain complex, and St. Louis Bay.

Silty clay is the dominant sediment in Mississippi Sound. Coastal bays receive large volumes of sandy and silty sandy sediments from the surrounding mainland. In addition, these embayments and the sound proper receive clay silt sediments from the rivers. Fine sediments are also carried into the sound via tidal currents from Lake Pontchartrain and Mobile Bay. The central portion of the sound is composed of silt and clay mud. In some areas, these sediments grade into fine and very fine sands. Medium and coarse sands characterize the barrier islands and are also found along the mainland beach west of the Pascagoula River. Medium to coarse sands extend from Round Island in Mississippi Sound to Horn Island.

The shallowness of the sound (average depth at mean low water is 2 m), its sediments, and wave action are responsible for the turbidity of the water. In most months, nearshore waters are brown in color due to suspended fine sediment in the water column. In periods of peak river flow, these muddy waters may reach and extend beyond the barrier islands.

There were 215.5 $km^2$ of estuarine emergent wetlands, 51.2 $km^2$ of palustrine emergent wetlands, and a total of 268.2 $km^2$ of emergent wetlands in coastal Mississippi in 2007 (Handley et al. 2013b). Between 1979 and 2007, Mississippi lost ~174 $km^2$ (54.5%) of its emergent wetland habitat (Handley et al. 2013c). Common species of emergent wetlands include black needlerush, smooth cordgrass, marsh hay cordgrass, and threecorner grass (*Scirpus olneyi*). Emergent wetlands are most extensive in the Pascagoula and Pearl River basins.

Handley and Lockwood (2020) reported that there were 10.12 km$^2$ of seagrass were present in coastal Mississippi with the majority of the seagrass found in Point-aux-Chenes Bay and around Cat and Horn Islands.

### Louisiana

Coastal Louisiana is predominately a broad marsh indented by shallow bays containing innumerable valuable nursery areas. Total estuarine area in 1970 encompassed more than 29,000 km$^2$, over 15,000 km$^2$ in marsh vegetation, and more than 13,000 km$^2$ of surface water area (Perret et al. 1971). These waters are generally shallow with over half between zero and 1.8 m in depth. Sediments consist of mud, sand, and silt and are very similar across the coast ranging from coarse near the Gulf and barrier islands to fine in the upper estuaries (Barrett et al. 1971). Extensive wetlands loss is occurring in coastal Louisiana. The current loss of wetlands in the Louisiana Coastal Zone is estimated to be 43 km$^2$/yr (Couvillion et al. 2011).

Emergent marsh amounts to more than 15,800 km$^2$ and is made up of four main types; saline, brackish, intermediate, and fresh (USGS 1997). Approximately 3,492.3 km$^2$ of saline marsh consisting of smooth cordgrass, glasswort (*Salicornia* sp.), black needlerush, black mangrove, seashore saltgrass, and saltwort (*Batis marina*) are located in the Louisiana Coastal zone; 4,871.7 km$^2$ of brackish marsh made up of marsh hay cordgrass, threecorner grass, and coco (*Scirpus robustus*); 2,632.9 km$^2$ of intermediate marsh consisting of marsh hay cordgrass, deer pea (*Vigna repens*), bulltongue (*Sagittaria* sp.), wild millet (*Echinochloa walteri*), bullwhip (*Scirpus californicus*), and sawgrass (*Cladium jamaicense*); and 4,829.4 km$^2$ of fresh marsh consisting of maiden cane (*Panicum hemitomon*), pennywort (*Hydrocotyle* sp.), pickerelweed (*Pontederia cordata*), alligator weed, bulltongue (*Sagittaria* sp.), and water hyacinth (*Eichhornia crassipes*).

In general, estuaries and nearshore Gulf waters of Louisiana are low saline, nutrient-rich, and turbid due to the high rainfall and subsequent discharges of the Mississippi, Atchafalaya, and other coastal rivers. The Mississippi and Atchafalaya Rivers deliver approximately 172 million metric tons of sediment annually to coastal Louisiana (Meade and Moody 2010). Average daily discharge for the Mississippi and Atchafalaya Rivers is 464,400 cfs and 223,800 cfs, respectively (USEPA 1994). Peak discharge usually occurs in April and May; low flow occurs typically in September and October. During floods, freshwater is carried far into the Gulf resulting in lower salinities near the mouths of the rivers and into neighboring estuaries. As a probable consequence of the large fluvial nutrient input, the Louisiana nearshore shelf is considered one of the most productive areas in the Gulf of Mexico.

The public oyster seed grounds and reservations encompass approximately 6,803.6 km$^2$ and private oyster leases cover approximately 1,558.1 km$^2$ of water bottoms in Louisiana (Banks personal communicationion). Mapped oyster reefs account for approximately 3.7% of total water bottom coverage (254.5 km$^2$) within the public oyster areas and additional hectares of reefs exist, but these areas have not been delineated. The largest portion of known oyster reef within these public oyster areas is located east of the Mississippi River in St. Bernard and Plaquemines Parishes where 209.4 km$^2$ are located (82.3%). It is unknown what portion of the total hectares of private leases is covered in oyster reef, although it is likely significant considering the majority of Louisiana's oyster landings come from private leases (Banks personal communication). Additional habitat is also located in extensive reef complexes near Marsh Island (Iberia Parish) and in both Calcasieu and Sabine Lakes (Cameron Parish). Total area of live oyster reef is currently unknown, although Perret et al. (1971) estimated more than 538.3 km$^2$.

More than 1,610 km of navigation channels designed and/or maintained by the U.S. Army Corps of Engineers are in the estuarine zone. The longest is the Gulf Intracoastal Waterway (486 km) from Lake Borgne to the Sabine River. Navigation channels account for nearly all of the more than 105.2 $km^2$ of fill.

Cho and Poirrier (2005) reported SAV in Lake Pontchartrain had declined by more than 50% since the mid-1950s. No grass beds were found along the south shore of the lake between 1996 and 1998 (Penland et al. 2002). By the early 1990s, most of the extensive beds of wild celery had disappeared, but there was an increase in widgeon grass during 1996-2000 (Cho and Poirrier 2005). Cho and Poirrier (2002) estimated SAV coverage in Lake Pontchartrain in 2000 was 1.5 $km^2$ of widgeon grass plus 0.12 $km^2$ of water celery. Cho and Poirrier (2002) stated that total SAV habitat was about 4.5 $km^2$. While Poirrier and Handley (2007) reported that approximately 45.12 $km^2$ of seagrass were present around the Chandeleur Islands in 1995, with turtle grass being the predominant species, Handley and Lockwood (2020) reported only 10.58 $km^2$ of seagrass were measured in 2011. Representatives from the LDWF reported beds of widgeon grass around the Mississippi River delta and in the Pointe aux Chenes Wildlife Management Area.

### Texas

Unless otherwise noted, the following information on Texas estuaries was compiled from Diener (1975). The estuaries in Texas are characterized by extremely variable salinities and reduced tidal action. Estuarine salinities trend low to high from north to south. Texas has approximately 612 km of open Gulf shoreline and contains 3,528 km of bay-estuary-lagoon shoreline. Coastal habitats in Texas contain more than 2,476.7 $km^2$ of fresh, brackish, and salt marshes. Saline and brackish marshes are most widely distributed south of Galveston Bay, while intermediate marshes are the most extensive marsh type east of Galveston Bay. The lower coast has only a narrow band of emergent marsh but has an extensive system of bays and lagoons.

From the Louisiana border to Galveston, the coastline is comprised of marshy plains and low, narrow beach ridges. From Galveston Bay to the Mexican border, the coastline consists of long barrier islands and large shallow lagoons. The Laguna Madre contains profuse seagrass beds while Padre Island is the longest barrier island in the world (TGLO 1996). The Intracoastal Waterway, a maintenance-dredged channel, extends from the Lower Laguna Madre to Sabine Lake. Dredging of the channel has created numerous spoil banks on islands adjacent to the channel.

Eight major estuarine systems are located in Texas. The major bay systems from the lower to upper coast are Lower and Upper Laguna Madre; Corpus Christi and Aransas bays; San Antonio, Matagorda and Galveston bays; and Sabine Lake. Riverine influence is highest in Sabine Lake and Galveston Bay. In 1992, these estuaries contained 6,275.6 $km^2$ of open water (estuarine subtidal areas), and 15,768 $km^2$ of wetlands. About 85.3% of the total wetlands were palustrine, 14.5% estuarine, and 0.1% marine. There were 7,115.8 $km^2$ of deepwater rivers (243.6 $km^2$); reservoirs (596.6 $km^2$); and estuarine bays (6,275.6 $km^2$) (Moulton et al. 1997). Climate ranged from semi-arid on the lower coast (where rainfall averages 25 inches) to humid on the upper coast where average annual rainfall is 55 inches (Diener 1975).

Texas estuaries support a number of species of emergent vegetation consisting of shoregrass (*Monanthochloe littoralis*), glasswort (*Salicornia bigelovii*), seacoast bluestem (*Schizachyrium scoparium*), marsh hay cordgrass, rush saltwort (*Batis maritima* and *B. maritima*), glasswort (*Salicornia bigelovii*), smooth cordgrass, coastal dropseed (*Sporobolus virginicus*), seashore saltgrass, seablite (*Suaeda linearis*), sea oats (*Uniola paniculata*), black needlerush, shoregrass (*Monanthochloe littoralis*), bulrush (*Scirpus* *maritimus* and *S. olneyi*), and gulfdune paspalum (*Paspalum monostachyum*) (Diener 1975). Common reed (*Phragmites communis*) was reported in a few areas as well.

Submergent aquatic vegetation includes shoal grass, turtle grass, paddle grass, manatee grass, and widgeon grass (Diener 1975, Pulich et al. 1997, Pulich 1999). According to Pulich (1999), shoal grass is the most abundant seagrass species in Texas. Submerged seagrass coverage was approximately 690 $km^2$ in 1998 (Pulich and Onuf 2007) with the overwhelming majority being located in the Upper and Lower Laguna Madre. Handley and Lockwood (2020) reported there were 924.75 $km^2$ of seagrass measured during surveys conducted in 2004, 2007, and 2012. The largest seagrass areas were the Lower Laguna Madre with 445.29 $km^2$ and the Upper Laguna Madre with 242.12 $km^2$.

## *Red Drum Habitat*

### Spawning Habitat

Red Drum spawning has generally been thought to take place near inlets and passes in nearshore, coastal waters (Jannke 1971, Holt et al. 1985, Murphy and Taylor 1990, Rooker et al. 1998a, Hernandez et al. 2013). Murphy and Taylor (1990) found evidence of Red Drum spawning activity within estuaries in Florida. Studying Red Drum in Tampa Bay, Peters and McMichael (1987) reported that most Red Drum around Tampa Bay spawn near the bay mouth with some spawning also occurring in nearshore Gulf waters. Lyczkowski-Shultz et al. (1988) found eggs and larvae out to 34 km from shore off Mississippi. Murphy and Taylor (1990) also collected mature or recently spent fish out to depths of 69.5 m suggesting that spawning also takes place offshore in the Gulf of Mexico. Holt (2008) reported Red Drum spawning all along the nearshore region of the central Texas coast and stated that that spawning activity was widespread and not concentrated at inlets. Using a towed hydrophone array to listen for clusters of drumming sounds, Holt (2008) found areas of the coastline far removed from the inlets had relatively intense drumming activity. Based on these findings, it appears that Red Drum use estuaries, nearshore, and offshore waters for spawning.

Holt et al. (1981a) found that Red Drum eggs hatched 28 to 29 hours after fertilization, while Vetter et al. (1983) found eggs hatched in as little as 19 hours. Due to these relatively short incubation periods, the presence of fish eggs at a given location can be used to infer local spawning events (Hernandez 2001). Hernandez et al. (2013) found that Red Drum eggs were generally distributed in the northcentral Gulf of Mexico, and were consistently collected in nearshore waters with depths of 10-15 m south of the Texas-Louisiana border, between the Mississippi-Alabama border and Pensacola, and in the Big Bend area of Florida (Figure 4.2).

Red Drum tend to concentrate in large numbers in relatively small spawning sites during the spawning season (Lowerre-Barbieri et al. 2016a). Using acoustically tagged Red Drum off Florida, Lowerre-Barbieri et al. (2019) found that Red Drum have strong spawning site fidelity (91% in 2013 and 85% in 2014) each year with very little straying (6-13%) between nearby spawning sites. Rooker et al. (2010) also found that while some mixing occurs among regional estuaries in the Gulf of Mexico, the majority of adult Red Drum appear to either remain in close proximity to their estuarine nurseries or return to natal areas to spawn following a dispersive phase.

Using data from plankton surveys, Comyns et al. (1991) found that most Red Drum spawning occurred from August through November in coastal waters off Louisiana, Mississippi, and Alabama with peak spawning occurring in September. Off Texas, Rooker and Holt (1997) found that over 95% of all Red Drum larvae collected were from September and October spawns. Wilson and Nieland (1994) studied Red

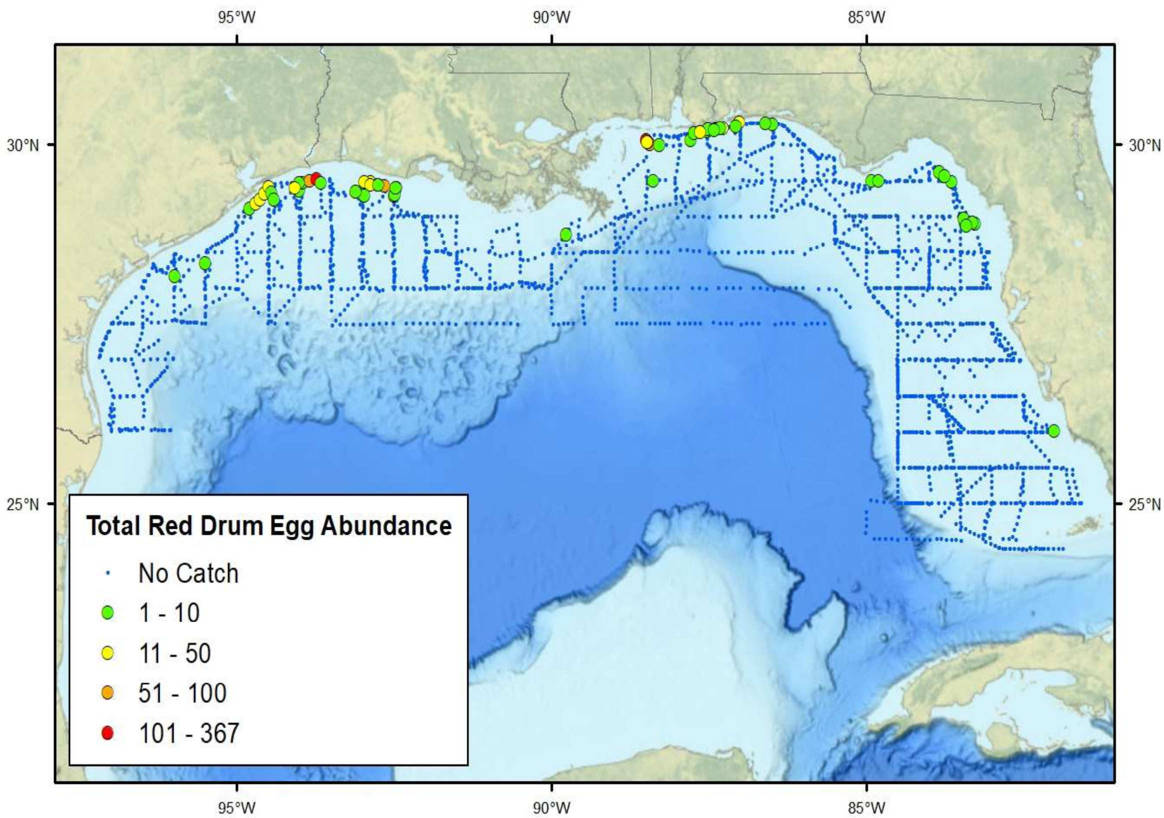



Figure 4.2 Total number of Red Drum eggs collected using a CUFES during SEAMAP Fall Plankton Surveys in 2007, 2009, 2010, and 2011 (data *from* Hernandez et al. 2013).

Drum spawning from Mobile Bay, Alabama to Galveston Bay, Texas and concluded that Red Drum had an eight to nine-week spawning season from mid-August to October. Murphy and Taylor (1990) stated that spawning peaked off Florida from September through October while Peters and McMichael (1987) stated that spawning might extend early August through early December with peaks between late August and mid-October.

During the Comyns et al. (1991) study, water temperatures off Louisiana, Mississippi, and Alabama in early September were 27-29°C and decreased to 24-25°C in October. Lowerre-Barbieri et al. (2008) stated that Red Drum spawning in Georgia was temperature dependent and that spawning was initiated when coastal temperatures began to drop from 29°C and spawning concluded when temperatures dropped below 26°C. In the Gulf of Mexico, these temperatures generally correspond to a spawning season beginning in mid-August and continuing through October (Rooker and Holt 1997). Comyns et al. (1991) reported that salinities ranged from 25-34 ppt in August and September, from 28-34 ppt in October, and from 32-35 ppt in early November. Hernandez et al. (2013) found most Red Drum eggs were collected between 28-31°C and salinities between 21-28 ppt.

### Larval Habitat

In a laboratory setting, Holt et al. (1981b) found that optimum conditions for Red Drum larvae hatching and survival were 25°C and 30 ppt. They also reported that temperature was an important factor as larvae develop. Holt et al. (1981b) stated that two-week larval survival was reduced at temperatures below 25°C and that temperature had a profound effect on larval growth rate with growth being much higher at 25° or 30°C than at lower temperatures. They found reduced survival when water temperatures were below 20°C, theorizing that with lower water temperatures Red Drum were unable to transition to active feeding, a critical period in fish development.

While Holt et al. (1981b) found that salinity had little influence on larval growth, Kesaulya and Vega (2019) in a laboratory setting found that egg hatch-out rates and larval growth were reduced at 28 ppt and 48 ppt salinity treatments. They reported that at salinities greater than 40 ppt and a temperature of 25°C affected the hatching success of Red Drum eggs. The percentage of egg hatching success and length of larvae were reduced in the 28 ppt and 48 ppt treatments. Kesaulya and Vega (2019) concluded that Red Drum eggs can hatch within a wide range of salinities with best hatch-out and growth rates occurring between 33-43 ppt.

After examining plankton samples off the Mississippi Coast, Lyczkowski-Shultz et al. (1988) reported that Red Drum larvae were concentrated in the upper 5 m of the water column. Comyns et al. (1991) supported this finding with plankton samples off the Louisiana, Mississippi, and Alabama coasts where they found that mean larval density in the upper 5 m was 34.2 larvae per 100 $m^3$, while mean density between 7 and 12 m was only 3.7 larvae per 100 $m^3$. Lyczkowski-Shultz and Steen (1991) found that Red Drum larvae ranging in mean size from 1.7 to 5.0 mm were vertically stratified and that larvae were concentrated in the upper water column during the day with no clear relationship between vertical aggregation of larvae and temperature or salinity profiles or prey microzooplankton distribution.

During the SEAMAP Fall Plankton Survey, Gulf-wide, most Red Drum larvae were caught in nearshore waters in a variety of sampling gear (Figures 4.3 and 4.4). While the majority of the Red Drum are caught

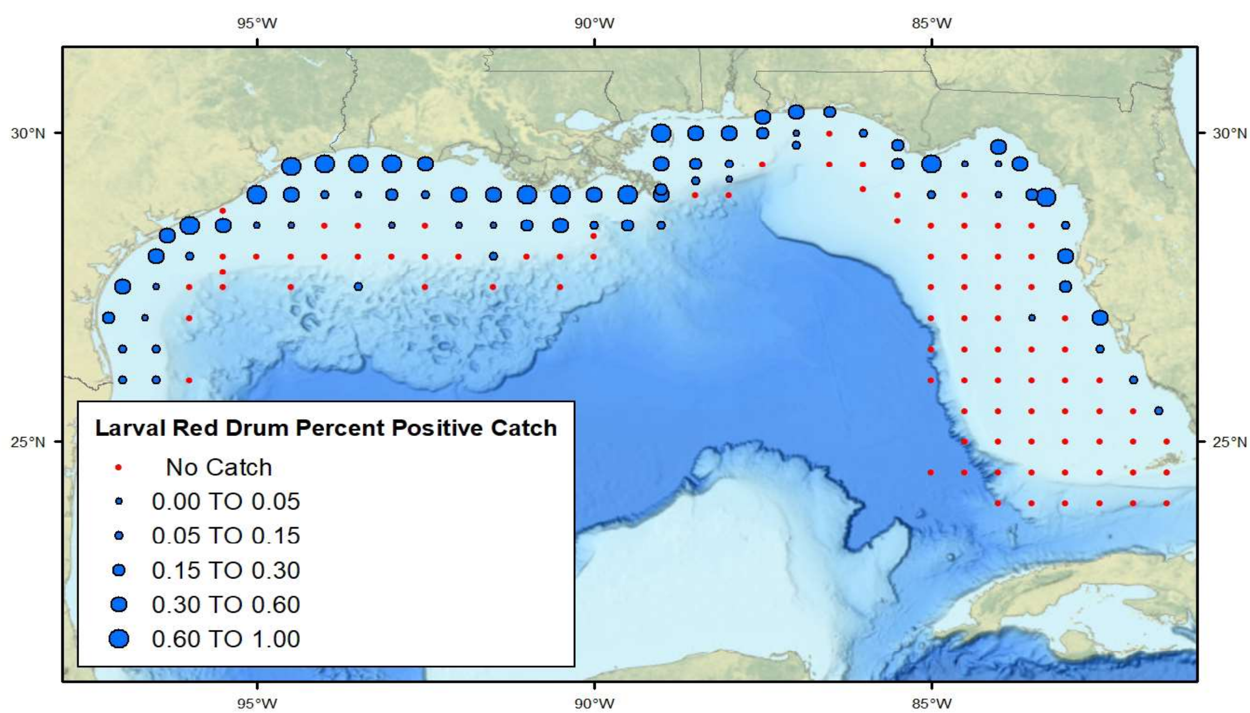



Figure 4.3 Red Drum catches from 3,220 bongo plankton samples collected from 1986-2014 as part of the SEAMAP Fall Plankton Survey. Red Drum were collected at 529 stations. Numbers represent the percent positive larval Red Drum catch occurrence in the bongo samples from 1986-2014 (SEAMAP unpublished data).

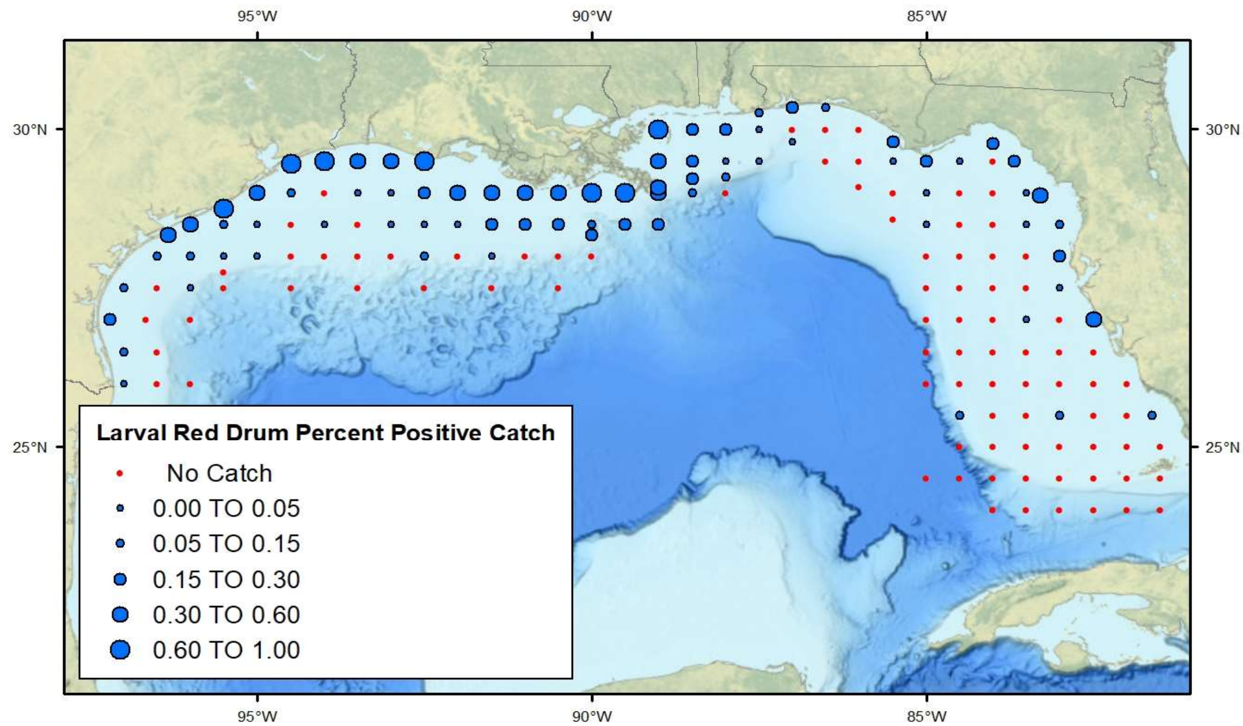



Figure 4.4 Red Drum catches from 3,346 neuston plankton samples collected from 1986-2014 as part of the SEAMAP Fall Plankton Survey. Red Drum were collected at 367 stations. Numbers represent the percent positive larval Red Drum catch occurrence in the neuston samples from 1986-2014 (SEAMAP unpublished data).

in nearshore waters, there are some observed further offshore, however, larvae and juveniles in the offshore waters would probably not be able to recruit to inshore estuaries.

Dance and Rooker (2016) found that Red Drum larvae in Galveston Bay were abundant at salinities of 0-25 ppt. Abundances peaked at salinities near 20 ppt in all three estuaries they studied. Perez-Dominguez et al. (2006) found in a laboratory that Red Drum larvae grew from 10-34°C with growth rates increasing linearly with temperature between 11-30°C. Rooker and Holt (1997) also determined that growth was positively associated with temperature.

After two to three weeks in the plankton, Red Drum larvae are transported by currents into estuaries where they have shown a preference for a variety of habitats including marsh edges and seagrass beds (Holt et al. 1983, Rooker and Holt 1997, Rooker et al. 1999, Stunz et al. 2002a). In Texas, larval Red Drum were found associated with shoal grass (*Halodule wrightii*) and turtle grass (*Thalassia testudinum*) (Holt et al. 1983, Rooker and Holt 1997). Larval Red Drum also were found in *Spartina alterniflora* marshes with the marsh edge interface supporting much higher densities than nearby non-vegetated bottom (Stunz et al. 2002a).

Even though oysters provide structure like seagrass, Stunz et al. (2002a) did not collect any Red Drum larvae on oyster reefs. Havel et al. (2015) found that larval Red Drum settled on oyster shells at a larger size than to either sand or seagrass. They postulated that oyster shells were a less favorable habitat for Red Drum larvae than seagrass possibly due to the predators and/or prey associated with each habitat. Field experiments examining larval Red Drum growth rates have shown that the lowest daily growth rates were on oyster reef and non-vegetated bottom while the highest daily growth rates were in seagrass and salt marsh (Stunz et al. 2002b). Height or complexity differences between seagrass and oyster shells could also play a role in oysters being a less favorable habitat (Havel et al. 2015).

Using 15-30 mm Red Drum in cage experiments, Gain (2009) found that in the absence of a predator, Red Drum larval habitat selection was not influenced by structured habitats. However, when exposed to predators, Red Drum showed a clear preference for more structured, complex habitat. Predators influencing larval Red Drum habitat selection has been shown in several other studies also. Holt et al. (1983) concluded that in shoal grass meadows, larval Red Drum were more abundant along seagrass edges due to a need for feeding in open areas while also having seagrass nearby for protection from predators. Rooker et al. (1998b) found larval Red Drum mortality rates to be three to four times higher in unvegetated areas than in seagrass habitats. Rooker et al. (1998b) concluded that the higher mortality rates in unvegetated areas was due to larval Red Drum being more vulnerable to predators as habitat complexity decreased.

Researchers have found differences in larval Red Drum densities in different species of seagrass. Rooker and Holt (1997) found that larval Red Drum were more abundant in shoal grass, *Halodule wrightii*, than in turtle grass, *Thalassia testudinum*. Rooker and Holt (1997) found similar larval Red Drum growth rates between shoal and turtle grass and suggested that abundance differences were due to anti-predator behaviors rather than spatial variability in growth and foraging conditions. The researchers postulated that the structural differences between shoal and turtle grass, with shoot density being eight to ten times higher in shoal grass than turtle grass, made larval Red Drum less vulnerable to predators.

### Juvenile and Adult Habitat

Juvenile Red Drum can tolerate wide water temperature (13-28°C) and salinity (0-50 ppt) regimes (Perret et al. 1980, McDonald et al. 2015). Using fishery independent data in Texas, Dance and Rooker (2016) found that early juvenile Red Drum were most abundant in estuarine areas with water temperatures between 15-25°C and salinities greater than 29 ppt. They also found that juvenile Red Drum were rarely caught in areas with water temperatures less than 15°C. In Louisiana, Peterson (1986) found that while juvenile Red Drum were caught in salinities ranging from 4-27 ppt, juvenile Red Drum were most abundant between 16 and 25 ppt. Peterson (1986) also found that juvenile Red Drum were more abundant in salinities between 21 and 25 ppt.

Juvenile Red Drum are generally found in inshore waters of the Gulf of Mexico, except during fall and winter (Chen 2017). Habitat preferences include rivers, bays, canals, tidal creeks, passes in estuaries, seagrass beds, oyster bars, mud flats, and sand bottom (Chen 2017). Winner et al. (2014) found that most Red Drum (95%) utilizing these nursery habitats were age-0 fish of less than 100 mm TL. Juvenile Red Drum are frequently found in shallow water during summer and fall, but these fish move to warmer water in deeper areas during winter (Dance and Rooker 2015). As juvenile Red Drum grow and approach 200 mm during their first spring, Peters and McMichael (1987) found that juvenile Red Drum may remain in deep basins and bayous, venture into the shallows, or congregate near passes.

Within the estuary, Peterson (1986) found that juvenile Red Drum in Louisiana seemed to prefer saline *Spartina alterniflora* marshes with shallow water and mud or sandy bottoms. In Texas, Dance and Rooker (2015) found that seagrass beds are important habitat for juvenile Red Drum with seagrass beds being a preferred habitat to salt marsh when both are present. They also found that in Galveston Bay, juvenile Red Drum rarely utilized open bay and oyster reef habitat. Dance and Rooker (2016) found that early juvenile Red Drum abundance was associated with greater seagrass coverage in Galveston Bay, moderate coverage in Aransas-Corpus Bay, and lower coverage in Laguna Madre. They postulated that the differences were because of early juvenile Red Drum's preference for seagrass edge habitats as the edges of seagrass beds often provide greater foraging opportunities while still providing predator protection. A juvenile Red Drum preference for habitat edges or boundaries was also found by Moulton et al. (2017). In the Laguna Madre where seagrass is ubiquitous, early juvenile Red Drum seemed to prefer areas with reduced seagrass coverage and more edge habitat. In Galveston Bay, early juvenile Red Drum were more abundant with increasing seagrass coverage likely due to the limited nature of seagrass in Galveston Bay. High numbers of early juveniles in the eastern Gulf have been found to use non-vegetated river channels in Tampa Bay and Charlotte Harbor (Whaley et al. 2016). Peters and McMichael (1987) reported that Red Drum between the ages of one and four years used various estuarine habitats within Tampa Bay and that as Red Drum aged, they gradually moved into deeper basins or bayous within rivers and creeks or ventured into shallow shoreline areas in the bay.

Sampling mangroves, emergent vegetation, fringing oyster bars, and seagrass flats on the west coast of Florida, Winner et al. (2014) found that large juvenile Red Drum began recruiting to these estuarine shoreline habitats between the ages of six months and one year when the fish were 150-300 mm TL. These subadult Red Drum occupied these habitats until age-3 or age-4 when the fish were 500-800 mm TL.

As Red Drum mature, they move out of the estuaries into nearshore shelf waters and along coastal beaches (Peters and McMichael 1987) and that by age-5, the vast majority of Red Drum over 800 mm TL had completed their migration into nearshore coastal waters (Winner et al. 2014). Figure 4.5 and Figure 4.6 display the nearshore nature of adult Red Drum from SEAMAP Shrimp/Groundfish Surveys, the SEAMAP Bottom Longline Survey, and the NMFS Bottom Longline Survey. Adult Red Drum spend less

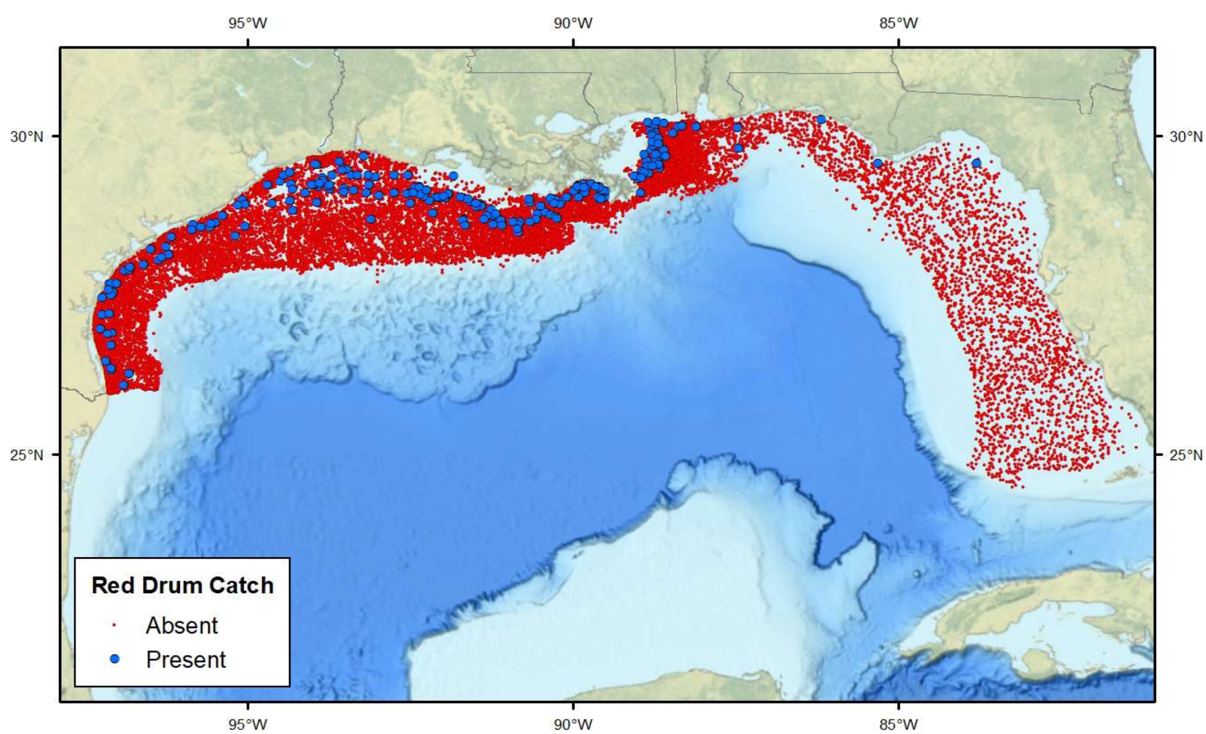



Figure 4.5 Red Drum catches from 33,847 trawl stations sampled from 1982-2020 as part of routine SEAMAP Shrimp/Groundfish Survey sampling from 1982-2020. Blue dots represent one or more Red Drum captured at a station (SEAMAP unpublished data).

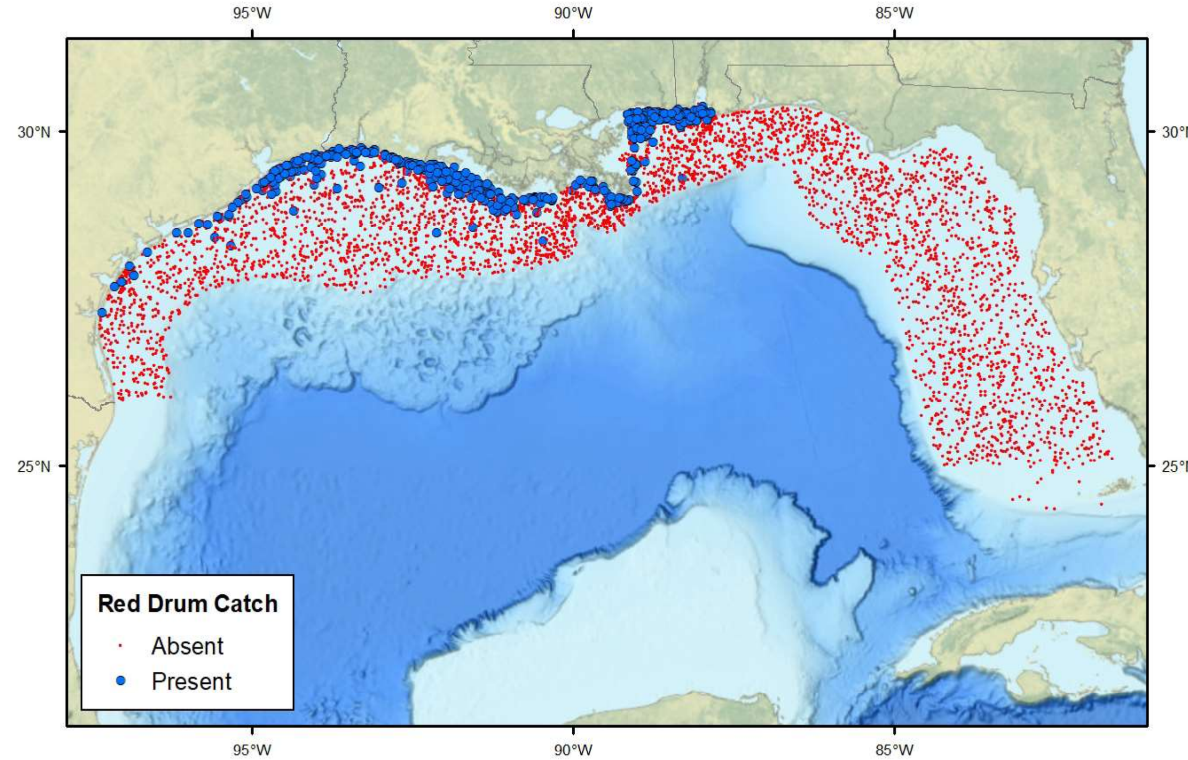



Figure 4.6 Red Drum catches from NMFS and SEAMAP bottom longline sampling. Data are from 5,432 bottom longline sets sampled from 1995-2020 as part of bottom longline surveys conducted by NMFS (1995-2019) and SEAMAP (2008-2020). SEAMAP samples water depths from 3-10m but does not sample off Florida. NMFS samples water depths from 9-366 m. Blue dots represent one or more Red Drum captured at a station (SEAMAP unpublished data).

time in bays and estuaries and more time in open Gulf of Mexico waters. Off Texas, Rooker et al. (2010) stated that the majority of subadult and adult red drum were collected within or near the same region they occupied as juveniles. The researchers found that as you move northward along the Texas Coast, more mixing of adult Red Drum from adjacent estuaries occurred. Rooker et al. (2010) postulated that mixing occurs among regional estuaries in the Gulf of Mexico, but the majority of subadult and adult Red Drum appear to either remain in close proximity to their native estuary or return to natal areas to spawn following a dispersive phase.

## *Habitat Threats*

### Coastal Development

Increasing human population and coastal development are major threats to estuarine and marine aquatic habitats since urban growth and development in coastal areas of the U.S. are approximately four times greater than that in other areas of the country (Hanson et al. 2003). While the amount of coastal wetlands lost to development has decreased in the last several decades, the rate of loss of coastal wetlands has remained roughly the same. The loss rate was estimated to be 0.2% per year from 1922-1954, while loss rates from 1982-1987 were approximately 0.18% per year (Valiela et al. 2004).

Increasing human populations and development within coastal regions generally leads to an increase in impervious surfaces, including but not limited to roads, residential and commercial development, and parking lots. Impervious surfaces cause greater volumes of runoff and associated contaminants in aquatic and marine waters. The increase of impervious surfaces from construction of urban, suburban, commercial, and industrial centers results in land use conversions that remove vegetation and negatively impact habitat. According to USEPA (1995), impervious surface runoff and storm sewers are the most widespread source of pollution into the nation's waterways. When impervious surfaces exceeded 20-30% of total land cover, Holland et al. (2004) found reduced abundances of stress-sensitive macroinvertebrates and altered food webs in headwater tidal wetlands. Holland et al. (2004) also found measurable adverse changes in the physical and chemical environment when impervious cover exceeded 10-20% land cover.

Non-point and point source pollution discharges may cause organisms to be more susceptible to disease or impair reproductive success (USEPA 2005). While the effects of non-point source pollution can be lower in severity than the effects of point source pollution, non-point source pollution may be more damaging to fish and their habitats. Non-point source pollution may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for years. When population impacts are detected, a single source or event is usually hard to determine and population impacts may be difficult to correct, clean up, or mitigate.

Urban runoff is generally difficult to control because of the intermittent nature of rainfall and the associated runoff, the large variety of pollutant source types, and the variable nature of source loadings. The National Water Quality Inventory (USEPA 2009) reported that runoff from urban areas was the leading source of impairment in surveyed estuaries. Urban areas can have a chronic and insidious pollution potential that one-time events do not. The effects of pollution on coastal fishery resources may not necessarily represent a serious, widespread threat to all species and life history stages but are dependent upon the type and concentration of the chemical compound and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong bottom currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas or enclosed bays and estuaries. Similarly, species whose egg, larval, and juvenile stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

Urban runoff from coastal development can result in an unnatural influx of suspended particles from soil erosion having negative effects on riverine, nearshore, and estuarine ecosystems. Impacts from this include high turbidity levels, reduced light transmittance, and sedimentation which may lead to the loss of submerged aquatic vegetation and other benthic structure (USEPA 2005, Orth et al. 2006). Developed watersheds tend to have reduced stormwater storage capacity. Other impacts include disruption in the respiration of fishes and other aquatic organisms, reduction in filtering efficiencies and respiration of invertebrates, reduction of egg buoyancy, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh et al. 1991, Wilber and Clarke 2001, USEPA 2005).

Severely eutrophic conditions may adversely affect aquatic systems in a number of ways, including reductions in submerged aquatic vegetation through reduced light transmittance, epiphytic growth, and increased disease susceptibility (Goldsborough 1997); mass mortality of fish and invertebrates through poor water quality; and alterations in long-term natural community dynamics. The environmental effects of excess nutrients and elevated suspended sediments are the most common and significant causes of submerged aquatic vegetation decline worldwide (Orth et al. 2006). There is evidence that nutrient over enrichment has led to increased incidence, extent, and persistence of harmful algal blooms; increased frequency, severity, spatial extent, and persistence of hypoxia; alterations in the dominant phytoplankton species and size compositions; and greatly increased turbidity of surface waters from planktonic algae (O'Reilly 1994).

Petroleum products consist of thousands of chemical compounds that can be toxic to marine life. Polycyclic aromatic hydrocarbons (PAH) are particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Kennish 1998). Fulton et al. (1993) reported finding significantly higher PAHs in developed watersheds when compared to non-developed watersheds. By far, the largest amount of petroleum released through human activity comes from the use of petroleum products (e.g., cars, boats, paved urban areas, and two-stroke engines) (ASMFC 2004). While most of the activities that use petroleum are based on land, rivers and streams carry the petroleum into nearby estuaries and bays. While individual petroleum product releases are small, they are so ubiquitous that when combined, they contribute nearly 85% of the total petroleum pollution from human activities (ASMFC 2004).

Petroleum products are a major stressor on inshore fish habitats because they can potentially interfere with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fish, especially early life history stages (Gould et al. 1994). Polycyclic aromatic hydrocarbons can degrade aquatic habitat, consequently interfering with biotic communities and may be discharged into rivers from non-point sources, including municipal runoff and contaminated sediments. Also, oil has been shown to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others and generally eggs and larvae of organisms are most sensitive (Gould et al. 1994, Rice et al. 2000).

Although agricultural runoff is a major source of pesticide pollution in aquatic systems, residential areas are also a notable source. Other sources of pesticide discharge into coastal waters include atmospheric deposition and contaminated groundwater (Meyers and Hendricks 1982). Pesticides may bioaccumulate in the ecosystem by accumulating in sediments and detritus that is then ingested by macroinvertebrates, which in turn are eaten by larger invertebrates and fish.

Hanson et al. (2003) found three basic ways that pesticides can adversely affect fish health and productivity through direct toxicological impact on the health or performance of exposed fish, indirect impairment of the productivity of aquatic ecosystems, and loss or degradation of habitat that provides physical shelter for fish and invertebrates. The majority of effects from pesticide exposures are sublethal. Sublethal effects can impair the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success (Hanson et al. 2003). Early development and growth of organisms involve important physiological processes and include the endocrine, immune, nervous, and reproductive systems. Many pesticides have been shown to impair one or more of these physiological processes in fish (Moore and Waring 2001, Gould et al. 1994). Evidence has shown that DDT (dichloro-diphenyl-trichloroethane) and its chief metabolic by-product, DDE (dichloro-diphenyl-dichloroethylene), can mimic estrogen or inhibit androgen effectiveness. Gould et al. (1994) showed that DDT can cause deformities in winter flounder eggs and Atlantic cod embryos and larvae. Generally, however, the sublethal impacts of pesticides on fish health are poorly understood.

The direct and indirect effects of pesticides on fish and other aquatic organisms can be a key factor in determining the impacts on the structure and function of ecosystems (Preston 2002). This factor includes impacts on primary producers (Hoagland et al. 1996) and aquatic microorganisms (DeLorenzo et al. 2001), as well as macroinvertebrates that are prey species for fish. It is not surprising that pesticides are relatively toxic to insects and crustaceans that inhabit estuaries since they are designed to kill insects.

Lee and Oshima (1998) found that pesticides including chlorophyrifos, cypermethrin, fenvalerate, and diflubenzuron all inhibited hatching of blue crab embryos. Horst and Walker (1999) found that methoprene used for mosquito control interrupted chitin production in adult post molt blue crabs, increased mortality of hatching zoeae, and was toxic to megalopae by delaying molting time.

Herbicides may alter long-term natural community structure by hindering aquatic plant growth or destroying aquatic plants. Hindering plant growth can have notable effects on fish and invertebrate populations by limiting nursery and forage habitat. Chemicals used in herbicides may also be endocrine disrupters, exogenous chemicals that interfere with the normal function of hormones. Coastal development and water diversion projects contribute substantial levels of herbicides into estuaries. A variety of human activities such as noxious weed control in residential development and agricultural lands, right-of-way maintenance, algae control in lakes and irrigation canals, and aquatic habitat restoration results in contamination from these substances.

### Energy-Related Activities

Oil and gas activities can directly and indirectly impact coastal and estuarine habitats through vessel traffic, maintenance dredging of navigational canals, construction and operation of onshore facilities, installation and maintenance of pipelines, expansion of ports and docks, and operation of offshore oil and gas facilities. The potential for impacts is largely influenced by site-specific factors, such as the habitat types and distribution in the vicinity of oil and gas activities. Many of the activities associated with oil and gas development, such as platform construction, would occur in offshore waters.

A variety of contaminants can be discharged into the marine environment as a result of petroleum extraction operations. Waste discharges associated with a petroleum facility include drilling well fluids, produced waters, surface runoff and deck drainage, and drilling mud and cuttings (NMFS 2011). In addition to crude oil spills, chemical, diesel, and other contaminant spills can occur with petroleum-related activities (NMFS 2011). In even moderate quantities, oil discharged into the environment can affect habitats and living marine resources. Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the outer continental shelf and in nearshore coastal areas and can occur from a number of sources, including equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms (Hanson et al. 2003).

Accidental spills and daily operational discharges are the major sources of oil releases as a result of oil and gas activities. The National Research Council (NRC 2003) estimated the largest anthropogenic source of petroleum hydrocarbon releases into the marine environment is from petroleum extraction-related activities. Approximately 2,700 tons per year in North America are introduced to the marine environment as a result of produced waters (NRC 2003). Produced waters are waters that are pumped to the surface from oil reservoirs which cannot be separated from the oil. Produced waters contain finely dispersed oil droplets that can stay suspended in the water column or can settle out into sediments. Produced waters are generally more saline than seawater and contain elevated concentrations of radionuclides, metals, and other contaminants. Produced waters are either injected back into reservoirs or discharged into the marine environment (NRC 2003). Over 90% of the oil released from extraction activities is from produced water discharges which contain dissolved compounds (i.e., PAHs) and dispersed crude oil (NRC 2003). These compounds stay suspended in the water column and undergo microbial degradation or attach to suspended sediments and are deposited on the seabed. Elevated levels of PAH in sediments are typically found up to 300 m from the discharge point (NRC 2003).

Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters which disrupts the pelagic community. The water column may be polluted with oil as a result of wave action and currents dispersing the oil. Benthic habitat and the shoreline can be covered and saturated with oil, leading to the protracted damage of aquatic communities, including the disruption of population dynamics. Oil can persist in sediments for decades after the initial contamination, causing disruption of physiological and metabolic processes of demersal fish (Vandermeulen and Mossman 1996). These changes may lead to disruption of community organization and dynamics in affected regions and permanently diminish fishery habitat.

The discharge of oil drilling mud can change the chemical and physical characteristics of benthic sediments at the disposal site by introducing toxic chemical constituents. The addition of contaminants can reduce or eliminate the suitability of the water column and substrate as habitat for fish species and their prey. The discharge of oil-based drill cuttings is currently not permitted in U.S. waters. However, where oil-based drill cuttings have been discharged, there is evidence that sediment contamination and benthic impacts can occur up to 2 km from the production platform (NRC 2003).

Direct loss of marsh habitat can result from pipeline construction through coastal wetlands and impacts depend upon avoidance of wetlands in pipeline route selection and the technique used for laying the pipeline. The use of directional boring under wetlands during pipeline construction can avoid major impacts on wetlands. Trenching results in direct impacts on marsh habitat due to excavating the pipeline right of way. Long-term reduction in vegetation productivity above and adjacent to the pipeline, including backfilled areas, can lead to potential losses of wetland habitat and wetland loss depends on the success of backfilling, time of year, and duration of construction (Turner et al. 1994).

Refining converts crude oil into gasoline, home heating oil, and other refined products. The refining process produces effluents, which can degrade coastal water quality. Oil refinery effluents contain many different chemicals at different concentrations including ammonia, sulfides, phenol, and hydrocarbons. Toxicity tests have shown that most refinery effluents are toxic but to varying extents. Some species are more sensitive and the toxicity may vary throughout the life cycle. Experiments have shown that not only can the effluents be lethal, but they can often have sublethal effects on growth and reproduction (Wake 2005). Field studies have shown that oil refinery effluents often have an adverse impact on aquatic organisms that is more pronounced in the area closest to the outfall (Wake 2005).

Impacts on coastal marsh vegetation from oil spills could range from a short-term reduction in photosynthesis to extensive mortality and subsequent loss of marsh habitat as a result of substrate erosion and conversion to open water (Hoff 1995, Proffitt 1998). Long-term impacts could include reduced stem density, biomass, and growth (Proffitt 1998). Direct exposure to petroleum can lead to die-off of submerged aquatic vegetation (SAV) in the first year of exposure. Certain species which propagate by lateral root growth rather than seed germination may be less susceptible to oil in the sediment (NRC 2003). Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Mangroves might decrease canopy cover or die over a period of weeks to months (Hoff et al. 2002, Hayes et al. 1992). Other effects of spills could include a change in plant community composition or the displacement of sensitive species by more tolerant species. In locations where soil microbial communities were affected, effects might be long-term, and wetland recovery might be slowed. The degree of impacts on wetlands from spills are related to the oil type and degree of weathering, amount of oil, duration of exposure, season, plant species, percentage of plant surface oiled, substrate type, and oil penetration (Hayes et al. 1992, Hoff 1995, Proffitt 1998, Hoff et al. 2002). Higher mortality and poorer recovery of vegetation generally result from spills of lighter petroleum products (such as diesel fuel), heavy deposits of oil, spills during the active growing period of a plant species, contact with sensitive plant species (especially those located in coastal fresh marsh), completely oiled plants, and deep penetration of oil and accumulation in substrates. Because of the changes in the northern Gulf's barrier island profiles as a result of hurricanes Katrina, Rita, and Ivan, there is a greater potential for oil spill impacts on coastal marshes (MMS 2008).

Many factors determine the degree of damage from a spill, including the composition of the petroleum compound, the size and duration of the spill, the geographic location of the spill, and the weathering process present (NRC 2003). Although oil is toxic to all marine organisms at high concentrations, certain species and life history stages of organisms appear to be more sensitive than others. In general, the early life stages (i.e., eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al. 2000). Some marine species may be particularly susceptible to hydrocarbon spills if they require specific habitat types in localized areas and utilize enclosed water bodies, like estuaries or bays (Stewart and Arnold 1994).

Numerous sublethal effects were observed in recently hatched Red Drum larvae after eggs were exposed to weathered slick oil, including reductions in brain and eye size, and abnormal cardiac and nervous system development (Khursigara et al. 2017, Xu et al. 2017). Magnuson et al. (2018) also reported impaired ocular development in Red Drum larvae, which resulted in observable reductions in behavioral (optomotor) responses to external stimuli.

Disruption of the areas from dredging and sedimentation may cause spawning fish to leave the area for more suitable spawning conditions. Dredging, as well as the equipment used in the process such as pipelines, may damage or destroy other sensitive habitats such as emergent marshes and SAV (Mills and Fonseca 2003) and macroalgae beds. The stabilization and hardening of shorelines for the development of upland facilities can lead to a direct loss of SAV, intertidal mudflats, and salt marshes that serve as important habitat for a variety of living marine resources.

Offshore wind energy facilities have been proposed for the Gulf of Mexico, and these facilities convert wind energy into electricity through the use of turbines that harness the kinetic energy of the moving air. An offshore facility generally consists of a series of wind turbine generators, an array of submarine electric cables that connect each of the turbines, and a single electric service platform (ESP). An ESP is a central offshore platform that provides a common electrical interconnection for all of the wind turbine generators in the array and serves as a substation where the outputs of multiple collection cables are combined, brought into phase, and stepped up further in voltage for transmission to a land-based substation that is connected to the onshore grid (MMS 2007a). Electricity is transmitted from the ESP to an onshore facility through one or a series of submarine cables.

The construction of offshore wind turbines and support structures can result in benthic habitat conversion and loss because of the physical occupation of the natural substrate. Scour protection around the structures, consisting of rock or concrete mattresses, can also lead to a conversion and modification of habitat. The burial and installation of submarine cable arrays can impact the benthic habitat through temporary disturbance from plowing and from barge anchor damage. In some cases, plowing or trenching for cable installation can permanently convert benthic habitats when top layers of sediments are replaced with new material. The installation of cables and associated barge anchor damage can adversely affect SAV, if those resources are present in the project area. Cable maintenance, repairs, and decommissioning can also result in impacts to benthic resources and substrate.

### Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs, the toxic components of oil and petroleum products, enter the Gulf of Mexico in two ways: oil spills through human activities and from natural oil seeps that leak crude oil and form tar balls. MacDonald (1998) and MacDonald et al. (1993, 1996) using remote sensing estimated that natural seeps released 1.2-21.9M gallons of oil each year in the northern Gulf of Mexico. Kvenvolden and Cooper (2003) estimated about 350 seeps in the Gulf of Mexico while MacDonald (2011) estimated 1,424 persistent oil and gas seeps across the entire Gulf of Mexico.

The initial effects of PAHs to marine organisms often result in increased mortality rates or, in the case of mobile wildlife, it can result in their avoidance of affected habitats (Rozas et al. 2000). The consequences of an oil spill in marine and estuarine habitats depend on several factors related to the spill, 1) the amount of oil spilled, 2) the duration of the spill and 3) the weight of the oil that comes in contact with these habitats (Mendelssohn et al. 1993, USDOC 2010). The intensity of the negative impacts will also be affected by several meteorological components (wind-wave energy, rain and storm events). The residual time that the oil remains available to these meteorological variables will expose these habitats to adverse effects (NOAA 2010).

Remediation techniques used during oil spill events have shown that the cleanup of oil products should focus first and foremost on preventing oil from reaching marine and estuarine habitats, simply because it is easier and more effective to prevent the oiling of these habitats than cleaning them after the fact (NOAA 2010, USDOC 2010). Additionally, cleanup efforts that take place within marine and estuarine habitats have often resulted in additional damage to those habitats (Hoff 1995, Baker 1999, NOAA 2010). As toxic as petroleum products can be to the environment, marine and estuarine habitats have been documented to recover in one to three years, depending on the volume and type of crude oil spilled (Hoff 1995, Baker 1999). However, when marine and estuarine habitats have been exposed to large volumes of oil, the effects to marine and estuarine habitats, due to the entrainment of the oil in the sediments, has been measured in decades (Hoff 1995, Bergen et al. 2000).

Provided below is a short synopsis of the potential effects to marine and estuarine habitats that are used by Red Drum, as well as a myriad of other organisms which may be predators on, or prey for Red Drum.

### Saltmarsh

The negative effects to salt marshes have varied due to the types of oils spilled and also due to the remedial clean-up actions taken in response to those spills (Hoff 1995, NOAA 2010). The expected adverse effects to the saltmarsh community would include reduced productivity, short- and long-term loss of marsh plants, and persistent levels of hydrocarbons in the sediments.

Recovery of saltmarsh from the effects of oil has ranged from as little as one growing season for the recolonization of smooth cordgrass to longer than 30 years for partial recovery of the entire marsh community due to the retention of oil in the sediments (Hoff 1995, Bergen et al. 2000). When saltmarsh habitat has been lightly oiled, it is recommended to allow the area affected to heal naturally, which reduces restoration costs and ancillary damage to the marsh vegetation. This recommendation is further supported by evidence that some of the cleaning methods can cause greater damage to this community than the spill itself (Hoff 1995, NOAA 2010).

### Seagrasses

Studies of oil spill impacts on seagrasses are largely confined to observations of spill events or physiological studies. Oil in the water column has a primarily phototoxic effect on seagrasses, which is caused by the plant tissue absorption of the water-soluble fraction of the oil (Fonseca et al. 2017). Impaired photosynthesis is a major resultant symptom of oil toxicity (Runcie et al. 2005). The type of oil to which seagrass plants are exposed determines the effects on different species of seagrass. The combined effects of dispersants and oil are poorly understood. The use of dispersants during a spill encourages the oil to spread and increase the bioavailable fraction of oil by increasing the concentration and variety of petroleum-derived hydrocarbons in the water column (Yamada et al. 2003) and altering the interaction of these compounds with biological membranes (Wolfe et al. 2001). Adverse impacts which have been noted included short-term sloughing and die-off of seagrass blades, as well as mortality or displacement of encrusting biota (USDOC 2010). The loss of seagrasses may also adversely affect forage areas for Red Drum and habitat for their forage species as well.

### Oysters

The impacts of oil on oyster habitats depend on the type and amount of oil to which oysters are exposed. However, oyster preferential settling behavior and foraging strategies increase their risk of exposure. Oyster habitats typically occupy shallow subtidal, intertidal or estuarine regions susceptible to direct contact with oil. Oil exposure can substantially reduce feeding rates, decrease respiration, increase energy expenditure, and reduce byssal thread production resulting in weakened substrate attachment strength (Suchanek 1993). Impacts of oil exposure during the spring months, when oysters begin their spawning season, could be magnified because oil can reduce egg production and hatching rates, cause abnormal larval development or survival, and decrease survival and settlement of spat. In addition, because oysters filter large volumes of water for food and oxygen (ATSDR 1995, Law and Hellou 1999), they are particularly sensitive to contamination from the accumulation of toxic PAHs.

### Mangroves

In southwest Florida, the mangrove community replaces saltmarsh as the predominant estuarine shoreline vegetation. Hoff et al. (2002) identified effects of oil on the mangrove community, which depend on the type of oil or fuel spilled and also on the geomorphology and hydrology of the site. However, given the complex structure and biodiversity of mangrove communities, they tend to be highly susceptible to oiling by petroleum products of all types. Apparent effects include mangrove mortality within weeks, months, or years due to acute and chronic consequences of oil in direct contact with the plants and within surrounding sediments. Oil primarily acts as a physical barrier over lenticels on mangrove roots and pneumatophores, thereby disrupting gas, nutrient, and salt exchange. Mangrove leaf yellowing over weeks, months, or years is common. Other effects include long-term decreases in mangrove survivorship, leaf production, reproduction, seedling recruitment, and peat deposition (leading to erosion/subsidence of sediment and organic layers).

### Hypoxia

Localized anoxic bottom conditions have occurred on occasion throughout the Gulf including Mobile Bay, several bay systems in Florida (Tampa, Sarasota, and Florida Bays), and isolated areas in Louisiana. In 2013, over 5,000 Red Drum died in Breton Sound Louisiana from a suspected freshwater plume from the Mississippi River. Areas of predictable low dissolved oxygen exist in Louisiana waters (e.g., Terrebonne Bay and Pointe Aux Chenes) and are susceptible to annual kills during the summertime when conditions are right, but these are not dominated by Red Drum (Adriance personal communication). In 2017, Red Drum and catfish died in Pensacola Bay, Florida from unknown causes.

Over the past 20 years in Alabama, Red Drum have been reported and documented as dying in small and large numbers off Alabama's coast along with a few other species during March through May with no observable marks for predation, disease, or fishing activity. Most of these events affect predominantly Red Drum and are documented with the cause unknown, some reports do list low dissolved oxygen as a contributing factor. These events seem to only affect larger Red Drum, occur predominantly in the spring, and along the Gulf beaches. Such characteristics suggest these occurrences can be considered unusual mortality events. In March 2022, one such unusual mortality event occurred in coastal Alabama where large numbers of adult Red Drum were observed to be floating in the surface waters. This event occurred in conjunction with a large freshwater discharge event that impacted Mobile Bay and the coastal waters (Figure 4.7). Given the extensive freshwater impacting the region, it is hypothesized that the influx of freshwater created a strong salt wedge, as depicted in lower Mobile Bay (Figure 4.8), that limited the dissolved oxygen (DO) in the water column across the region, resulting in the death of larger Red Drum. The stratification associated with the salt wedge results from fresh river water layering on top of high salinity Gulf of Mexico waters and prevents oxygen from the atmosphere mixing into deeper portions of

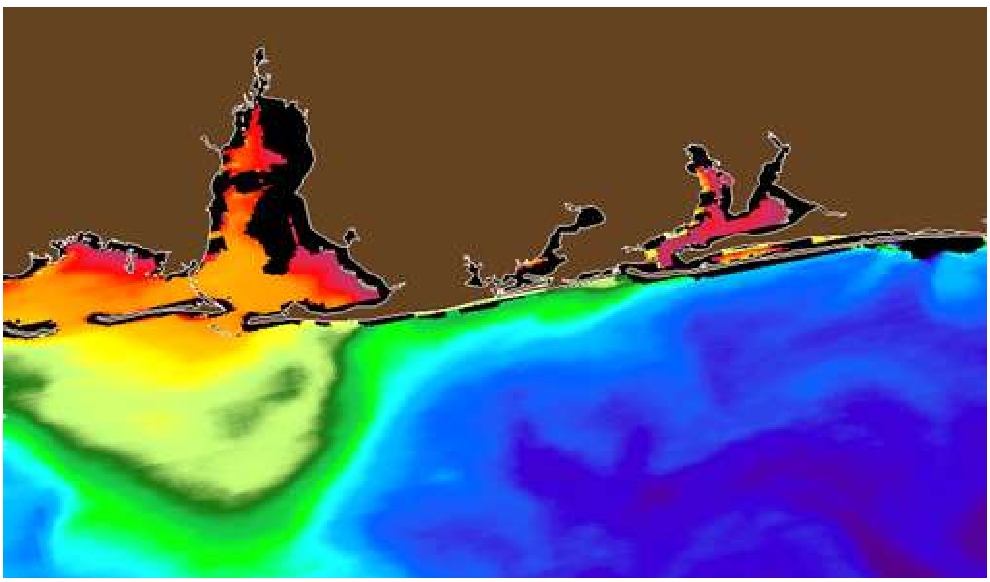


Figure 4.7. Satellite images of chlorophyll-a concentrations, a proxy of river discharge in the coastal zone, from the MODIS sensor on March 20, 2022. A large freshwater plume (yellow/green colors) can be seen exiting Mobile Bay (Dzwonkowski personal communication; Image Source: https://optics.marine.usf.edu).

the water column. These bottom pockets of low DO can be moved around by ambient water circulation from tides and winds, and potentially encapsulate a school of Red Drum. Due to their tight schooling formations, proximal oxygen content within the school was already decreased and in conjunction with a sudden drop in water column dissolved oxygen from the stratifying effects of the river plume, may have led to the die off of over one thousand Red Drum.

Estimates of dead Red Drum mortality events have ranged from three to over 1,000 fish dying off Alabama from 2003 to 2022. While most of these events report the losses of less than 200, several have exceeded 400 in the estimate of Red Drum killed. When Red Drum were exposed to these conditions, they died and sank to the bottom, begin to float days later which makes it difficult to access water quality conditions at the time of the event. While observing these flooding events is possible, predicting the

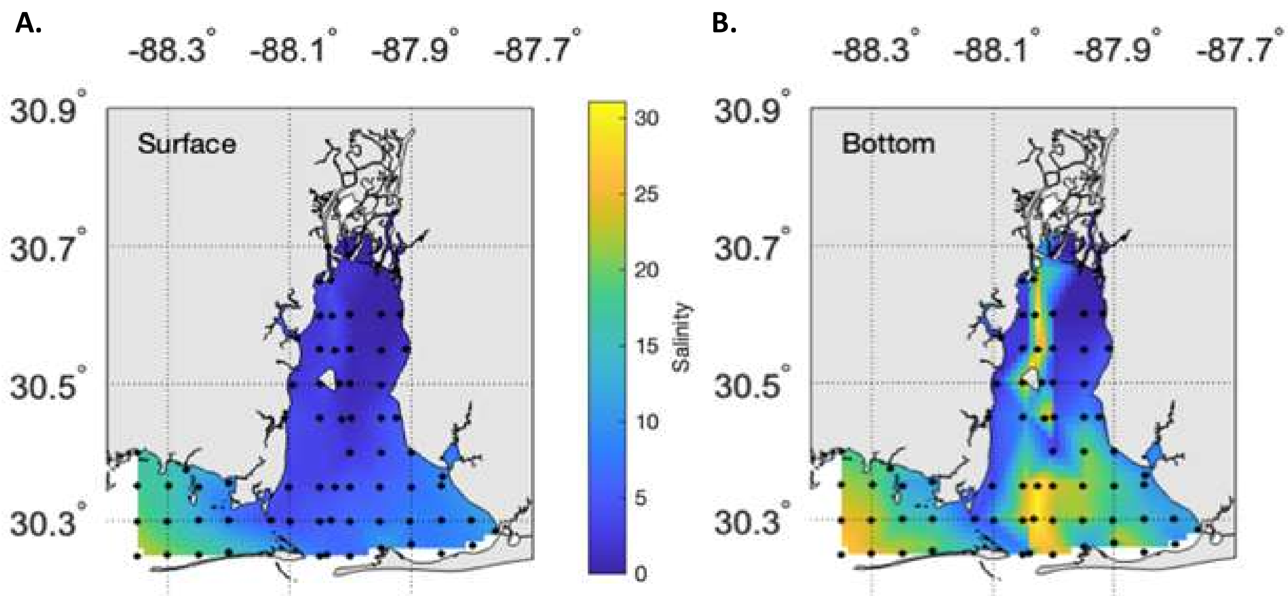



Figure 4.8. March 2022 salinity isobaths for the surface and bottom of Mobile Bay. Areas of high stratification can be seen in the lower parts of the bay where the A). fresh surface water (blue, left panel) as located over the B). salt bottom water (yellow, right panel) (Lehrter personal communication).

interactions of a school, or multiple schools, of Red Drum within these events in unlikely and isolating the schools of Red Drum from these mortality events is unpreventable.

In offshore waters, extensive areas (1,820,000 ha) of low DO (< 2 ppm) occur off Louisiana and Texas during February through early October. This phenomenon is most prevalent during the warmer summer months (Rabalais et al. 1997, Rabalais et al. 1999). The large Gulf hypoxic zone, commonly known as the ‘dead zone’, is created by low dissolved oxygen due primarily to nitrogen and phosphorus runoff from upstream agricultural activity along the Mississippi and Atchafalaya Rivers. These two rivers account for 80% of the freshwater input into the northern Gulf region that encompasses the area of this large recurring hypoxic zone. Although first documented in 1972, this hypoxic zone has been monitored since 1985 and has averaged 14,000 $km^2$ over the past five years (USEPA 2021). A Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (WNTF) made up of representatives from ten states and six federal agencies has written an action plan to address the excessive freshwater nutrient input from the Mississippi River. The WNTF (2008) has set a goal of reducing the annual average size of the Gulf hypoxic zone to 5,000 $km^2$.

### Alteration of Freshwater Inflow

Suitable freshwater inflow is necessary to dilute sea water and create salinity gradients for optimum fishery production, transport nutrients to the coast and then distribute them into estuaries, where they fuel production of fish, crustaceans, and other organisms, and distribute sediment into the estuary to keep tidal wetlands from subsiding, and ultimately disappearing. Changes to freshwater inflow affect estuarine habitats and organisms. The effects include mortality, changes in growth and development, and changes in species distributions. Sediment loads, pH, temperature, salinity, turbidity, tidal exchange, and nutrients are affected by any alteration of freshwater inflow.

The dredging, damming, and channelization of rivers in the U.S. has greatly altered the sedimentation patterns and the timing and volume of freshwater inflows into bays and estuaries. The result of dam construction, channelization, and deforestation is a decline in base flows to estuaries during critical dry seasons and an increase in extreme freshwater pulses during wet seasons (Browder 1991). In arid areas like southwest Texas, dams are of particular concern due to their relation to significant declines in dry season flows and to ecologically stressed hypersaline coastal lagoons (Browder and Moore 1981). For coastal systems in Texas and Florida, small changes in inflow volumes during the dry season can significantly alter salinity gradients (McPherson and Hammett 1991). However, declines in wet season flows can also impact estuarine biota. The shrimp fishery in Sabine Lake was negatively impacted by the Toledo Bend Dam because heavy summer demand for electricity decreased the formerly high winter water discharges and increased summer discharges. This changed the salinity regime in Sabine Lake by creating a low salinity nursery ground for brown shrimp in the spring and a high salinity nursery ground for white shrimp in the summer (White and Perret 1974).

Levee and canal construction can significantly impact coastal wetlands by causing ponding, impoundments, low sedimentation rates, high subsidence, and increased saltwater intrusion. In Louisiana's highly organic soils, these conditions tend to stress plants and cause mortality due to high levels of hydrogen sulfide (Mendelssohn and McKee 1988, Burdick et al. 1989) and salinity (Pezeshki et al. 1987). The loss of plants causes increased erosion and land loss (Scaife et al. 1983). In Florida's oligotrophic marl soils, the network of canals and levees has a different effect. By delivering relatively high nutrient loads and increasing the flooding duration in some areas and decreasing flooding duration in others, these alterations have stimulated primary productivity and the invasion of opportunistic native plants, such as cattail (*Typha domingensis*), and invasive exotic species such as Melaleuca (*Melaleuca quinquenervia*) and Brazilian pepper (*Schinus terebinthifolius*) (Jensen et al. 1995, Wu et al. 1995).

River diversions, channelization, and rainfall runoff within the watershed can affect nutrient distribution to estuaries. Watershed runoff can lead to estuarine eutrophication, while river diversions and channelization can lead to eutrophication or nutrient deprivation. The input of nutrients from freshwater inflow is directly related to estuarine primary production and help form the community structure of the downstream estuary (Odum 1971).

Freshwater inflow helps distribute sediments that shape and maintain river deltas, deposit nutrients, and influence turbidity. These functions are critical to coastal vegetation succession (Sklar et al. 1985) and act to counter coastal subsidence and sea level rise. Alterations in freshwater inflow can affect sediment loads in differing ways. Deforestation and agriculture usually increase the sediment load of rivers, while dams block sediments from being carried into downstream estuaries. Water management policies need to consider the serious issue of sediment deprivation due to the significant need for sediment in coastal areas. Diverting Mississippi River sediments to offshore water has led to the loss of coastal wetlands in Louisiana (Craig et al. 1979) and cutting off wetlands from other sediment sources through intensive canal dredging for oil exploration (Scaife et al. 1983, Cahoon and Turner 1989).

### Marine Transportation

As the human population increases, so does the demand for increased marine transportation vessels, facilities, and port infrastructure. Port facility expansion, vessel operations, and commercial and recreational marinas can adversely impact fish habitat through the filling of aquatic habitat and wetlands, dredging activities, and other land use changes. While some impacts related to marine transportation may be minimal and site specific, the cumulative impact of marine transportation activities can have substantial impacts on habitat over time.

### Ports and Marinas

Most marinas or port facilities will have a footprint that alters the surrounding environment. The construction of ports and marinas can directly fill habitat for port and marine structures or replace wetlands, SAV, and intertidal mud flat habitat with hardened structures such as bulkheads and jetties that provide few ecological services. Port construction usually leads to increased impervious surfaces which exacerbates storm water runoff and can increase the siltation and sedimentation loads in estuarine and marine habitats. Oil and fuel can accumulate on dock surfaces, facilities properties, adjacent parking lots, and roadways and can pollute surrounding waters through storm water runoff. Shoreline armoring is usually associated with ports and marinas. Shoreline armoring is used to prevent erosion due to increased boat traffic. Shoreline armoring reduces habitat complexity and directly reduces intertidal habitat. Installing breakwaters and jetties can lead to community changes as habitat is altered. Jetties and channels for marinas and ports can also lead to increased erosion and changes to sedimentation patterns due to alteration and amplification of tides and currents.

Marinas and docks often contain pilings and docks treated with chemicals such as chromated copper arsenate, ammoniacal copper zinc arsenate, and creosote to help extend their service life in the marine environment. These preservatives can leach harmful chemicals into the water that have been shown to produce toxic effects on fish and other organisms (Weis et al. 1991). The leaching rate and leaching duration of these preservatives after installation are highly variable and dependent on many factors, including the pH, salinity, and the type of compounds used in the preservatives (Hingston et al. 2001). The metals and chemicals in preservatives can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). Weis and Weis (2002) found that chromated copper arsenate can cause reductions in species richness and diversity in localized areas.

Vessel operations can have a wide range of impacts to habitat, ranging from minor to potentially large-scale impacts. Direct disturbance of bottom habitat can result from propeller scarring and vessel wake impacts on SAV and direct contact by groundings. Uhrin and Holmquist (2003) found that propeller scarring can result in a loss of benthic habitat, decreased productivity, potentially fragmented SAV beds, and further erosion and degradation of the habitat. The disturbance of sediments and rooted vegetation decreases habitat suitability for fish and shellfish resources and can affect the spatial distribution and abundance of fauna (Uhrin and Holmquist 2003). Burfeind and Stunz (2007) found that white shrimp showed significantly lower growth in highly scarred areas than in regions of low-level propeller scarring (<15%) and concluded that higher levels of propeller scarring may affect habitat quality.

Wave energy caused by industrial and recreational shipping and transportation can lead to high levels of shoreline erosion and cause additional problems such as damaging vegetation, disturbing substrate, and increasing turbidity. Johnson and Gosselink (1982) measured canal widening rates of over 2.5 m/year in heavily traveled oilfield canals in Louisiana. Size of the vessel, vessel hull configuration, and vessel speed all affect the wave energy and surge produced by vessels. The wave energy and surge, the slope of the shoreline, the shoreline sediment type, and the type of shoreline vegetation, and the depth and bottom topography of the water body affect the degree of shoreline erosion caused by vessels.

## Navigational Channel Dredging

Around the Gulf of Mexico, dredging usually is required in and around ports, harbors, and marinas. Dredging can often affect the surrounding environment and negatively impact sensitive aquatic habitats. Dredging can be classified as creating new or expanded waterways, maintaining existing waterways, or deepening existing waterways. The increasing size of commercial cargo vessels has led to increased competition among the major coastal ports to provide facilities to accommodate these vessels. Larger vessels mean that ports must continually deepen their navigation channels. Port, harbors, and marina facilities usually require maintenance dredging because of the continuous deposition of sediments.

The location and method of dredged material disposal depends on the suitability of the material determined through chemical, and often, biological analyses conducted prior to the dredging project. Generally, sediments determined to be unacceptable for open water disposal are placed in confined disposal facilities or contained aquatic disposal sites and capped with uncontaminated sediments. Sediments that are determined to be uncontaminated may be placed in open water disposal sites or used beneficially. Beneficial uses are intended to provide environmental or other benefits to the human environment, such as shoreline stabilization and erosion control, habitat restoration/enhancement, beach nourishment, capping contaminated sediments, parks and recreation, agriculture, strip mining reclamation and landfill cover, and construction and industrial uses. Some open water disposal sites are designed so that the material remains at the disposal site while others are designed for the material to be dispersed by currents and/or wave action. The potential for environmental impacts is dependent upon the type of disposal operation used, the physical characteristics of the material, and the hydrodynamics of the disposal site.

Dredging involves a number of fishery habitat impacts. These include the direct removal or burial of demersal and benthic organisms and aquatic vegetation, alteration of physical habitat features, the disturbance of bottom sediments (resulting in increased turbidity), contaminant releases in the water column, light attenuation, releases of oxygen consuming substances and nutrients, entrainment of living organisms in dredge equipment, noise disturbances, and the alteration of hydrologic and temperature regimes (Johnson et al. 2008). Dredging is often accompanied by a significant decrease in the abundance, diversity, and biomass of benthic organisms in the affected area and an overall reduction in the aquatic productivity of the area (Allen and Hardy 1980, Newell et al. 1998). The rate of recovery of the benthic community is dependent upon an array of environmental variables which reflect interactions between sediment particle mobility at the sediment-water interface and complex associations of chemical and biological factors operating over long time periods (Newell et al. 1998).

Bathymetry alterations, changes to benthic habitat features, and substrate type changes caused by navigational dredging activities may have long-term impacts on the functions of estuarine and other aquatic environments. The impacts of an individual project are proportional to the scale and time required for a project to be completed, with small-scale and short-term dredging activities having less impact on benthic communities than long-term and large-scale dredging projects. Dredging can have cumulative effects on benthic communities, depending upon the dredging interval, the scale of the dredging activities, and the ability of the environment to recover from the impacts. The new exposed substrate in a dredged area may be composed of material containing more fine sediments than before the dredging, which can reduce the recolonization and productivity of the benthos and the species that prey upon them. The impacts to benthic communities vary greatly with the type of sediment, the degree of disturbance to the substrate, the intrinsic rate of reproduction of the species, and the potential for recruitment of adults, juveniles, eggs, and larvae (Newell et al. 1998). Following a dredging event, sediments may be nearly devoid of benthic infauna, and those that are the first to recolonize are typically opportunistic species which may have less nutritional value for consumers (Allen and Hardy 1980, Newell et al. 1998).

In general, dredging can be expected to result in a 30-70% decrease in the benthic species diversity and 40-95% reduction in number of individuals and biomass (Newell et al. 1998). Recovery of the benthic community is generally defined as the establishment of a successional community which progresses towards a community that is similar in species composition, population density, and biomass to that previously present or at nonimpacted reference sites (Newell et al. 1998). The factors which influence the recolonization of disturbed substrates by benthic infauna are complex, but the suitability of the post-dredging sediments for benthic organisms and the availability of adjacent, undisturbed communities which can provide a recruitment source are important (Barr 1987, ICES 1992). Rates of benthic infauna recovery for disturbed habitats may also depend upon the type of habitat being affected and the frequency of natural and anthropogenic disturbances. Benthic infauna recovery rates may be less than one year for some fine-grained mud and clay deposits, where a frequent disturbance regime is common, while gravel and sand substrates, which typically experience more stability, may take many years to recover (Newell et al. 1998). Sheridan (2004) found that recovery from dredged material placement was nearly complete for the water column and sediment components after 1.5-3.0 years, but recovery of the benthos and nekton was predicted to take 4-8 years.

The small, localized disturbance of SAV associated with dredging may be viewed as a significant impact in the context of diminished regional health and distribution resulting from stressors such as poor water quality and cumulative effects such as dredging, prop scarring, and shoreline alteration (Goldsborough 1997, Thayer et al. 1997). In a study of dredging impacts on seagrass in the Laguna Madre in Texas, Onuf (1994) found that off-site dredging effects were detectable for the 15-month study period and noted that resuspension and dispersion events caused by wind-generated waves were responsible for the propagation of dredge-related turbidity over space and time in the system. Also, in a study of dredged material placement sites in Laguna Madre, Texas, Sheridan (2004) found that recovery from dredged material placement for seagrass took from 4-8 years. Sheridan (2004) stated that the current two to five-year dredging cycle for the area virtually insured that the ecosystem did not recover before being disturbed again.

Dredging degrades habitat quality through the resuspension of sediments which creates turbid conditions and can release contaminants into the water column, in addition to impacting benthic organisms and habitat through sedimentation. Turbidity plumes ranging in the hundreds to thousands of mg/L are created and can be transported with tidal currents to sensitive resource areas. Alterations in bottom sediments, bottom topography, and altered circulation and sedimentation patterns related to dredge activities can lead to shoaling and sediment deposition on benthic resources such as spawning grounds, SAV, and shellfish beds (Wilber et al. 2005, MacKenzie 2007). Early life history stages (eggs, larvae, and juveniles) and sessile organisms are the most sensitive to sedimentation impacts (Barr 1987, Wilber et al. 2005).

Large channel-deepening projects can potentially alter ecological relationships through a change in freshwater inflow, tidal circulation, estuarine flushing, and freshwater and saltwater mixing. Dredging may also modify longshore current patterns by altering the direction or velocity of water flow from adjacent estuaries. These changes in water circulation are often accompanied by changes in the transport of sediments and siltation rates resulting in alteration of local habitats used for spawning and feeding (Messieh et al. 1991).

Maintenance dredging of navigation channels between barrier islands can remove sediments from the longshore sediment drift. Maintained channels intercept and capture sediments, and dredged materials are often discharged to ocean dump sites. Dredging may contribute to the reduction of sediment deposition and affect the stability of barrier landforms (MMS 2007b). Reductions in sediment supply could subsequently contribute to minor local losses of adjacent barrier beach habitat, with impacts over a broader area where the sediment supply is low.

Dredging of navigation channels can contribute to increased flushing and draining of interior marsh areas by tides and storms, which could result in shifts in species composition, habitat deterioration, erosion, and wetland loss. Channels alter the hydrology of coastal marshes by affecting the amount, timing, and pathways of water flow (Day et al. 2000). Hydrologic alterations can result in changes in salinity and inundation, causing a dieback of marsh vegetation and a subsequent loss of substrate and conversion to open water (Day et al. 2000). Saltwater intrusion into brackish and freshwater wetlands further inland could result in mortality of salt-intolerant species and loss of some wetland types such as cypress swamp, or transition of wetland types such as freshwater marsh to brackish and salt marsh or open water (MMS 2007b). The deposition of dredged material onto adjacent disposal banks could potentially result in a localized and minor contribution to ongoing impacts of disposal banks, such as preventing the effective draining of some adjacent areas, resulting in higher water levels or more prolonged tidal inundation, or restricting the movement of water, along with sediments and nutrients, into other marsh areas (Day et al. 2000).

Navigational channels that are substantially deeper than surrounding areas can become anoxic or hypoxic as natural mixing is decreased and detrital material settles out of the water column and accumulates in the channels. This concentration of anoxic or hypoxic water can stress nearshore biota when mixing occurs from a storm event (Allen and Hardy 1980). The potential for anoxic conditions can be reduced in areas that experience strong currents or wave energy, and sediments are more mobile (Barr 1987, Newell et al. 1998).

### Methyl-Mercury

Mercury is found naturally in the environment as a result of volcanic activity. Mercury is also added to the environment through human activities, including incineration of solid waste, combustion of fossil fuels, and other industrial activities. Elemental inorganic mercury in the environment is converted into methyl-mercury (MeHg) by bacteria in the water. Through feeding on aquatic organisms, fish absorb MeHg. The higher on the food chain and the older the fish are, the higher the concentration of MeHg in the tissues. In the 1970s, the U.S. Food and Drug Administration (FDA) established a standard of 0.5 ppm for the substance in part as a result of industrial poisonings in Japan in the 1950s. In the late 1970s, the courts overturned that standard, and an action level of 1.0 ppm was established. This level was based on new data, partly contributed by the NMFS, which indicated that exposure levels would not increase significantly by consumption of seafood at 1.0 ppm. The FDA issued a fish consumption advisory for MeHg in 1995 and consumption advisories have been revised several times since then. The October 2021 revision warned that pregnant women and women who may become pregnant should avoid shark, swordfish, King Mackerel, marlin, Bigeye Tuna, Orange Roughy, and tilefish (USFDA 2021).

### Invasive Species

Effects of invasive species can be devastating on both habitat and native species. Impacts may include a decrease in biological diversity of native ecosystems, a decrease in the quality of important habitats for native fish and invertebrate species, a reduction in habitats needed by threatened and endangered species, and an increase in direct and indirect competition with aquatic plants and animals. Invasive species have been introduced to coastal areas through industrial shipping, recreational boating, and intentional and unintentional human releases. These introductions can be in the form of fouling organisms on the bottoms of vessels as they are transported between water bodies or through the release of ballast water from large commercial vessels. Introductions of non-native invasive species into marine and estuarine waters are a significant threat to living marine resources in the U.S. (Carlton 2001). Hundreds of species have been introduced into U.S. waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001).

Invasive species that occur in Gulf of Mexico freshwater, estuarine, and marine environments include 483 aquatic microbes, invertebrates and aquatic vertebrates, and 221 aquatic plants (Battelle 2000). These introduced species have the potential to affect native populations and their habitat. During the summer of 2000, an invasion of Pacific spotted jellyfish (*Phyllorhiza puncata*) covered 150 $km^2$ in the northern Gulf of Mexico. An estimated six million of these jellyfish consumed vast amounts of plankton. The green mussel (*Perna viridis*) found in Tampa Bay, Florida, is well established on hard surfaces in the bay. This species is now being reported attaching to unconsolidated sediments and creating new shellfish communities. Nutria (*Myocastor coypus*) is an invasive species that has had a significant adverse impact on Louisiana marshes. Nutria affect nursery habitat for many estuarine species by undermining and converting tidal emergent marsh habitat to open water.

Tiger shrimp (*Penaeus monodon*) and the Bocourt swimming crab (*Callinectes bocourti*) are non-native crustaceans that have been found in the Gulf. Tiger shrimp feed on small crabs and also compete with native blue crab populations for food and habitat. Increasing numbers of tiger shrimp have the potential to threaten population levels of Blue Crabs in some areas of the Gulf of Mexico.

Invasive species can have severe impacts on the quality of habitat (Deegan and Buchsbaum 2005). Non-native aquatic plant species can infest water bodies, impair water quality, cause anoxic conditions when they die and decompose, and alter predator-prey relationships. Fish may be introduced into an area to graze and biologically control aquatic plant invasions. However, introduced fish may also destroy habitat, which can eliminate nursery areas for native juvenile fish, accelerate eutrophication, and cause bank erosion (Kohler and Courtenay 1986).

Increased competition for food and space between native and non-native species can alter the trophic structure of an ecosystem (Kohler and Courtenay 1986, Caraco et al. 1997, Strayer et al. 2004, Deegan and Buchsbaum 2005) as well as through predation by invasive species on native species (Kohler and Courtenay 1986). Competition may result in the displacement of native species from their habitat or a decline in recruitment, which are factors that can collectively contribute to a decrease in population size (Kohler and Courtenay 1986). Predation on native species by non-native species may increase the mortality of a species. Whether the predation is on the eggs, juveniles, or adults, a decline in native forage species can affect the entire food web (Kohler and Courtenay 1986).

### Fish

Since 2010, lionfish (*Pterois miles* and *Pterois volitans*), a non-indigenous species from the Indo-Pacific region, have rapidly increased in numbers throughout the coastal waters of the Gulf of Mexico. Lionfish can be found in brackish river mouths, bays, estuaries, and open oceans to a depth of at least 275 m and are general predators that consume a wide variety of fish and invertebrates posing a large threat to many native marine species.

### Harmful Algal Blooms (HABs)

Harmful algal blooms (HABs) are caused by naturally occurring dinoflagellates and algae. Over 60 species of dinoflagellates that can cause harmful algal blooms are found in the Gulf of Mexico with the most common being *Karenia brevis*. Toxic dinoflagellates such as *Karenia* spp. are common in the Gulf of Mexico all year long at background cell concentrations of approximately 1,000 cells/liter. The harmful impacts caused by these HABs only occur when cell concentrations increase significantly above the low background concentrations. Brown tides have been caused in Texas by blooms of *Aureoumbra*.

In the Gulf of Mexico, HABs occur most commonly in Florida waters. Louisiana, Mississippi, and Alabama have each experienced at least one red tide event, but Texas has experienced 13 red tide events attributed to *K. brevis* since 1935 (Magana et al. 2003). Most of these HABs have been concentrated along the west Florida shelf from Clearwater to Sanibel Island and the Texas coast between Port Arthur and Galveston Bay. In 1996, red tides occurred in the coastal waters of all five Gulf states. Most blooms occur during late summer to fall (Tester and Steidinger 1997). These blooms can extend for hundreds to thousands of square kilometers and can persist for months. High concentrations of cells are variable due to the influence of currents. Off Florida, harmful algal blooms usually start offshore in oligotrophic waters between 18 and 74 km off central Florida at depths of 12-40 m and can take about a month or so to develop into a fish-killing bloom depending on environmental conditions (Liu et al. 2001). Most harmful algal blooms off Texas occur in inshore or nearshore waters.

Ingestion of brevetoxin, the toxic compound produced and released by red tide cells by fish, paralyzes the respiratory system causing death. The red tide bloom off Texas in 1997 killed a minimum of 22M finfish (McEachron et al. 1998). Clupeids and other schooling fishes were the main species impacted, although about 100 total species were identified, including recreationally and commercially important fish such as Spotted Seatrout (*Cynoscion nebulosus*), Red Drum, flounder (*Paralichthys* sp.), Black Drum (*Pogonias cromis*), and Atlantic Croaker (*Micropogonias undulatus*). Brevetoxin also affects top predators through bioaccumulation of toxin in planktivorous prey fish that ingest the cells or are otherwise exposed to a bloom. Finfish are not the only casualties of harmful algal blooms. In addition, bottlenose dolphins (*Tursiops truncatus*), marine turtles, and the Florida manatee (*Trichechus manatus latirostrus*) have all died as a result of toxins associated with HABs. In 1996, 149 Florida manatees died and, in 2005, 138 marine turtles died due to HABs in Florida Gulf waters.

Unexplained fish kills and other animal mortalities in red tide endemic areas are increasingly linked with post-bloom exposures of biota to brevetoxins (Landsberg et al. 2009). Landsberg et al. (2009) collected animal tissues and environmental samples for brevetoxin analyses after red tide events. They found that a persistence of high concentrations of brevetoxins in various biotic reservoirs can remain a stable source of toxicity, even in the absence of *K. brevis* cells.

A persistent *Aureoumbra* brown tide bloom began in 1990 in the Laguna Madre and Baffin Bay, Texas. The brown tide stopped in 1997, but developed again the following summer (Buskey et al. 2001). Brown tide blooms have occurred intermittently in the Laguna Madre system since then but have not been as severe. Brown tides affect seagrass due to decreased light penetration. Onuf (1996) recorded a 9.4 $km^2$ loss of seagrass over the course of several years. Ward et al. (2000) found a decrease in the biomass and diversity of benthic invertebrates in the Laguna Madre due to the brown tide bloom.

The dinoflagellate *Gonyaulax monilata* has been responsible for fish mortalities across the Gulf of Mexico (Connell and Cross 1950, Gates and Wilson 1960, Williams and Ingle 1972, Wardle et al. 1975). Perry et al. (1979) reported on an extensive outbreak of *G. monilata* in coastal and offshore waters of the northern Gulf in the summer of 1979 with fish kills reported in Alabama and Florida.

### Climate Change

Climate change could have many consequences for most U.S. coastal and marine ecosystems, and some of the consequences may substantially alter human dependencies and interactions with these complex and linked systems. The climatic effects will be superimposed upon, and interact with, a wide array of current stresses, including excess nutrient loads, overfishing, invasive species, habitat destruction, and toxic chemical contamination. While the ability of these ecosystems to cope with or adapt to climate change or variability is compromised by extant stresses, the inverse is also likely to be true. Ecosystems will be better suited to deal with climate variability and change if other stresses are significantly reduced.

Climate change may result in higher water temperatures, stronger stratification, and increased inflows of freshwater and nutrients to coastal waters in many areas. Both past experience and model forecasts suggest that these changes will result in enhanced primary production, higher phytoplankton and macroalgal standing stocks, and more frequent or severe hypoxia.

Natural biological and geological processes should allow responses to gradual changes, such as transitions from marsh to mangrove swamp as temperatures warm, as long as environmental thresholds for plant survival are not crossed. Accelerated sea level rise also threatens these habitats with inundation, erosion, and saltwater intrusion. Over the last 6,000 years, coastal wetlands expanded inland as low-lying areas were submerged, but often did not retreat at the seaward boundary because sediment and peat formation enabled them to keep pace with the slow rate of sea level rise. If landward margins are armored, effectively preventing inland migration, then wetlands could be lost if they are unable to accumulate substrate at a rate adequate to keep pace with future increased rates of sea level rise.

Increased air, soil, and water temperature may also increase growth and distribution of coastal salt marshes and forested wetlands. For many species, including mangroves, the limiting factor for the geographic distribution is not mean temperature, but rather low temperature or freezing events that exceed tolerance limits (McMillan and Sherrod 1986, Snedaker 1995). The Gulf of Mexico is a prime candidate for mangrove expansion to occur because it is located at the northward limit of black mangrove habitat (Comeaux et al. 2012). This may come at the expense of *Spartina* spp. dominated marshes. Historically, small populations of black mangroves have been present in Louisiana in the extreme southern portion of the state. Black mangrove distribution was limited by cold winter temperatures. Black mangrove populations are now expanding in southern Louisiana's *Spartina* dominated marshes (Perry and Mendelssohn 2009). Caudill (2005) found that blue crabs were collected in higher abundances in mangrove areas in south Louisiana sites than at adjacent *Spartina* sites.

Fodrie et al. (2010) sampled seagrass areas in Mississippi, Alabama, and northern Florida previously sampled in the 1970s to compare the ichthyofauna between the two periods. The comparison showed several new species including Lane Snapper (*Lutjanus synagris*), Red Grouper (*Epinephelus morio*), and Yellowtail Snapper (Ocyurus chrysurus). Several other species showed large increases in abundance between 1979 and 2006, including Gag (*Mycteroperca microlepis*), and Mangrove Snapper (*Lutjanus griseus*). The researchers also observed increased air and sea surface temperatures, which they theorize have led to northern shifts in the distribution of these warm water fish. Fodrie et al. (2010) found that nearly 20% of the fish species collected in northern Gulf of Mexico seagrass meadows during 2006–2007 were tropical or subtropical, and were either absent, or much less abundant than they were in the 1970s. Fodrie et al. (2010) conclude that the presence of these fish may be an early indicator for the extension of tropical conditions in the northern Gulf of Mexico.

Changes in the timing and volume of freshwater delivery to coastal wetlands will also be critical, yet perhaps the most difficult to assess. In contrast to uncertainties associated with regional impacts of climate change on hydrology, it is clear that increased human population and coastal development will create higher demands for freshwater resources. While increased freshwater is likely to decrease osmotic stress and increase productivity, less freshwater may increase salinity stress. Wetlands may accommodate gradual increases in salinity as salt and brackish marshes replace freshwater marshes and swamps, although sustained or pulsed changes in salinity can have dramatic negative effects. maidencane, *Panicum hemitomon*, a typical freshwater marsh species, grew at a reduced rate in water of 9 ppt salinity in one study (McKee and Mendelssohn 1989) and had reduced carbon assimilation at 5 ppt in another (Pezeshki et al. 1987).

Climate change will likely influence the vulnerability of estuaries to eutrophication in several ways, including changes in mixing characteristics caused by alterations in freshwater runoff, and changes in temperature, sea level, and exchange with the coastal ocean (Kennedy 1990, Peterson et al. 1995, Najjar et al. 2000). A direct effect of changes in temperature and salinity may be seen through changes in suspension feeders such as mussels, clams, and oysters. The abundance and distribution of these consumers may change in response to new temperature or salinity regimes and they can significantly alter both phytoplankton abundance and water clarity (Alpine and Cloern 1992, Meeuwig et al. 1998, NRC 2000).

Increased anthropogenic nutrient loading and a changing climate will make coastal ecosystems more susceptible to the development of hypoxia through enhanced stratification, decreased oxygen solubility, increased metabolism and remineralization rates, and increased production of organic matter. All these factors related to global change may progressively result in an onset of hypoxia earlier in the season and possibly an extended duration of hypoxia.

### Weather-Related Events

Tropical storms generally form from June until October each year in the Gulf of Mexico, and in a typical year, 11 tropical storms will form in the region with approximately six reaching hurricane status (Blake et al. 2007). Hurricanes and tropical storms can increase surface current speeds to between 1 and 2 m/s in continental shelf regions (Nowlin et al. 1998, Teague et al. 2007). Storm surges can impact coastal areas and have been reported to range between 2-8 m for hurricanes reaching the northern Gulf (NOAA 2013). Storms affect estuaries through overwash events and by erosion from wind and waves.

Evidence of an increase in intense tropical cyclone activity in the North Atlantic over the past 40 years (Meehl et al. 2007, Trenberth et al. 2007) supports predictions that the frequency (Holland and Webster 2007, Mann et al. 2007) and intensity (Emanuel 2005, Webster et al. 2005) of extreme weather events have been increasing and will continue to increase with warmer global temperatures. However, these predictions have been challenged by suggestions that the apparent trend in increasing storm frequency is an artifact of improved monitoring (Landsea 2007) and by predictions that increased vertical wind shear could dampen the effects of increasing hurricane intensity (Vecchi and Soden 2007). Meehl et al. (2007) suggest that a warmer climate will increase the overall intensity of tropical cyclones and, whereas the number of storms is expected to decrease globally by the end of the 21st century, the number of storms in the North Atlantic could increase by as much as 34% during this period (Oouchi et al. 2006).

El Niño, also called the El Niño Southern Oscillation (ENSO), is a change in the eastern Pacific Ocean's surface water temperatures that contributes to major changes in global weather. It is a periodic phenomenon that is caused by changes in surface trade wind patterns. The tropical trade winds normally blow east to west, piling up water in the western Pacific and causing upwelling of cooler water along the South American coast. El Niño occurs when this normal wind pattern is disrupted. El Niño generally produces cooler and wetter weather in the southern United States and warmer than normal weather in the northern part of the country. In addition, there seems to be reduced, though no less severe, tropical activity during El Niño years (NAS 2000). The resulting increased summer rainfall can significantly increase river discharge, flow rates, water clarity, and other physical-chemical parameters in estuaries.

The effects of La Niña are nearly opposite to that of El Niño. La Niña is characterized by unusually cold ocean temperatures in the eastern equatorial Pacific Ocean. La Niña periods are characterized by wetter than normal conditions across the Pacific Northwest and very dry and hot conditions in the Southeast. Also, a greater than average number of tropical storms, and possibly hurricanes, are likely in the Gulf from June-October.

Tropical storm and hurricane damage to coastal property is a recognized physical and monetary threat to the states located along the Gulf Coast. Costanza et al. (2008) estimated that the coastal wetlands of the United States provide $23.2B per year in storm protection services. Each hectare of coastal wetland lost corresponds to an average of $33,000 of increased damage from specific storms. Louisiana alone lost $816M per year of wetland services prior to Hurricane Katrina and an additional $34M were lost due to Hurricane Katrina. These values emphasize the need to protect and restore coastal wetlands.

# Chapter 5
# FISHERY MANAGEMENT JURISDICTIONS, LAWS, AND POLICIES AFFECTING THE STOCK(S)

A significant increase in commercial Red Drum harvest in the early 1980s resulted in implementation of rules to prohibit any directed commercial harvest from the U.S. Exclusive Economic Zone (EEZ). By 1987, the EEZ was closed to all Red Drum fishing and remains closed today. President George W. Bush signed Executive Order 13449 in 2007 effectively banning all recreational and commercial take of Red Drum from any of the Atlantic or Gulf EEZ waters. As a result, all harvest of Red Drum originates from state water boundaries and the population is managed under a recovery plan based on escapement rates from non-EEZ waters. Considering their wide range throughout the Atlantic and Gulf of Mexico, a number of state and federal management institutions have jurisdiction over this species. The following is a partial list of some of the important agencies and a brief description of the laws and regulations that directly or indirectly affect Red Drum throughout the Gulf of Mexico and the EEZ. Individual Gulf states and federal agencies should be contacted for specific and up-to-date state laws and regulations, which are subject to change on a state-by-state basis. Additional U.S. laws, treaties, and agencies may have jurisdiction over the habitat and environment affecting Red Drum and can be found in detail in the Commission's other fishery management plans and profiles.

## Federal

### Management Institutions

Red Drum are found along the eastern coast of north America and most of the Gulf of Mexico. They occur from Massachusetts to northern Mexico in coastal waters and the EEZ (Robins et al. 1986). Because the adult fish primarily live offshore, Red Drum are managed by the regional fishery management councils (see *Regional Fishery Management Councils* below).

#### *National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (USDOC)*

The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all federal fishery management plans (FMPs) prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The NMFS also collects data and statistics on fisheries and fishermen. It performs research and conducts management authorized by international treaties. The NMFS has the authority to enforce the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (Mag-Stevens), the Lacey Act, other federal laws protecting marine organisms including the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA), and is the federal trustee for living and nonliving natural resources in coastal and marine areas.

The USDOC, in conjunction with coastal states, administers the National Estuarine Research Reserve and National Marine Sanctuaries Programs as authorized under Section 315 of the Coastal Management Act of 1972. Those protected areas serve to provide suitable habitat for a multitude of estuarine and marine species and serve as sites for research and educational activities relating to coastal management issues.

## Regional Fishery Management Councils

Eight regional fishery management councils were established by Mag-Stevens to advise NMFS on federal fishery management issues. The regional councils include the Gulf, Caribbean, South Atlantic, Mid-Atlantic, New England, Pacific, Western Pacific, and North Pacific Fishery Management Councils. These Councils develop fishery management plans and submit recommended regulations to the U.S. Secretary of Commerce based on public comment and scientific data. NMFS and the councils have jurisdiction in the EEZ to manage species that occur in federal waters.

### South Atlantic Fishery Management Council

The South Atlantic Fishery Management Council manages fisheries in federal waters (beyond three nautical miles) off East Florida, Georgia, South Carolina, and North Carolina.

### Caribbean Fishery Management Council

The Caribbean Fishery Management Council manages fisheries in federal waters (beyond three nautical miles) off the Commonwealth of Puerto Rico and the U.S. Virgin Islands (St. Thomas, St. John, St. Croix, and Water Island).

### Gulf of Mexico Fishery Management Council

The Gulf of Mexico Fishery Management Council manages fisheries in federal waters (beyond nine nautical miles) off West Florida and Texas and the federal waters (beyond three nautical miles) off the coasts of Alabama, Mississippi, and Louisiana.

This Management Profile will consider the entire Gulf of Mexico as a single 'Gulf' stock based on the genetics and migration work to date. The following information will be limited primarily to Red Drum in the five Gulf states respective waters and the EEZ unless discussing the fisheries in relation to the total U.S. landings, values, or effort.

## Treaties and Other International Agreements

There are no treaties or other international agreements that affect the harvesting or processing of Red Drum. No foreign fishing applications to harvest Red Drum have been submitted to the United States.

## Federal Laws, Regulations, and Policies

The following federal laws, regulations, and policies may directly and indirectly influence the quality, abundance, and ultimately the management of Red Drum.

### Magnuson-Stevens Fishery Conservation and Management Act of 1976 (MFCMA); Magnuson-Stevens Fishery Conservation and Management Act of 1996 (Mag-Stevens), Also Called The Sustainable Fisheries Act (P.L. 104-297); Magnuson-Stevens Fishery Conservation and Management Reauthorization Act 2006

Mag-Stevens mandates the preparation of FMPs for important fishery resources within the EEZ. It sets national standards to be met by such plans. Each plan attempts to define, establish, and maintain the optimum yield for a given fishery. The 1996 Mag-Stevens reauthorization included three additional national standards (eight through ten) to the original seven for fishery conservation and management, included a rewording of standard number five, and added a requirement for the description of essential fish habitat and definitions of overfishing.

1. Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry;
2. Conservation and management measures shall be based on the best scientific information available;
3. To the extent practicable, an individual stock shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or close coordination;
4. Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various U.S. fishermen, such allocations shall be:
    - fair and equitable to all such fishermen;
    - reasonably calculated to promote conservation; and
    - carried out in such a manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.
5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of the resources; except that no such measures shall have economic allocation as its sole purpose.
6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fisheries resources, and catches.
7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.
8. Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to:
    - provide for the sustained participation of such communities, and
    - to the extent practicable, minimize adverse economic impacts on such communities.
9. Conservation and management measures shall, to the extent practicable,
    - minimize bycatch and
    - to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.
10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

The 2006 reauthorization builds on the country's progress to implement the 2004 Ocean Action Plan which established a date to end over-fishing in America by 2011, use market-based incentives to replenish America's fish stocks, strengthen enforcement of America's fishing laws, and improve information and decisions about the state of ocean ecosystems.

The 2019 amendment to Mag-Stevens (H.R. 3514) provided fisheries disaster relief for commercial fishery failures that are due to duties on U.S. seafood or fish products imposed as retaliation for increases in duties imposed by the United States.

### Interjurisdictional Fisheries Act (IFA) of 1986 (P.L. 99-659, Title III)

The IFA of 1986 established a program to promote and encourage state activities in the support of management plans and to promote and encourage regional management of state fishery resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

### Federal Aid in Sport Fish Restoration Act (SFRA); The Wallop-Breaux Amendment of 1984 (P.L. 98-369)

The SFRA, passed in 1950, provides funds to states, the USFWS, and the three interstate marine fisheries commissions to conduct research, planning, and other programs geared at enhancing and restoring marine sportfish populations. The 1984 amendment created the Aquatic Resources Trust Fund which is a 'user pays/user benefits' program. The amendment allows transfer of fishing and boating excise taxes and motorboat gas taxes (user pays) to the improvement of fishing and boating programs (user benefits) and provides equitable distribution of funds between freshwater and saltwater projects in coastal states.

### MARPOL Annex V and United States Marine Plastic Research and Control Act of 1987 (MPRCA), Revised MEPC.201(62) 2011

MARPOL Annex V is a product of the International Convention for the Prevention of Pollution from Ships, 1973/1978. Regulations under this act prohibit ocean discharge of plastics from ships; restrict discharge of other types of floating ship's garbage (packaging and dunnage) for up to 46 km from any land; restrict discharge of victual and other recomposable waste up to 22 km from land; and require ports and terminals to provide garbage reception facilities. The MPRCA of 1987 and 33 CFR, Part 151, Subpart A, implement MARPOL V in the United States.

The revision includes specific language prohibiting the at sea disposal of 'plastics' as

> "a solid material which contains as an essential ingredient one or more high molecular mass polymers and which is formed (shaped) during either manufacture of the polymer or the fabrication into a finished product by heat and/or pressure. Plastics have material properties ranging from hard and brittle to soft and elastic. For the purposes of this annex, 'all plastics' means all garbage that consists of or includes plastic in any form, including synthetic ropes, synthetic fishing nets, plastic garbage bags and incinerator ashes from plastic products."

### Joint Enforcement Agreements (JEAs)

All five of the Gulf of Mexico state marine agencies participate in the NOAA Cooperative Enforcement Initiative for Joint Enforcement Agreements (JEAs) with NOAA's Office of Law Enforcement (OLE). State partner agencies provide fully trained, equipped and deputized officers who perform at-sea and dockside patrols, outreach, and public education in federal waters where OLE presence is limited. Since its creation in 2002, 27 coastal states and territories have entered into JEA partnerships with NOAA and are receiving JEA funds. The JEAs have led to significant progress in creating uniform enforcement databases, identifying regional and local fishery enforcement priorities, and extending coordination to other areas, such as investigations. The JEA program has been particularly effective because state agents are familiar with local waters, know when and where enforcement infractions are likely to occur, and provide opportunities for significant public outreach and education. The JEA program also serves as the mechanism to provide the region with funding for federal fishery enforcement efforts. These efforts provide NOAA OLE visibility and routine interaction with the regulated industry, ensure stakeholders' understanding, establish enforcement in EEZ, and ultimately achieve prevention with resource user group support and compliance with Federal marine resource conservation mission.

## Federal Red Drum Regulations

Red Drum in the Gulf of Mexico are managed by NOAA through the regional fishery management council, but the five-state marine resource management agencies regulate their own state waters. The restrictions discussed in this section are current through the publication of this profile, and are subject to change at any time thereafter.

## Gulf of Mexico Fishery Management Council (GMFMC)

Gulf of Mexico Fishery Management Council
4107 West Spruce Street
Suite 200
Tampa, FL 33607

## Management of Federal Waters

NOAA and the Secretary of Commerce through the Gulf Council under the Red Drum Fishery Management Plan (FMP) manage Red Drum in the Gulf of Mexico. The Red Drum FMP implemented in 1986 prohibited any directed harvest from the EEZ (GMFMC 1986). The FMP was amended (Amendment 1) in 1987 which further extended the commercial closure and created TACs for catches by recreational anglers (GMFMC 1987). They also requested the five Gulf states manage their respective waters for escapement rates of 20% SSB as part of the rebuilding plan for the fishery. In 1988, the Gulf Council amended the FMP again (Amendment 2) to prohibit any retention or possession of Red Drum from the EEZ and increased the escapement rates for the states to 30% SSB (GMFMC 1988). The last amendment to the FMP occurred in 1992 when the Gulf Council and NOAA began setting an annual TAC and required assessments of the stock on a biennial basis to adjust the TAC (Amendment 3; GMFMC 1992).

## Penalties for Violations

§600.735 Penalties. Any person committing, or fishing vessel used in the commission of a violation of the Magnuson-Stevens Act or any other statute administered by NOAA and/or any regulation issued under the Magnuson-Stevens Act, is subject to the civil and criminal penalty provisions and civil forfeiture provisions of the Magnuson-Stevens Act, to this section, to 15 CFR part 904 (Civil Procedures), and to other applicable law.

## Laws and Regulations

There is zero retention or possession of any Red Drum from the EEZ anywhere in the U.S. Gulf of Mexico.

### Closed Areas and Seasons

All EEZ waters in the U.S. Gulf of Mexico are closed for Red Drum and harvest is prohibited to commercial fishermen and recreational anglers.

## Historical Changes to Regulations in Federal Waters Affecting Red Drum

The following federal regulatory changes may have notably influenced Red Drum landings during a particular year and are summarized here for informative purposes.

1986 An emergency commercial 90-day quota of one million pounds was imposed in June and was reached in less than a month.

1987 All commercial take in the EEZ of Red Drum is banned. Shrimpers will be allowed to catch about 200,000 pounds of Red Drum, taken incidentally. A 100,000-pound incidental catch of Red Drum will be allowed for other commercial fishermen. Recreational fishermen will be limited to one fish per person per trip, unless state laws prohibit such landings

1988 Commercial and recreational take is banned from EEZ in the Gulf of Mexico and eliminated any incidental catch. States begin management for ≥20% SSB escapement from estuarine waters.

1992 State escapement rates increased to ≥30% SSB.

2007 President George W. Bush signed Executive Order 13449 effectively banning all recreational and commercial take of Red Drum from any of the Atlantic or Gulf EEZ waters and recommending listing the species as a gamefish by the states where appropriate.

## State

### Florida

### Florida Fish and Wildlife Conservation Commission (FWC)

Florida Fish and Wildlife Conservation Commission
620 South Meridian Street
Tallahassee, FL 32399
Telephone: (850) 487-0554
https://myfwc.com/

Table 5.1 Size and bag limits for Red Drum in the Gulf of Mexico by state at the time of publication. Each state should be contacted directly for most current regulations.

<table>
<tr><th rowspan="2">State</th><th rowspan="2">Season</th><th colspan="2">Commercial</th><th colspan="2">Recreational</th></tr>
<tr><th>Min Length (inches)</th><th>Bag/ Possession</th><th>Min Length (inches)</th><th>Bag/ Possession</th></tr>
<tr><td>Florida</td><td>Open year round in state waters</td><td colspan="2">PROHIBITED</td><td>18 - 27 TL</td><td>Regulations for West Florida only<br>Panhandle and Big Bend regions: 1/person/day; 4 fish vessel limit<br>Tampa Bay, Sarasota Bay, Charlotte Bay, and Southwest regions: 1/person/day; 2 fish vessel limit</td></tr>
<tr><td>Alabama</td><td>Open year round in state waters</td><td colspan="2">PROHIBITED</td><td>16 - 26 TL</td><td>3/person/day; 1 oversized fish allowed/ day</td></tr>
<tr><td>Mississippi</td><td>Open year round in state waters</td><td>18 - 30 TL</td><td>QUOTA (60,000 lbs)</td><td>18 - 30 TL</td><td>3/person/day<br>1 oversized fish allowed/day</td></tr>
<tr><td>Louisiana</td><td>Open year round in state waters</td><td colspan="2">PROHIBITED</td><td>16 - 27 TL</td><td>5/person/day; 2 oversized fish allowed/ day<br>2 bag possession limit; 2 oversized fish possession limit</td></tr>
<tr><td>Texas</td><td>Open year round in state waters</td><td colspan="2">PROHIBITED</td><td>20 - 28 TL</td><td>3/person/day<br>Up to 2 oversized fish allowed/year when using a Red Drum Tag and/or Bonus Red Drum Tag</td></tr>
</table>

The agency charged with the administration, supervision, development, and conservation of natural resources in Florida is the FWC. This Commission is not subordinate to any other agency or authority of the state's executive branch. The administrative head of the FWC is the executive director. Within the FWC, the Division of Marine Fisheries Management is empowered to manage marine and anadromous fisheries in the interest of the people of Florida. The Division of Law Enforcement is responsible for enforcement of all marine-resource-related laws, rules, and regulations of the state.

The FWC, a seven-member board appointed by the governor and confirmed by the senate, was created by constitutional amendment in November 1998, effective July 1, 1999. This Commission was delegated authority over all aspects of rulemaking concerning marine life with the exception of requiring fees and establishing penalties.

Florida has habitat protection and permitting programs, and a federally approved Coastal Zone Management (CZM) program.

## Legislative Authorization

Prior to 1983, the Florida Legislature was the primary body that enacted laws regarding management of marine species in state waters. In 1983, the Florida Legislature established the Florida Marine Fisheries Commission (MFC) and provided the MFC with various duties, powers, and authorities to promulgate regulations affecting marine fisheries. Beginning Sept 12, 1985, CH 46-22, FAC contained regulations regarding Red Drum. On July 1, 1999, the MFC, parts of the Florida Department of Environmental Protection (DEP) including the Florida Marine Patrol and the Florida Game and Freshwater Fisheries Commission (GFC) were merged into one commission, the FWC. Marine fisheries rules of the FWC are now codified under Division 68B, Florida Administrative Code (FAC).

## Reciprocal Agreements and Limited Entry Provisions

### Reciprocal Agreements

Florida statutory authority provides for reciprocal agreements related to fishery access and licenses. Florida has no statutory authority to enter into reciprocal management agreements.

### Limited Entry

Florida has no provisions for limited entry in the Red Drum fishery.

## Commercial Landings Data Reporting Requirements

The commercial harvest, purchase, sale, or exchange of any Florida native Red Drum has been prohibited since January 1, 1989. This prohibition, however, does not apply to legally harvested non-native Red Drum that have entered the State of Florida in interstate commerce. The burden shall be upon any person possessing such Red Drum for sale or exchange to establish the chain of possession from the initial transaction after harvest, by appropriate receipt(s), bill(s) of sale, or bill(s) of lading, and to show that such Red Drum originated from a point outside the waters of the State of Florida, and entered the state in interstate commerce. Failure to maintain such documentation or to promptly produce same at the request of any duly authorized law enforcement officer shall constitute a violation of 68B-22.005(5).

## Penalties for Violations

Penalties for violations of Florida laws and regulations are established in Florida Statutes, Section 379.407. Additionally, upon the arrest and conviction of any license holder for violation of such laws or regulations, the license holder is required to show just cause as to why their saltwater license should not be suspended or revoked.

## License Requirements

In the state of Florida, a license is required to land Red Drum recreationally along either the Gulf of Mexico or Atlantic. Recreational saltwater fishing licenses are required of residents and non-residents fishing in state territorial waters or the EEZ off the state and current regulations must be adhered to. Check with the FWC for current Red Drum regulations. All children under the age of 16, regardless of residency, and resident seniors who are 65 or older are not required to purchase most recreational licenses. Other exemptions exist for active military and individuals with disabilities. Check with the FWC for details.

## Laws and Regulations

Florida's laws and regulations regarding the harvest and retention of Red Drum vary by region. The following discussions are general summaries of laws and regulations, and the FWC should be contacted for more specific information. The restrictions discussed in this section are current through the publication of this profile and are subject to change at any time thereafter.

### General

The purpose and intent of this chapter is to protect, manage, conserve and replenish Florida's Red Drum (redfish) resource.

Accordingly, it is the intent of this chapter to repeal and replace those portions of Section 370.11(2)(a)4., F.S. (1985), dealing with redfish. This chapter is not intended, and shall not be construed, to repeal any other portion of Section 370.11(2)(a)4., F.S. (1985); any other subdivision of Section 370.11, F.S. (1985); or any other general or local law directly or indirectly relating to or providing protection for the redfish resource.

Redfish are hereby declared and designated a protected species. The purposes of this designation are to increase public awareness of the need for extensive conservation action in order to prevent this resource from becoming endangered and to encourage voluntary conservation practices, including catch-and-release practices for all redfish caught unless they are needed for food.

### Size Limits

A slot limit not less than 18" and no more than 27" total length recreational harvest.

### Quotas and Bag/Possession Limits

Recreational Bag Limits – Except as provided in Rule 68B-22.007, F.A.C., a recreational harvester may not harvest or land per day or possess more redfish than the specified bag limit established in this subsection within the following regions while in or on Florida Waters, or on any dock, pier, bridge, beach, boat ramp, or other fishing site adjacent to such waters, and any parking location adjacent to said fishing sites:

(a) Panhandle Region – One (1) redfish.
(b) Big Bend Region – One (1) redfish.
(c) Tampa Bay Region – One (1) redfish.
(d) Sarasota Bay Region – One (1) redfish.
(e) Charlotte Harbor Region – One (1) redfish.
(f) Southwest Region – One (1) redfish.
(g) Southeast Region – One (1) redfish.
(h) Indian River Lagoon Region – A person may not harvest, land, or possess a redfish within the Indian River Lagoon Region.
(i) Northeast Region – One (1) redfish.

Recreational Vessel Limits – The persons aboard a vessel in or on Florida Waters may not collectively harvest, possess, or land more redfish than the specified vessel limit established in this subsection within the following regions. This provision will not be construed to authorize harvest or possession of redfish in excess of applicable bag limits.

(a) Panhandle Region – Four (4) redfish.
(b) Big Bend Region – Four (4) redfish.
(c) Tampa Bay Region – Two (2) redfish.
(d) Sarasota Bay Region – Two (2) redfish.
(e) Charlotte Harbor Region – Two (2) redfish.
(f) Southwest Region – Two (2) redfish.
(g) Southeast Region – Two (2) redfish.
(h) Indian River Lagoon Region – The persons aboard a vessel in or on the Indian River Lagoon Region may not harvest, possess, or land a redfish.
(i) Northeast Region – Four (4) redfish.

Captain and Crew Harvest Prohibited – On a vessel for hire, a person who is the captain or a crew member may not harvest or possess a redfish.

Transport Possession Limit – No person shall possess more than four native red drum while in transit on land.

Commercial Harvest Prohibited – A person may not harvest or land a redfish for commercial purposes from Florida Waters or possess a redfish from Florida Waters for commercial purposes.

Sale of Native Redfish Prohibited – A person may not purchase or sell a redfish that was harvested from Florida Waters. A person may purchase, sell, or possess a redfish that was legally harvested outside of Florida Waters that has entered the State of Florida in interstate commerce. A person in possession of a redfish for sale has the burden of establishing the chain of possession of such redfish beginning with the initial transaction after harvest by producing the appropriate receipt(s), bill(s) of sale, and bill(s) of lading. A person in possession of a redfish for sale has the burden of showing that such redfish originated from a point outside of Florida Waters and entered the state in interstate commerce. A person in possession of a redfish for sale must maintain, and shall promptly produce at the request of any duly authorized law enforcement officer, such documentation.

## Gear Restrictions

The harvest of any redfish in or from state waters by or with the use of any multiple hook in conjunction with live or dead natural bait is prohibited.

Spearing or snagging (snatch hooking) of redfish in or from state waters is prohibited.

The simultaneous possession aboard a vessel of any gillnet or entangling net together with any redfish is prohibited.

## Closed Areas and Seasons

A person may not harvest, land, or possess a redfish within the Indian River Lagoon Region.

## Other Restrictions

It is unlawful for any person to possess, transport, buy, sell, exchange or attempt to buy, sell or exchange any redfish harvested in violation of this chapter.

No operator of a vessel in or on state waters shall allow the possession aboard the vessel of any redfish not in compliance with established bag limits, size limits, seasons or any prohibited gear as specified in this chapter or in Chapter 68B-4, F.A.C.

All redfish harvested from Florida waters shall be landed in a whole condition. The possession, while in or on state waters, on any public or private fishing pier, or on a bridge or catwalk attached to a bridge from which fishing is allowed, or on any jetty, of any redfish that has been deheaded, sliced, divided, filleted, ground, skinned, scaled or deboned is prohibited. Mere evisceration or “gutting” of redfish, or mere removal of gills from redfish, before landing is not prohibited. Preparation of redfish for immediate consumption on board the vessel from which the fish were caught is not prohibited.

Provisions of this rule chapter shall not apply to redfish artificially spawned and raised in commercial aquaculture facilities. Failure to maintain appropriate receipt(s), bill(s), bill(s) of sale, or bill(s) of lading, that such redfish were artificially spawned and raised in commercial aquaculture facilities, shall constitute a violation of this rule.

### Catch-Hold-and-Release Tournament Exemption

Except as provided in this rule, the practice of catching, holding, and releasing redfish is prohibited. The Executive Director of the FWC, or his designee, shall issue a tournament exemption permit to the director of a catch-and-release fishing tournament to allow redfish to be caught, held, and released during the tournament, and to allow the tournament to exceed redfish bag and possession limits pursuant to Rule 68B-22.005, F.A.C., after redfish have been weighed-in, provided that each of the following conditions is met:

(a) Tournament anglers and tournament staff agree to attempt to release alive all redfish that are caught, including those fish that are weighed-in.

(b) Each two person team of tournament anglers possesses no more than two live redfish in the boat’s live well or recirculating tank at any one time.

(c) All boats used in the tournament contain recirculating or aerated live wells that are at least 2.4 cubic feet or 18 gallons in capacity.

(d) Dead redfish possessed by a two person team of tournament anglers are not discarded. A dead redfish is considered harvested and will count as the daily bag limit for the team of tournament anglers who harvested that fish.

(e) Redfish are maintained in an aerated recovery holding tank prior to release. Recovery holding tank requirements may be specified in the tournament exemption permit at the FWC’s discretion in order to increase survival of released redfish.

(f) The tournament provides the FWC with a description of the aerated recovery holding tank(s) used to maintain redfish alive after weigh-in.

(g) The tournament provides the FWC with a description of the location where tournament caught redfish will be released after they are weighed in. In order to increase survival of released redfish, release locations may be specified in the tournament exemption permit at the FWC’s discretion.

(h) The tournament permit holder shall submit a post-tournament report to the FWC indicating the number of fish weighed-in each day of the tournament, the number of fish weighed-in dead each day, and the number of fish that died after being weighed-in, but prior to release each day. The FWC may specify additional tournament reporting requirements as a condition of the tournament exemption permit.

(i) The tournament agrees to allow FWC staff the opportunity to collect research data and conduct research and onboard monitoring during the tournament, as needed.

Application for issuance of a tournament exemption permit shall be made on a form provided by the FWC [Form DMF-SL 5000 (3-04), incorporated herein by reference]. Tournament exemption permits will only be issued to catch-and-release redfish tournaments that agree to the permit conditions in subsection (1).

Any anglers participating in a redfish tournament for which a tournament exemption permit has been issued shall have a copy of the permit in his or her possession at all times during tournament operating hours.

Any violation of the conditions and requirements specified within the tournament exemption permit will be considered a violation of this rule.

### Biscayne National Park

Red Drum are included within the 10-fish aggregate recreational bag limit per person.

## Historical Changes to Regulations in Florida Affecting Red Drum

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for informative purposes.

1985 CH 46-22, FAC (Effective Sept. 12, 1985)

- Minimum size limits: 16 inches total length in state waters from Florida/Alabama border east and south to a straight line drawn from Bowlegs Point in Dixie County southwesterly through Marker 16, and 18-inches total length in all other state waters.
- Maximum size limit: Statewide possession limit of one redfish 32 inches total length, or larger, per person.

1986 Emergency Rule, CH 46ER86-3, FAC (Effective Nov. 7, 1986 – Feb. 4, 1987)

- Prohibits all harvest of redfish in Florida waters. Prohibits sale of native redfish.

1987 CH 46-22, FAC (Effective Feb. 12, 1987)

- 18 inches total length minimum size limit extended to all state waters
- Establishes March and April as closed season to all harvest in state waters
- Must be landed in whole condition (head and tail intact)
- Prohibits use of treble hooks while fishing with natural bait
- Prohibits snatch hooking

1987 Emergency Rule, CH 46ER87-1, FAC (Effective May 1, 1987 - July 29, 1987)

- Prohibits all harvest in state waters. Prohibits possession, transportation, buying, selling, or exchanging any native redfish.

1987 CH 46-22, FAC (Effective July 9, 1987)

- Continues emergency rule above for an indefinite period.

1987 CH 46-22, FAC (Effective Oct. 1 - Dec. 31, 1987)

- Temporary season opening for redfish to include:
    - 1 fish recreational daily bag limit, with off-the-water possession limit of 2 fish
    - 5 fish daily bag limit per vessel for commercial fishermen
    - Size limit of 18 inches to 27 inches total length
    - Use of treble hooks while fishing with natural bait prohibited

- Fish must be landed in whole condition (heads and tails intact)
- Redfish designated as "restricted species"
- Prohibits harvest of native redfish beginning 1/1/1988; sale of native redfish allowed until 1/5/1988

1989 CH 46-22, FAC (Effective Jan. 1, 1989 - Oct. 1, 1991)

- Establishes 18-inch minimum size limit and 27-inch maximum size limit for redfish harvested in state waters
- Establishes daily bag limit of 1 native redfish per person and an off-the-water possession limit of 2 fish per person
- Prohibits the sale of native redfish
- Closes the months of March, April, and May to harvest and possession of redfish
- Allows the sale of redfish harvested elsewhere with proper documentation

1991 CH 46-22, FAC (Effective June 3, 1991)

- Continues above rule indefinitely, declares redfish as a "protected species", and prohibits gigging and spearing of redfish.

1996 CH 46-22, FAC (Effective Jan. 1, 1996)

- Eliminates the March, April, and May closed season
- Prohibits the simultaneous possession aboard a vessel of any gillnet or entangling net together with any Red Drum
- Requires all Red Drum to be landed in a whole condition, and prohibits the possession of Red Drum that are not in a whole condition in or on state waters, on any public or private fishing pier, on a bridge or catwalk attached to a bridge from which fishing is allowed, or on any jetty
- Defines "total length" for Red Drum to mean the length of the fish measured from the most forward point of the head to the hindmost point of the tail

2004 CH 68B-22, FAC (Effective March 17, 2004)

- Allows the executive director of the FWC, or a designee, to issue permits to participants in qualified catch and release redfish tournaments to catch, hold, and release fish under the following conditions:
  - Tournament competitors and staff must attempt to release all redfish alive, including those fish that are weighed in
  - Best management practices must be used for handling of fish
  - Tournament boats must contain aerated or re-circulating live wells, with a minimum size of 18-gallons or the volumetric equivalent
  - Dead redfish may not be discarded when fish are caught, held, and released
  - Redfish must be placed in recovery tanks after weigh-in before being released
  - The tournament must provide the FWC with a description of the release location (as a condition of the exemption permit, the FWC may specify the tournament release location)
  - The tournament must submit a post-tournament report
  - The tournament must agree to allow the FWC the opportunity to conduct research and onboard monitoring, as needed
  - Two-person tournament teams may possess two redfish

- Tournament catch, hold, and release permits may only be issued to catch-and-release redfish tournaments that agree to all permit conditions
- All tournament competitors must possess a copy of the tournament catch, hold, and release exemption permit during the tournament

2006 CH 68B-22, FAC (Effective July 1, 2006)

- Provides that, for purposes of determining the legal size of Red Drum, "total length" means the straight-line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side.

2012 CH 68B-22, FAC (Effective Feb. 1, 2012)

- Defines "Northeast region," "Northwest region" and "South region"
- Increases Bag limit in the Northeast and Northwest regions from 1 fish to 2 fish
- Establishes a statewide vessel limit of 8 Red Drum
- Eliminates the off-water possession limit
- Establishes that bag limits apply to the land in the area adjacent to the fishing site
- Establishes a transport possession limit of 6 fish per person

2016 EO 16-12 (Effective May 1, 2016)

- Reduces the daily bag limit from two fish to one fish per person in the Northwest Red Drum management zone (Escambia County through Fred Howard Park near Pasco County)

2016 CH 68B-22.005, FAC (Effective Nov. 1, 2016)

- Reduces the daily bag limit from two fish to one fish per person in the Northwest Red Drum management zone

2018 EO 18-45 (Effective Sept. 28, 2018 – May 10, 2019)

- Temporary modification of regulations for Red Drum and Snook in southwest Florida
- Adds the inclusions of all waters of Pasco, Pinellas and Hillsborough counties to provisions of EO 18-38
- Extends the expiration date of EO 18-38 to May 10, 2019
- This order supersedes EO 18-38

2018 EO 18-38 (Effective Aug. 30 – Oct. 12, 2018)

- Temporary modification of regulations for Red Drum and Snook in southwest Florida
- A person must immediately release any Red Drum caught in or on the described region during the term of this order and may not possess a Red Drum in the described region
- A person may temporarily possess a Red Drum in or on the described region, only for the purpose of photographing, measuring, or weighing (with a hand-held scale) such Red Drum
- A person who temporarily possesses a Red Drum pursuant to this paragraph must release such Red Drum alive and unharmed in the immediate area where it was caught, immediately after it has been photographed, measured, or weighed

2019 EO 19-14 (Effective May 11, 2019 – May 31, 2020)

- Temporary modification of regulations for Red Drum, Snook, and Spotted Seatrout in Southwest Florida

- A person must immediately release any Red Drum, Snook, or Spotted Seatrout caught in or on the described region during the term of this order and may not possess or land a Red Drum, a Snook, or a Spotted Seatrout in the described region
- A person may temporarily possess a Red Drum, Snook or a Spotted Seatrout in or on the described region, only for the purpose of photographing, measuring, or weighing (with a handheld scale) such Red Drum, Snook, or Spotted Seatrout
- A person who temporarily possesses a Red Drum, a Snook, or a Spotted Seatrout pursuant to this paragraph must release such Red Drum, Snook, or Spotted Seatrout alive and unharmed in the immediate area where it was caught, immediately after it has been photographed, measured, or weighed
- During the term of this order, no *Redfish Catch-Hold-and-Release Tournament Exemption Permits* will be issued for activities conducted within the described region
- The provisions of this order apply in and on all Florida waters of the following geographic areas:
  - All Florida waters of Pasco, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, and Lee counties; and
  - All Florida waters of Collier County north of a line extending due east and due west from the south bank at the mouth of Gordon Pass

2020 EO 20-05 (Redfish, Snook, and Spotted Seatrout) Effective: June 1, 2020 – May 31,

- Continues catch-and-release provisions of 19-14
  - Prohibits the harvest, possession, and landing of all redfish, Snook, and Spotted Seatrout (including both recreational and commercial seatrout fisheries).
  - Allows for temporary possession for the purposes of photographing, measuring, or weighing fish provided that they are immediately released alive and unharmed.
  - States that no *Redfish Catch-Hold-And-Release Tournament Exemption* permits will be issued for activities within the described area.
  - Applies in all state waters from Pasco Cunty south to a line extending due east and due west from the south bank at the mouth of Gordon Pass south of Naples.

2021 EO 21-07 (Redfish, Snook, and Spotted Seatrout: Southern Manatee through Northern Collier) Effective: June 1, 2021 – May 31, 2022

- Redfish and Snook: Catch-and-release only
  - Prohibits harvest, possession, and landing of all redfish and Snook.
  - Allows for temporary possession for the purposes of photographing, measuring, or weighing fish provided that they are immediately released alive and unharmed, and.
  - States that no *Redfish Catch-Hold-and-Release Tournament Exemption* permits will be issued for activities within the described area.
- Applies in all state waters south of State Road 64 in Manatee County (including Palma Sola Bay, but not including the Manatee or Braden Rivers) and north of the south bank at the mouth of Gordon Pass in Collier County.

2021 EO 21-16 (Redfish, Snook, and Spotted Seatrout: Tampa Bay Area) Effective: July 16, 2021 – September 16, 2021

- Makes Redfish, Snook, and Spotted Seatrout catch-and-release only for the Tampa Bay area
  - Prohibits harvest, possession, and landing of all Redfish, Snook, and Spotted Seatrout.

- Allows for temporary possession for the purposes of photographing, measuring, or weighing fish provided that they are immediately released alive and unharmed, and.
- States that no *Redfish Catch-Hold-and-Release Tournament Exemption* permits will be issued for activities within the described area.

- Applies in all state waters north of State Road 64 in Manatee County (excluding Palma Sola Bay but includes waters of the Manatee and Braden Rivers), all state waters of Hillsborough County, and all state waters of Pinellas County excluding waters of the Anclote River and its tributaries.

2021 EO 21-16 Amendment 1 (Redfish, Snook, and Spotted Seatrout: Tampa Bay Area) Effective: July 16, 2021 – October 11, 2021

Extends provisions of EO 21-16 to October 11, 2021

2022 EO 21-07 Amendment 1/EO 22-14 (Redfish, Snook, and Spotted Seatrout: Southern Manatee through Northern Collier) Effective: June 1, 2021 – August 31, 2022

Extends provisions of EO 21-07 to August 31, 2022

## Alabama

### *Alabama Department of Conservation and Natural Resources (ADCNR); Alabama Marine Resources Division (MRD)*

Alabama Department of Conservation and Natural Resources
Marine Resources Division
P.O. Box 189
Dauphin Island, Alabama 36528 (251) 861-2882
www.outdooralabama.com

Management authority of fishery resources in Alabama is held by the Commissioner of the ADCNR. The Commissioner may promulgate rules or regulations designed for the protection, propagation, and conservation of all seafood. He may prescribe the manner of taking, times when fishing may occur, and designate areas where fish may or may not be caught; however, all regulations are to be directed at the best interest of the seafood industry.

Most regulations are promulgated through the Administrative Procedures Act approved by the Alabama Legislature in 1983; however, bag limits and seasons are not subject to this act. The Administrative Procedures Act outlines a series of events that must precede the enactment of any regulations other than those of an emergency nature. Among this series of events are: (a) the advertisement of the intent of the regulation; (b) a public hearing for the regulation; (c) a 35-day waiting period following the public hearing to address comments from the hearing; and (d) a final review of the regulation by a Joint House and Senate Review Committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies and regulations of the ADCNR. The board consists of ten members appointed by the Governor for alternating terms of six years, and three ex-officio members in the persons of the Governor, the Commissioner of Agriculture and Industries, and the Director of the Alabama Cooperative Extension System. The Commissioner of the Department of Conservation and Natural Resources serves as the ex-officio secretary to the board.

The Marine Resources Division (MRD) has responsibility for enforcing state laws and regulations, for conducting marine biological research, and for serving as the administrative arm of the commissioner with respect to marine resources. The MRD recommends regulations to the Commissioner.

Alabama has a habitat protection and permitting program and a federally approved CZM program.

## Legislative Authorization

Chapters 2 and 12 of Title 9, Code of Alabama, contain statutes that affect marine fisheries.

## Reciprocal Agreements and Limited Entry Provisions

### Reciprocal Agreements

Alabama statutory authority provides for reciprocal agreements with regard to access and licenses. Alabama has no statutory authority to enter into reciprocal management agreements.

### Commercial Landings Data Reporting Requirements

Alabama law requires all saltwater finfish commercially harvested in state waters, except those lawfully taken by purse seine, shall be landed in the state and reported to a licensed seafood dealer. Wholesale seafood dealers are required to file monthly reports by the tenth of each month for the preceding month. Under a cooperative agreement, records of sales of seafood products are now collected jointly by NMFS and ADCNR port agents. Proof must be provided showing the out of state origin of Redfish. Fish brought into Alabama; proof must be provided where the fish were caught commercially. An affidavit with Fisherman's name, where caught, commercial fisherman's license number and issuing state must be on the records maintained by the seafood dealer.

### Penalties for Violations

Violations of the provisions of any statute or regulation are considered Class A, Class B, or Class C misdemeanors and are punishable by fines up to $6,000 and up to one year in jail.

### License Requirements

In Alabama waters, a license is required to land Red Drum recreationally. Recreational saltwater fishing licenses are required of residents and non-residents fishing in state territorial waters as well as the EEZ and current regulations must be adhered to. Check with the ADCNR MRD for current Red Drum limits and license requirements.

Residents and non-residents under the age of 16 and residents over the age of 65 are exempt from the purchase of a recreational license. Saltwater angler registration is required for residents who are not required to purchase an annual saltwater license such as those 65 or older, have a lifetime saltwater license, or fish exclusively on a pier that has purchased a pier fishing license. Resident and non-resident anglers under the age of 16 do not have to register.

### Laws and Regulations

Alabama laws and regulations regarding the harvest of Red Drum have been in place for several decades. The following is a general summary of these laws and regulations and are current through the publication of this profile. The ADCNR/MRD should be contacted for specific and up-to-date information.

### *Gear Restrictions*

Red Drum may ONLY be taken by ordinary hook-and-line.

### *Closed Areas and Seasons*

Red Drum are illegal to possess or catch in federal waters.

### *Size Limits*

Alabama has a 16” to 26” total length minimum size limit for recreationally caught Red Drum.

### *Quotas and Bag/Possession Limits*

There is a bag/possession limit of three fish per person per day, with one of the three fish allowed to be greater than 26”, for the recreational fishery.

### *Other Restrictions*

Alabama designated the Red Drum as a gamefish in 1985, thus making it illegal to commercially fish for or land Red Drum in Alabama territorial waters.

## Historical Changes to Regulations in Alabama Affecting Red Drum

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for informative purposes.

1978 Established a 25 per day limit on redfish (Red Drum). No more than two days limit on trips lasting more than two days. Minimum size is 14” Total Length, but not more than two over 36 inches. (78-MR-10)

1981 Size limit still 14” total length but no more than two fish over 36”. Establishes a 5% allowance for undersize fish of the 25 fish limit. (82-MR-1)

1982 Regulation reworded to change the 5% undersized fish to 5% OTHER SIZED fish.

1984 The rule changes that “individuals fishing in the waters of the State of Alabama are limited to…”. Limit changes to 15 fish per day, with a two-day limit still allowed for two-day (or more) trips. Commercial and Non-Commercial limit still allows 5% allowance for “other sized fish”. (83-MR-11)

1984 Regulation stating that the possession of Redfish for sale is now illegal. Illegal to catch Redfish with a trawl. (83-MR-12)

1984 Taking of Redfish by any means whatsoever is illegal for 30 days. January 11, 1984 to February 10, 1984. (84-MR-2)

1985 Proof must be provided showing the out of state origin of Redfish. Fish brought into Alabama; proof must be provided where the fish were caught commercially, Affidavit with Fisherman’s name, where caught, commercial fisherman’s license number and issuing state. (85-MR-1)

1985 Redfish and Speckled Sea Trout Gamefish Regulation with annual renewal (85-MR-2)

1986 Redfish slot limit max size changed from 36” to 32” (86-MR-4)

1986 Red Drum permanently declared gamefish (86-MR-5)

1987 Redfish creel limit changes to 5 fish per day. Two-day limit on trips two days or more still allowed. Other sized fish limit changes to 2 fish (from 5%). Maximum size limit changes to 32” total length (87-MR-1)

1988 Size changes to 16” minimum, but not longer than 26” total length. Two fish per day of OTHER SIZE fish no longer applies to Redfish. No oversized fish allowed and only one undersized fish allowed. Limit changes to 3 fish per day. (88-MR-3)

1989 The two-day possession limit is repealed. (89-MR-4)

1989 Limit changed from “daily catches” to “Possession Limit”. 3 per person per day. No redfish shall exceed the maximum size other than a maximum of 2 if bearing tags registered with the Marine Resources Division and only one Redfish may be smaller than the minimum size regardless of whether the fish is tagged or untagged. (89-MR-9)

1992 Taking of redfish prohibited by means of a trawl. (92-MR-9)

1994 Size 16” minimum to 26” total length. No undersize Red Drum allowed. One oversized Red Drum allowed. 3 fish per person per day. (94-MR-6)

1997 1 oversized fish allowed in the 3 fish limit. Redfish renamed Red Drum in the Regulations (97-MR-1)

2010 Federal agreement to allow state officers the ability to write a state citation instead of a Federal citation in federal waters for possession of Red Drum in federal waters: “No person who is subject to the jurisdiction of the State of Alabama shall possess a Red Drum in federal waters.”

## Mississippi

### Mississippi Department of Marine Resources (MDMR)

Mississippi Department of Marine Resources
1141 Bayview Avenue
Biloxi, Mississippi 39530
(228) 374-5000
www.dmr.ms.gov

The MDMR has the authority to exercise full jurisdiction over all aquatic life and to regulate matters pertaining to seafood. The administrative head of the MDMR is the Executive Director, who is appointed by the Governor, and has the authority to carry out all regulations and rules adopted by the MDMR. In addition to other powers and duties authorized by state law, MDMR, with advice from the Mississippi

Advisory Commission on Marine Resources (MACMR), has the power to adopt, promulgate, amend, or repeal regulations and policies regarding marine resources (Mississippi Code 49-15-15). All regulations adopted by the MDMR are listed under Title 22 Parts 1 – 23. The MACMR consists of five members appointed by the Governor with advice from the Senate. The five members represent different sectors of the seafood industry including the following: Commercial Fishing, Commercial Seafood Processing, Recreational Fishing, Charter Boat Operators, and Nonprofit Environmental Organizations. Full power is vested in the MACMR to advise the Executive Director of the MDMR on all matters pertaining to saltwater aquatic life and marine resources (Mississippi Code 49-15-301).

Mississippi has habitat protection and permitting programs, and a federally approved Coastal Zone Management (CZM) program.

## Legislative Authorization

Mississippi code 49-15-15 authorizes the MDMR, with the advice of the MACMR, to exercise full jurisdiction and authority over all marine aquatic life and to regulate any matters pertaining to seafood, including cultivated seafood. Mississippi Code 49-15-304 gives the MDMR, with the advice of the MACMR, the authority to adopt, modify, or repeal rules or regulations to utilize, manage, conserve, preserve and protect the flora, fauna, tidelands, coastal wetlands, coastal preserves, marine waters and any other matter pertaining to marine resources under its jurisdiction. Mississippi code 49-15-305 gives the Executive Director of the MDMR the authority to carry out all regulations and rules adopted by the department and enforce all licenses and permits issued by the department.

In 1993 the Mississippi Commission on Wildlife, Fisheries and Parks, pursuant to the authority in Mississippi code 25-43-9 (1972), adopted Public Notice No. 3306 (re-codified as Miss. Admin. Code 40-4:2.5) and established the dividing line between marine and fresh waters. Specifically, Public Notice No. 3306 provide: “Be it ordered that the southern boundary of Interstate 10 extending from the Alabama state line to the Louisiana state line is hereby declared to be the boundary line between salt and fresh waters for the purposes of the game and fish laws of this state. Be it further ordered that on all waters south of I-10 and north of U.S. Highway 90, either a salt or fresh water sportfishing license will be valid for the purpose of recreational fishing”. This adopted Public Notice became effective on September 24, 1993.

## Reciprocal Agreements and Limited Entry Provisions

### Reciprocal Agreements

Mississippi code 49-15-15 (h) provides MDMR the authority to enter into or continue any existing interstate and intrastate agreements, in order to protect, propagate, and conserve seafood in the state of Mississippi.

Mississippi code 49-15-30 gives the MDMR the authority to regulate nonresident licenses in order to promote reciprocal agreements with other states.

### Limited Entry

Mississippi code 49-15-16 gives the MDMR authority to develop a limited entry fisheries management program for all resource groups. Statute 49-15-29 (3), when applying for a license of any kind, the MDMR will determine whether the vessel or its owner is in compliance with all applicable federal and/or state regulations. If it is determined that a vessel or its owner is not in compliance with applicable federal and/or state regulations, no license will be issued for a period of one year.

Mississippi code 49-15-80, no non-resident will be issued a commercial fishing license for the taking of fish using any type of net, if the non-residents state of domicile prohibits the sale of the same commercial net license to a Mississippi resident.

## Commercial Landings Data Reporting Requirements

Title 22 Part 09, Chapter 06 of the MDMR establishes data reporting requirements for marine fisheries operations, including confidentiality of data and penalties for falsifying or refusing to make the information available to the MDMR. Furthermore, Title 22 Part 09 Chapter 06 Rule 6.1 states that each seafood dealer/processor is hereby required to complete Mississippi trip tickets provided by the MDMR. Commercial fishermen, who sell their catch to individuals other than a Mississippi dealer/processor, are hereby required to complete Mississippi trip tickets provided by the MDMR and be in possession of a fresh product permit. Commercial fishermen who transport their catch out-of-state are required to purchase and possess a fresh product permit and are required to comply with all regulations governing Mississippi seafood sales.

Mississippi implemented a trip ticket program under these guidelines beginning January 1, 2012. Under this rule, fishermen and dealer/processors must submit their completed trip tickets as well as a monthly summary form to the MDMR by the tenth of the following month.

## Penalties for Violations

Mississippi code 49-15-63 provides penalties for violations of Mississippi laws and regulations regarding Red Drum in Mississippi.

## License Requirements

A license is required to harvest Red Drum recreationally from all Mississippi marine waters. Recreational saltwater fishing licenses are required of residents and non-residents fishing in state territorial waters and all harvest must be in accordance with current MDMR regulations. A saltwater fishing license is required to fish south of Highway 90. Above Highway 90 and below Interstate 10, either a saltwater or freshwater license will suffice. Above Interstate 10 a freshwater license is required. Persons under the age of 16 are exempt. Residents 65 years of age or older can purchase a lifetime license for a one-time fee. A commercial hook and line and/or net boat license is required to harvest Red Drum commercially in Mississippi waters. Check with the MDMR for all current license requirements.

## Laws and Regulations

Mississippi Title 22 Part 03 contains the regulations regarding Red Drum harvest for the recreational and commercial fisheries. Chapters 07 and 08 of Title 22 Part 03 list the size limits, possession/bag limits, and the Total Allowable Catch (TAC) for Red Drum. The TAC only applies to the commercial Red Drum fishery. These regulations are current to the date of this publication and are subject to change at any time thereafter. The MDMR should be contacted for specific and current information.

### Size Limits

Mississippi has a slot limit for Red Drum harvest. The minimum size is 18” TL and a maximum length of 30” TL. Anglers are allowed to harvest one Red Drum over 30” each day. The slot limit is the same for the recreational and commercial fishery.

### Quotas and Bag/Possession Limits

There is a bag/possession limit of three fish/person/day for the recreational Red Drum fishery. The annual TAC for commercial Red Drum harvest is 60,000 pounds.

### Closed Areas and Seasons

There are no closed areas or seasons related to recreationally caught Red Drum in Mississippi waters. Commercial harvest of Red Drum is prohibited north of the CSX train bridges in the three coastal counties. The TAC for commercial harvest is divided into three four-month periods. Each four-month period has a 20,000 lb quota. The four-month periods are January 1 – April 30, May 1 – August 31, and September 1 – December 31. In the event the commercial TAC is not met or exceeded in any time period, the pounds shall be added or subtracted to the following time period.

## Historical Changes in Regulations in Mississippi Affecting Red Drum

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for interpretive purposes.

1986 Commercial quota set at 200,000 pounds. Closure for the harvest of Red Drum with nets (other commercial fishing methods unaffected) from September 15 - November 15. Harvest of Red Drum by purse seine or spotter aircraft prohibited.

Recreational 14-inch minimum TL set and ten (10) fish per day, with only two (2) Red Drum over 30 inches.

1989 Recreational season closure from November 15, 1989 through May 15, 1990.

1990 Commercial quota reduced to 35,000 pounds during the season from October 1 to September 30. Commercial minimum lengths set at 14-inches TL through May 31 and 22-inches TL after May 31.

Oct 1990 - Red Drum landed legally elsewhere and/or transported into or within Mississippi for sale, must be accompanied by an affidavit or certificate from the regulating agency of the point of origin stating that the fish were legally landed or accompanied by a Bill of Lading if imported from a foreign county. Cobia or Red Drum raised on permitted aquaculture facilities must be accompanied by a Bill of Lading with the permit number attached and may be sold below the prescribed minimum lengths

Recreational limits changed to two (2) Red Drum over 30-inches through May 31. Starting April 1, recreational Red Drum minimum size at 22-inches TL and three (3) fish per day, only one (1) exceeding 30-inches (total length)

1991 Commercial Red Drum minimum length changed to 22-inches TL. Commercial harvesters may land one (1) Red Drum over 30-inches in quota.

1994 July 1, commercial and recreational minimum size 16-inches TL and only one (1) exceeding 30-inches TL. After November 1, 1994 commercial and recreational minimum size 18-inches TL and only (1) exceeding 30-inches TL.

1996 Commercial and recreational minimum size 18-inches TL and only (1) exceeding 30-inches TL.

2014 Commercial quota increased to 50,000 pounds. Commercial and recreational minimum size 18-inches TL and only (1) exceeding 30-inches TL.

2015 Commercial quota increased to and annual TAC at 60,000 pounds and January 1 – December 31 season. The TAC was divided into three four-month periods of 20,000 pounds of quota allowed in each for January 1 – April 30, May 1 – August 31 and September 1 – December 31. In the event the commercial TAC is not met or exceeded in any time period, the pounds shall be added or subtracted to the following time period. Commercial and recreational minimum size 18-inches TL and only (1) exceeding 30-inches TL.

## Louisiana

### Louisiana Department of Wildlife and Fisheries (LDWF)

Louisiana Department of Wildlife and Fisheries
P.O. Box 98000
Baton Rouge, Louisiana 70898-9000
Marine Fisheries: (225) 765-2384
Law Enforcement: (225) 765-2989
www.wlf.state.la.us

The Louisiana Department of Wildlife and Fisheries (LDWF) is one of 21 major administrative units of the Louisiana government. The Governor appoints a seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC). Six of the members serve overlapping terms of six years, and one serves a term concurrent with the Governor. The commission is a policy-making and budgetary-control board with no administrative functions. The legislature has authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LWFC and the LDWF. The LWFC may set possession limits, quotas, places, seasons, size limits, and daily take limits based on biological and technical data. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control, and operation of the functions, programs, and affairs of the department. The Governor, with consent of the Senate, appoints the Secretary.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. This office performs:

> "the functions of the state relating to the administration and operation of programs, including research relating to oysters, water bottoms and seafood including, but not limited to, the regulation of oyster, shrimp, and marine fishing industries."

The Enforcement Division, in the Office of the Secretary, is responsible for enforcing all marine fishery statutes and regulations.

Louisiana has habitat protection and permitting programs and a federally-approved CZM program. The Department of Natural Resources is the state agency that monitors compliance of the state Coastal Zone Management Plan and reviews federal regulations for consistency with that plan.

## Legislative Authorization

Title 56, Louisiana Revised Statutes (L.R.S.) contains statutes adopted by the Legislature that govern marine fisheries in the state that empower the LWFC to promulgate rules and regulations regarding fish and wildlife resources of the state. Title 36, L.R.S. creates the LDWF and designates the powers and duties of the department. Title 76 of the Louisiana Administrative Code contains the rules and regulations adopted by the LWFC and the LDWF that govern marine fisheries.

Section 320 of Title 56 (L.R.S.) establishes methods of taking freshwater and saltwater fish. Additionally, Sections 325.1 and 326.3 of Title 56 (L.R.S.) give the LWFC the legislative authority to set possession limits, quotas, places, season, size limits, and daily take limits for all freshwater and saltwater finfish based upon biological and technical data.

## Reciprocal Agreements and Limited Entry Provisions

### Reciprocal Agreements

The LWFC is authorized to enter into reciprocal management agreements with the states of Arkansas, Mississippi, and Texas on matters pertaining to aquatic life in bodies of water that form a common boundary. The LWFC is also authorized to enter into reciprocal licensing agreements.

Louisiana seniors, 65 years of age and older, are not required to purchase a non-resident license to fish in all public waters in Texas. These anglers will be allowed to fish Texas water bodies with a Louisiana Senior fishing license but shall comply with Texas law. Senior anglers are advised that anglers turning 60 before June 1, 2000 are also required to possess a Louisiana Senior fishing license when fishing in Texas, except in border waters. Louisiana residents from 17-64 years of age will still be required to purchase a non-resident fishing license when fishing in Texas, except when fishing in border waters.

In all border waters, except the Gulf of Mexico, Texas and Louisiana anglers possessing the necessary resident licenses, or those exempted from resident licenses for their state, are allowed to fish the border waters of Louisiana and Texas without purchasing non-resident licenses. Border waters include Caddo Lake, Toledo Bend Reservoir, the Sabine River, and Sabine Lake.

Louisiana is also allowing Texas senior residents 65 years of age and older, to fish throughout Louisiana's public waters if they possess any type valid Special Texas Resident licenses for seniors as issued by Texas Parks and Wildlife, any type of water, saltwater or freshwater. Even Texas residents born before September 1, 1930 must possess the Texas Special Resident Fishing license when fishing in Louisiana, except in border waters.

### Limited Entry

No limited entry exists to commercially take Red Drum with legal commercial gear. Red Drum cannot be taken commercially in Louisiana

## Commercial Landings Data Reporting Requirements

Wholesale/retail seafood dealers who purchase Aquaculture Red Drum from licensed dealers are required to report those purchases by the tenth of the following month on trip tickets supplied by the Department for that purpose.

## Penalties for Violations

Violations of Louisiana laws or regulations concerning the commercial taking of Red Drum shall constitute a Class 5B violation. A class 5-B violation shall for the first offense be a fine of not less than $350 and not more than $500 and shall be imprisonment in jail for 30 days. For the second offense the violator shall be fined not less than $500 and not more than $1,000 and shall be imprisoned in jail for 60 days. For the third and all subsequent offenses, the violator shall be fined not less than $1,000 and not more than $2,000 and shall be imprisoned in jail for 90 days.

In addition to the above fines and jail sentences, the license under which the violation occurred shall be revoked and shall not be reinstated at any time during the period for which it was issued and for one year thereafter.

The above penalties in all cases shall include forfeiture to the department of anything seized in connection with the violation.

Violations of Louisiana laws or regulations concerning the recreational taking of Red Drum by legal gear shall constitute a Class 2 violation which is punishable by a fine from $100 to $350 or imprisonment for not more than 60 days, or both. Second offenses carry fines of not less than $300 or more than $550 and imprisonment of not less than 30 days or more than 60 days. Third and subsequent offenses have fines of not less than $500 or more than $750 and imprisonment for not less than 60 days or more than 90 days and forfeiture of all equipment involved with the violation. Civil penalties may also be imposed.

In addition to any other penalty, for a second or subsequent violation of the same provision of law, the penalty imposed may include revocation of the permit or license under which the violation occurred for the period for which it was issued, and barring the issuance of another permit or license for that same period.

## Laws and Regulations

Louisiana laws and regulations regarding the harvest of Red Drum include gear restrictions and other provisions. The following is a general summary of these laws and regulations. They are current to the date of this publication and are subject to change at any time thereafter. The LDWF should be contacted for specific and up-to-date information.

### Size Limits

There is a 16” minimum total length and a 27” maximum total length, with one fish allowed over 27”, recreational size limit for Red Drum. No commercial take is allowed in Louisiana.

### Gear Restrictions

Commercial take is prohibited.

Licensed recreational fishermen may take Red Drum recreationally with a bow and arrow, scuba gear, hook and line, and rod-and-reel.

### Closed Areas and Seasons

Recreational harvest of Red Drum is prohibited in and from the EEZ and commercial take is prohibited from all areas.

### Quotas and Bag/Possession Limits

There is a five fish recreational bag limit and a two-day possession allowed on land.

### Other Restrictions

The use of aircraft to assist fishing operations is prohibited. Red Drum must be landed 'whole' with heads and tails attached; however, they may be eviscerated and/or have the gills removed. For the purpose of consumption at sea aboard the harvesting vessel, a person shall have no more than two pounds of finfish parts per person on board the vessel, provided that the vessel is equipped to cook such finfish. The provisions shall not apply to bait species.

## Historical Changes in Regulations in Louisiana Affecting Red Drum

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for informative purposes.

1977 Monofilament webbing banned in all saltwater nets except on board properly permitted vessels while engaged in the Pompano and Black Drum underutilized species program. Maximum net lengths of 1,200 feet established. Established a minimum mesh size of 2 inches bar for saltwater gillnets, and minimum bar meshes of 1 inch for the inside wall of saltwater trammel nets and 1 inch for saltwater fish seines.

1980 Established a minimum mesh size of 3 inches bar on the outer layer of saltwater trammel nets.

1983 All saltwater trammel nets to consist of three layers. Implemented a minimum mesh size of 1-inch bar for saltwater fish seines.

1984 Recreational creel limit of 50 fish (combined Red Drum and Spotted Seatrout) established. One day limit in possession. No minimum size limit but a maximum of two fish over 36 inches total length established.

Possession of a saltwater fishing license required for all anglers fishing south of the officially established "saltwater line" for saltwater species.

Commercial slot limit with a minimum of 16 inches total length and a maximum of 36 inches total length established.

Required minimum bar mesh sizes of 1 ¾ inches for saltwater gillnets and $1^{5}/_{8}$ inches for the inside wall of saltwater trammel nets and a maximum mesh size of 12 inches bar for the outside wall of trammel nets. Mandated a mesh size of 1-inch bar for fish seines.

1986 Recreational size limit adjusted to no more than 2 fish over 30 inches total length allowed, still no minimum size limit. Creel remains unchanged.

Commercial 30-inch total length maximum size limit established. Ban on vessels carrying purse seines to possess Red Drum established.

1987 Recreational slot limit established with a minimum size limit of 14 inches total length and no more than 2 fish over 30 inches maximum total length allowed. Creel remains unchanged.

Commercial slot limit changed to 18-inch total length minimum size and 30-inch total length maximum size. Quota of 1.8 million pounds established.

Established a minimum bar mesh size of 1¾ inches for the inside wall of saltwater trammel nets and 1 ¾ inches for saltwater fish seines.

1988 January – Recreational minimum size limit changed to 15 inches total length. Creel and maximum size and over maximum size allotment remain unchanged.

February – Recreational harvest closed until July 21, 1988. Commercial harvest quota reached and commercial harvest closed.

July – Recreational creel limit changed to 5 fish per person. Recreational slot limit changed to a 16 inches total length minimum size and a 27 inches total length maximum size with 1 fish over 27 inches allowed within the creel limit. Commercial harvest moratorium established for 3 years. Gamefish status granted to Red Drum.

1991 Per R.S. 56:325.3(B), Commercial harvest moratorium extended indefinitely.

1995 Required possession of a Marine Resources Conservation Stamp by all saltwater anglers (three-year period with automatic expiration in 1998).

1997 Per R.S. 56:325.1(B)(2), Recreational saltwater fishermen in possession of a valid basic and saltwater license may possess twice the daily bag limit of Red Drum and Spotted Seatrout; however, no person shall be in possession of over the daily bag limit while fishing or while on the water, unless such recreational saltwater fisherman is aboard a trawler engaged in commercial fishing for a consecutive period of longer than 25 hours.

2018 Per R.S. 56:325.1(A)(4), The possession limit for Red Drum and Spotted Seatrout taken south of U.S. Highway 90 shall be three times the daily take limit when the fisherman holds and is in possession of a valid recreational fishing license and can show a landing receipt from a public boat launch located south of U.S. Highway 90 that demonstrates to the satisfaction of the department that the fisherman has been actively on the water or at a remote camp that can be accessed only by water for two days or more. The fish shall be kept whole or whole gutted in separate bags for each species of fish. The bags shall be marked with the date the fish were taken, the species, the number of fish contained in the bag, and the name and license number of the person taking the fish. The fish shall only be in the possession of the person who took the fish. However, no fisherman shall be actively fishing or engaged in fishing while in possession of more than the daily take limit.

2018 Per R.S. 56:325.1(A)(3)(b), Notwithstanding the provisions of Subparagraph (a) of this Paragraph and R.S. 56:325.2(A) and (B), a fisherman who holds and is in possession of a valid recreational fishing license and can demonstrate to the department's satisfaction use of a boat launch located south of U.S. Highway 90 and that the fisherman has been actively on the water or at a remote camp that can be accessed only by water for two days or more may possess up to the possession limit of filleted Red Drum, Spotted Seatrout, and Southern flounder. The filleted fish shall have sufficient skin remaining on the fillet to allow for identification of the species and shall be segregated by species into plastic bags or plastic containers that are marked by species to allow easy identification, the date caught, and the name and license number of the person who took the fish. The Spotted Seatrout fillets shall be no less than ten inches in length and the Red Drum shall be no less than fourteen inches in length. The fish shall be in the possession only of the person who took the fish. However, no fisherman shall be actively fishing or engaged in fishing while in possession of more than the daily take limit.

## Texas

### Texas Parks and Wildlife Department (TPWD)

Texas Parks and Wildlife Department
Coastal Fisheries Division
4200 Smith School Road Austin, Texas 78744
(512) 389-4863
www.tpwd.texas.gov

The TPWD is the administrative unit of the state charged with management of the coastal fishery resources and enforcement of legislative and regulatory procedures under the policy direction of the Texas Parks and Wildlife Commission (TPWC). The TPWC consists of nine members appointed by the Governor for staggered six-year terms. The TPWC selects an Executive Director who serves as the administrative officer of the department. The Executive Director selects the Director of Coastal Fisheries, Inland Fisheries, Wildlife, and Law Enforcement Divisions. The Coastal Fisheries Division, headed by a Division Director, is under the supervision of the Chief Operating Officer.

Texas has habitat protection and permitting programs and a federally-approved Coastal Zone Management (CZM) program. The Texas General Land Office (TGLO) is the lead agency for the Texas CZM. The Coastal Coordination Council monitors compliance of the state Coastal Management Program and reviews federal regulations for consistency with that plan. The Coastal Coordination Council is an 11-member group whose members consist of a chairman (the head of TGLO) and representatives from Texas Commission on Environmental Quality, TPWC, the Railroad Commission, Texas Water Development Board, Texas Transportation Commission, and the Texas Soil and Water Conservation Board. The remaining four places of the council are appointed by the governor and are comprised of an elected city or county official, a business owner, someone involved in agriculture, and a citizen. All must live in a coastal zone.

### Legislative Authorization

Chapter 11, Texas Parks and Wildlife Code, established the TPWC and provided for its make-up and appointment. Chapter 12, Texas Parks and Wildlife Code, established the powers and duties of the TPWC, and Chapter 61, Texas Parks and Wildlife Code, provided the TPWC with responsibility for marine fishery management and authority to promulgate regulations. Chapter 47, Texas Parks and Wildlife Code, provided for the commercial licenses required to catch, sell, and transport finfish commercially, and Chapter 66, Texas Parks and Wildlife Code, provided for the sale, purchase, and transportation of protected fish in Texas. All regulations pertaining to size, bag, and possession limits, and means and methods pertaining to fish and marine life are adopted by the TPWC and included in the Texas Statewide Recreational and Commercial Fishing Proclamations.

## Reciprocal Agreements and Limited Entry Provisions

### Reciprocal Agreements

Texas statutory authority allows the TPWC to enter into reciprocal licensing agreements in waters that form a common boundary, i.e., the Sabine River area between Texas and Louisiana. Texas has no statutory authority to enter into reciprocal management agreements.

### Limited Entry

Chapter 47, Texas Parks and Wildlife Code, provides that no person may engage in business as a commercial finfish fisherman unless a commercial finfish fisherman's license has been obtained. Beginning September 1, 2000, a commercial finfish license could only be sold to a person who documented, in a manner acceptable to the department, that the person held a commercial finfish license during the period after September 1, 1997 through April 20, 1999. In order to qualify for entry into the finfish license management program, the person was required to file an affidavit with the department at the time the license was applied for that stated:

1. the applicant was not employed at any full-time occupation other than commercial fishing; and,
2. during the period of validity of the commercial finfish fisherman's license, the applicant did not intend to engage in any full-time occupation other than commercial fishing.

## Commercial Landings Data Reporting Requirements

Commercial harvest of Red Drum in Texas was stopped in 1983 by the passage of House Bill 1000 which gave Red Drum "game fish" status, making their harvest by commercial fishermen illegal. The only commercial source of Red Drum in Texas is through aquaculture operations that provide farm raised Red Drum to wholesalers.

## Penalties for Violations

Penalties for violations of Texas' proclamations regarding Red Drum are provided in Chapter 61, Texas Parks and Wildlife Code, and most are Class C misdemeanors punishable by fines ranging from $25 to $500. Under certain circumstances, a violation can be enhanced to a Class B misdemeanor punishable by fines ranging from $200 to $2,000; confinement in jail not to exceed 180 days; or both.

## Annual License Fees

A license is required to land Red Drum recreationally from all Texas marine waters. Recreational harvest of Red Drum is not allowed in the EEZ. Recreational saltwater fishing licenses are required of residents and non-residents fishing in state territorial waters and current regulations must be adhered to. Check with the TPWD for current Red Drum regulations. Residents of Texas under the age of 17 and residents who were born before January 1, 1931, are not required to obtain a recreational fishing license. Other exemptions may exist for active military and the disabled. Check with the TPWD for details.

Senate Bill 1303 authorizes the TPWC under Parks and Wildlife Code 47, to establish a license limitation plan for the Texas commercial finfish fishery. Commercial fishermen must have appropriate fishing licenses and permits, gear licenses, and vessel permits to be properly licensed whenever taking or possessing fish for sale in Texas saltwater areas. Currently, commercial harvest of Red Drum from Texas waters is not allowed.

## Laws and Regulations

Various provisions of the Statewide Hunting and Fishing Proclamation adopted by the TPWC affect the harvest of Red Drum in Texas. The following is a general summary of these laws and regulations. It is current through the end of August 2020 and is subject to change at any time thereafter. The TPWD should be contacted for specific and up-to-date information.

### Size Limits

A minimum size of 20" total length and a maximum size of 28" total length has been established for Red Drum in Texas. The harvest of one Red Drum over 28" is allowed if the angler affixes a "Red Drum Tag" (a removable tag that is included with a saltwater fishing license in Texas) to the caudal peduncle of the fish. Once the Red Drum Tag has been used, a Bonus Red Drum Tag may be requested by the angler and used to harvest a second Red Drum over 28" total length.

### Quotas and Bag/Possession Limits

The recreational daily bag for Red Drum is three fish per person and the possession limit is equal to two times the daily bag limit. Any Red Drum retained under the authority of a Red Drum Tag or a Bonus Red Drum Tag may be retained in addition to the daily bag limit and possession limit.

### Gear Restrictions

Gillnets, trammel nets, seines, purse seines, and any other type of net or fish trap are prohibited in the coastal waters of Texas. Red Drum is a game fish and may be legally taken by pole and line or sail line only.

### Closed Areas and Seasons

There are no closed areas or seasons for the taking of Red Drum in Texas state waters. Red Drum harvest is not allowed in federal waters (Exclusive Economic Zone) in the Gulf of Mexico off of Texas.

### Other Restrictions

Red Drum must be kept in a 'whole' condition with heads and tails attached until landed on a barrier island or the mainland; however, viscera and gills may be removed.

## Historical Changes in Regulations in Texas Affecting Red Drum

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for informative purposes.

1955 A minimum length limit of 14 inches was established for Red Drum harvested in Cameron, Kenedy, and Willacy counties only.

1967 A minimum length limit of 14 inches was established for Red Drum in all state waters.

1977 Red Drum Conservation Act became law, setting Red Drum limits for both sport and commercial fishermen. Daily bag limit was set at 10 Red Drum per day with a possession limit of 20, and a limit of 2 fish greater than 35 inches for recreational anglers. A limit of

200 pounds of Red Drum per day was set for commercial fishermen. The minimum size limit remained at 14 inches.

1981 House Bill 1000 (Redfish Bill) passed - designated Red Drum and Spotted Seatrout as gamefish and prohibited their sale. An attempt to overturn the law in federal court by commercial finfish fishermen was unsuccessful, and subsequently directed fishing effort at Black Drum, Southern Flounder and other species. Minimum size limit was increased to 16 inches and a maximum size limit of 30 inches was established.

Redfish Bill violations increased to Class B misdemeanor with fines of $200 to $1,000.

1983 In response to the historic 1983 freeze, the TPWD Commission enacted emergency regulations which reduced bag and possession limits and increased minimum length limits on Red Drum and Spotted Seatrout.

1984 Minimum length limit was increased to 18 inches and the maximum length limit remained at 30 inches. The daily bag limit was decreased to 5 Red Drum and the possession limit was decreased to 10.

1988 TPWC closes Texas waters to all trammel nets and drag seines, to promote the escapement of adult Red Drum to the Gulf and reduce bycatch of non-targeted species. Minimum size limit was increased to 20 inches with a maximum length limit of 28 inches. Daily bag was decreased to 3 Red Drum and possession limit was reduced to 6.

1989 Legislation prohibits sale of wild Red Drum.

1994 Retention of 2 fish greater than 28 in (711 mm) allowed per person per license year with properly completed and attached Red Drum Tag and Bonus Red Drum Tag; not counted as part of daily bag and possession limit.

## Regional/Interstate

### Gulf States Marine Fisheries Compact (P.L. 81-66)

The Gulf States Marine Fisheries Commission (Commission) was established by an act of Congress (P.L. 81-66) in 1949 as a compact of the five Gulf states. Its charge is:

> "to promote better utilization of the fisheries, marine, shell and anadromous, of the seaboard of the Gulf of Mexico, by the development of a joint program for the promotion and protection of such fisheries and the prevention of the physical waste of the fisheries from any cause."

The Commission is composed of three members from each of the five Gulf states. The head of the marine resource agency of each state is an ex-officio member, the second is a member of the legislature, and the third, a citizen who shall have knowledge of and interest in marine fisheries, is appointed by the governor. The chairman, vice chairman, and second vice chairman of the Commission are rotated annually among the states.

The Commission is empowered to make recommendations to the governors and legislatures of the five Gulf states on action regarding programs helpful to the management of the fisheries. The states do not relinquish any of their rights or responsibilities in regulating their own fisheries by being members of the Commission.

Recommendations to the states are based on scientific studies made by experts employed by state and federal resource agencies and advice from law enforcement officials and the commercial and recreational fishing industries. The Commission is also authorized to consult with and advise the proper administrative agencies of the member states regarding fishery conservation problems. In addition, the Commission advises the U.S. Congress and may testify on legislation and marine policies that affect the Gulf states. One of the most important functions of the Commission is to serve as a forum for the discussion of various problems, issues, and programs concerning marine management.

## Red Drum Technical Task Force

The Red Drum Technical Task Force (TTF) is organized with one scientific representative from each of the five Gulf states who is appointed by each state's director serving on the State-Federal Fisheries Management Committee (SFFMC). In addition, the TTF includes a representative from each of the Commission's Commercial Fisheries and Recreational Fisheries Advisory Panels, the Law Enforcement Committee, and the Habitat Subcommittee (the representative is chosen by action of the respective committees). In addition, other experts and specialists from other disciplines may be included on the TTF as needed (i.e., public health, economics, sociology, etc.). As with all of the Commission's TTFs, the committee becomes inactive until there is a need for revision of a profile or work on specific issues related to Red Drum in the region. The members of the TTF may be called upon to advise the Technical Coordinating Committee (TCC), the SFFMC, or the Commission on Red Drum issues in the Gulf of Mexico.

## Interjurisdictional Fisheries Act (IFA) of 1986 (P.L. 99-659, Title III)

The IFA of 1986 established a program to promote and encourage state activities in the support of management plans and to promote and encourage regional management of state fishery resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

## Development of Biological and Management Profiles for Fisheries (Title III, Section 308(C))

Through P.L. 99-659, Congress authorized the USDOC to appropriate funding in support of state research and management projects that were consistent with the intent of the IFA. Additional funds were authorized to support the development of interstate management plans by the Gulf, Atlantic, and Pacific States Marine Fisheries Commissions.

# Chapter 6
# DESCRIPTION OF THE FISHERY

Commercial landings and recreational harvest of Red Drum have fluctuated widely across the U.S., especially by region (Figure 6.1). In the Gulf of Mexico, Red Drum have long been utilized as food fish similar to their Sciaenid cousins Spotted Seatrout (*Cynoscion nebulosus*), Atlantic Croaker (*Micropogonias undulatus*), and Black Drum (*Pogonias cromis*). However, declines in overall abundances in the 1980s resulted in a number of actions intended to protect Red Drum populations and begin to rebuild the stocks across their range (Chapter 5 - Commercial Fishery History below). As a result, the commercial and recreational catches changed significantly as tighter bag and size limits were put in place and fishing in the EEZ was eliminated. In this chapter, both the commercial and recreational fishing sectors in the Gulf of Mexico which target or incidentally impact Red Drum will be highlighted.

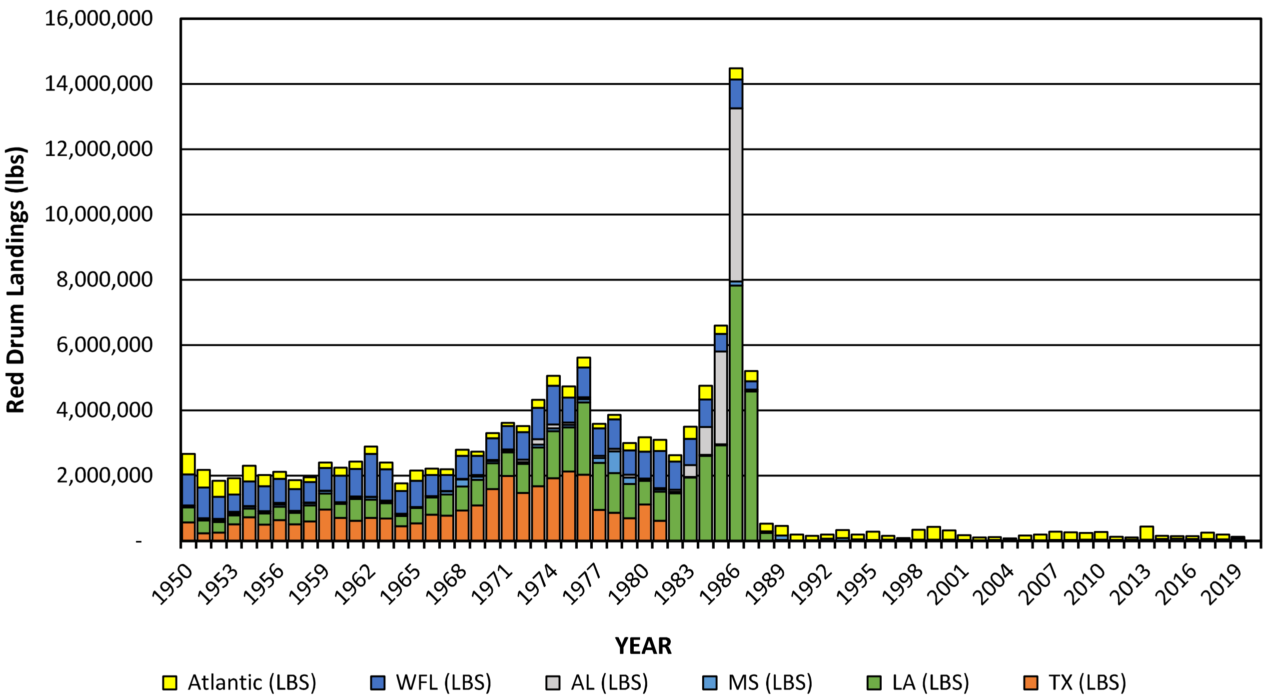



Figure 6.1 Total U.S. commercial Red Drum landings (lbs) separated for the five Gulf states and the Atlantic Coast from 1950-2020 (NOAA and FWC unpublished data).

## Commercial Fishery

### History

Red Drum have been commercially fished in the Gulf of Mexico since the 1700s (Galtsoff 1954) with annual landings consistently in the millions of pounds throughout most of the 20th century. Matlock (1980) provided an extensive history of the Red Drum fishery along both the Gulf and Atlantic Coasts and summarized the commercial landings data back to the late 1880s in the Gulf. Red Drum were never a large component of the commercial landings but were primarily landed only to meet local consumption. Matlock (1980) reported that until the 1970s, commercial landings in the Gulf were generally low in each state in the 1940s and 1950s. By 1970, the total landings were around 3.1M lbs Gulf wide. His analysis ends just prior to the explosion in demand by consumers and the rapid expansion of the fishery and need for intense management measures.

Commercial Red Drum landings along the Atlantic Coast never reached the quantity landed from the Gulf of Mexico (Figures 6.1 and 6.2). Red Drum were primarily taken in the Mid and South Atlantic as very few fish made it much further north than Chesapeake Bay. Despite the elimination of nearly the entire commercial fishery in the Gulf since 1988, the Atlantic fishery persists primarily in the state waters of North Carolina, although a few fish are landed in Virginia and Maryland.

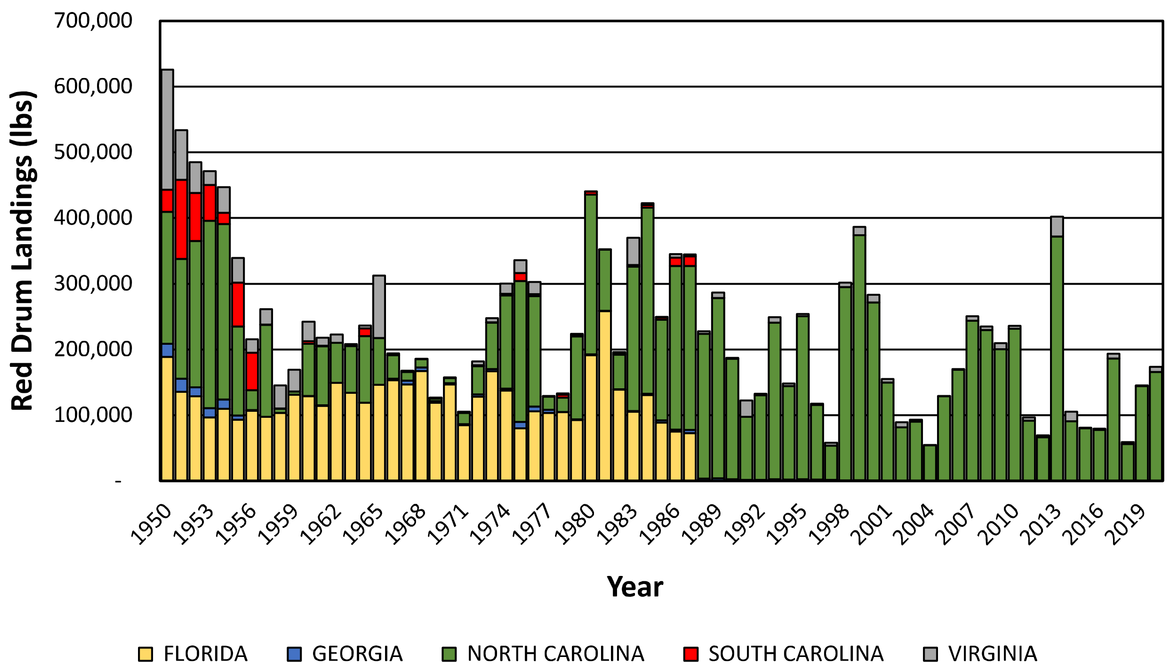



Figure 6.2 Atlantic Coast commercial Red Drum landings from 1950-2020 (NOAA and FWC unpublished data). The states of Maryland, New Jersey, and New York are not included due to minimal commercial landings historically.

Goodyear (1987) provides a history of the Red Drum fishery through 1986 when the Gulf-wide commercial landings reached the peak of 14.1M lbs (Figure 6.1). Landings for most of the states were relatively stable until the late 1970s, followed by significant increases in Louisiana and Alabama beginning in 1985 (see state sections below). The majority of the catch was derived from offshore waters in the northern Gulf when the Alabama and Louisiana purse fisheries began to target Red Drum and were quickly banned.

The increased fishing pressure on Red Drum was a direct result of the popularity of blackened redfish which was a creation of a restaurateur and chef in New Orleans in the early 1980s. As the demand for the seafood entre grew around the U.S., effort was increased by all participants in the Red Drum fishery. The significant increase (Figure 6.1) resulted in outcry from the recreational fishing community and conservation groups. In 1986, Congressman John Breaux held a hearing in New Orleans on behalf of the House Subcommittee on Fisheries, Wildlife Conservation and the Environment, to hear testimony on the expanding fishery and the need for future management. Congressman Breaux subsequently introduced H.R. 4690 (Redfish Conservation and Management Act of 1986) to require the Secretary of Commerce to implement emergency regulations to manage the fishery. As a result of the hearing and escalating offshore catches of adult fish, on June 25, 1986, the Secretary promulgated an emergency rule to limit commercial landings from the EEZ to 1M lbs while NMFS prepared a fishery management plan (FMP) for the fishery. In 1986, the Gulf of Mexico Fishery Management Council (GMFMC) held hearings regarding the status of Red Drum and implemented a rule to prohibit any directed commercial landings from the EEZ. The total landings were set at 625,000 lbs annual split between the commercial and recreational sector (325,000 and 300,000 respectively). The FMP was implemented on December 19, 1986, and prohibited directed commercial landings from the EEZ for 1987. The FMP provided for a recreational bag limit of one fish per person per trip, and an incidental catch allowance for commercial net and shrimp fishermen (GMFMC 1986).

The GMFMC prepared Red Drum Amendment 1 to the FMP which continued the prohibition of a directed commercial EEZ fishery, but converted the commercial and recreational estimated catch allowances into quotas that were restricted to EEZ waters off Louisiana, Mississippi, and Alabama (the primary area); landings were prohibited from the EEZ off Florida and Texas (secondary areas). The GMFMC also requested that all Gulf states implement rules within their jurisdictions that would provide for an escapement rate of juvenile fish to the Spawning Stock Biomass (SSB) equivalent to 20% of those that would have escaped had there been no inshore fishery. (GMFMC 1987). In late 1987, the allowances were converted to quotas off the three central states and total prohibition of EEZ landings off Florida and Texas. Finally, in 1988, Amendment 2 was implemented and possession was banned for any Red Drum from the EEZ (GMFMC 1988). Total closure of commercial Red Drum fishing from federal waters and most state waters, in combination with the eventual elimination of entanglement harvest of Red Drum near shore in most states, resulted in the near elimination of the commercial fishery by 1990 (Goodyear 1991; Figure 6.3). This action dropped commercial Red Drum landings to a fraction of what it had been (Figure 6.1).

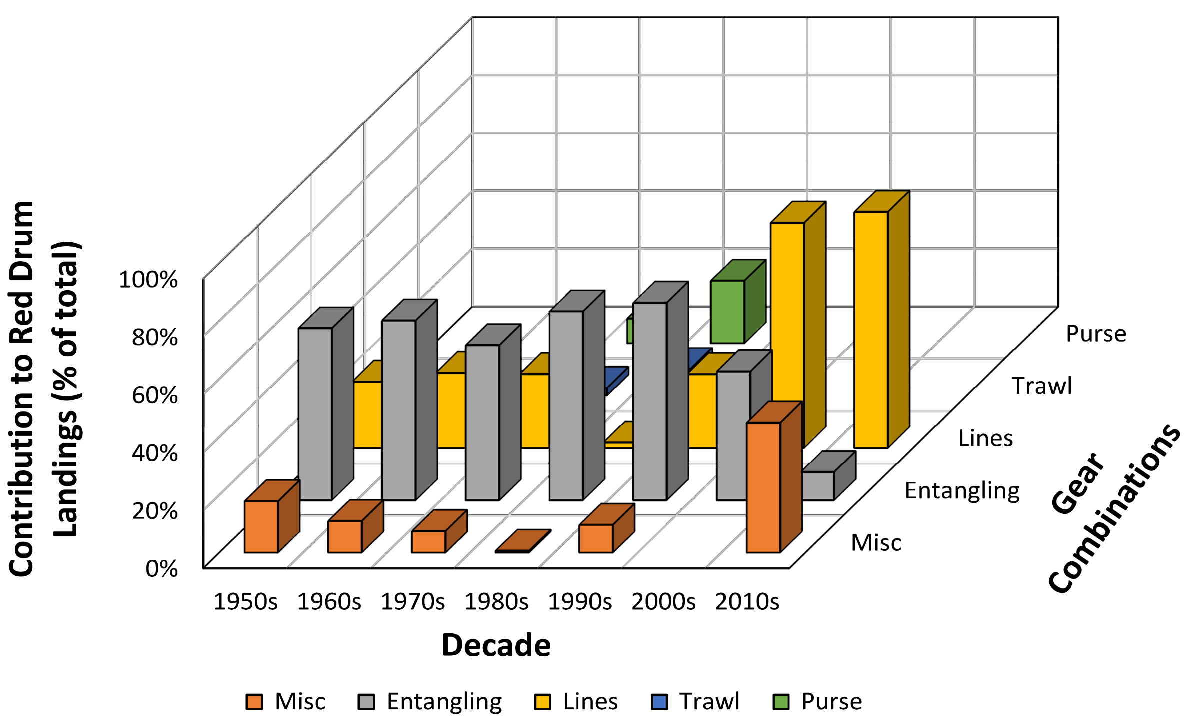



Figure 6.3 Decadal contribution by gear to the commercial Red Drum landings in the Gulf of Mexico from 1950-2019 (NOAA and FWC unpublished data).

The value of Red Drum in the market was never very high and generally supported local markets. However, with the popularity of the species in the blackened redfish craze, the value went up substantially in the Gulf. Values, as determined by NOAA, were divided against the landings to determine a rough dockside price (unadjusted for inflation; Figure 6.4). Dockside prices and market values will be detailed in Chapter 7 Economics.

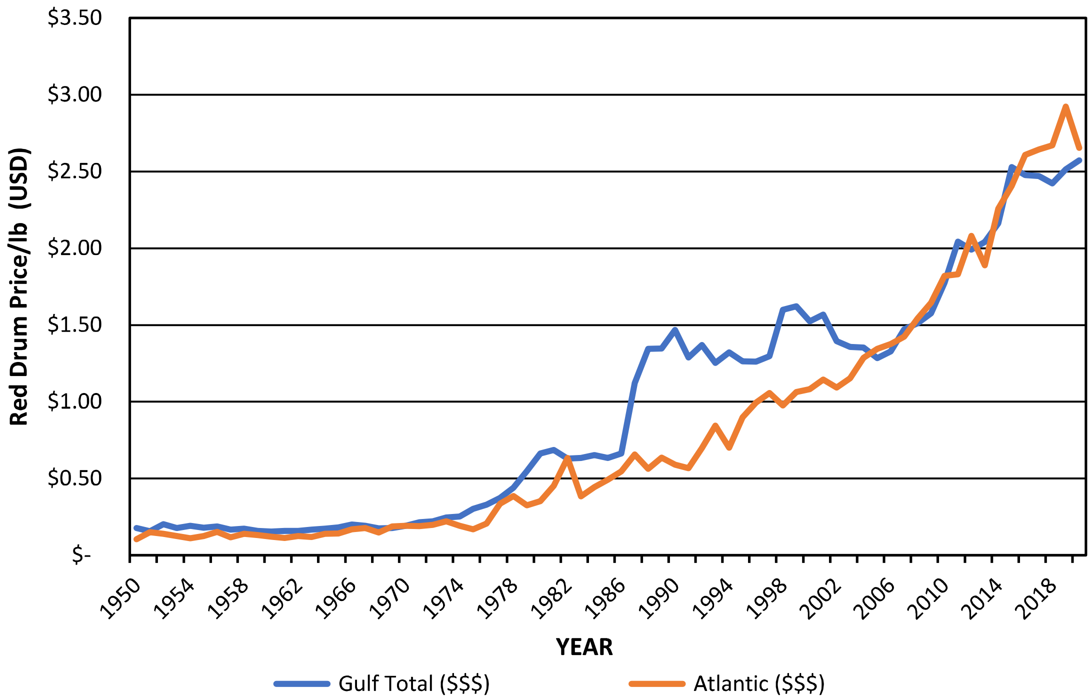



Figure 6.4 Dockside price of Red Drum in the Gulf and Atlantic as determined by the NOAA landings from 1950-2020 (NOAA unpublished data). The total landings may not accurately reflect the true landings as a number of years and states contain confidential data and have been excluded from the estimates.

## State Commercial Fisheries

Commercial landings of Red Drum have rarely exceeded 60,000 lbs in the Gulf region since the late 1980s due to the banning of commercial sales and/or harvest in Texas in 1981, Alabama in 1985, Florida in 1986, and Louisiana in 1988, and in all Federal waters in 1988. Only Mississippi has landed Red Drum commercially from their state waters with landings restricted by an annual quota; therefore, the following state-by-state descriptions of Red Drum commercial fishing is largely historic (Figure 6.5). A history of regulations impacting the commercial harvest of Red Drum in the Gulf of Mexico is summarized in Table 8.1.

Since 1990, North Carolina has become the primary source for commercial Red Drum in the U.S. despite a small commercial fishery existing in Mississippi (Figure 6.2). However, recent regulations aimed at reducing Southern Flounder harvest in North Carolina have removed the primary gear (anchored gillnets) that has been used to land Red Drum since Red Drum was regulated as a bycatch fishery. The fishery has adjusted some and Red Drum are still harvested in run-around nets targeting Striped Mullet and other species when anchored gillnets are not allowed (Kowalchyk personal communication).

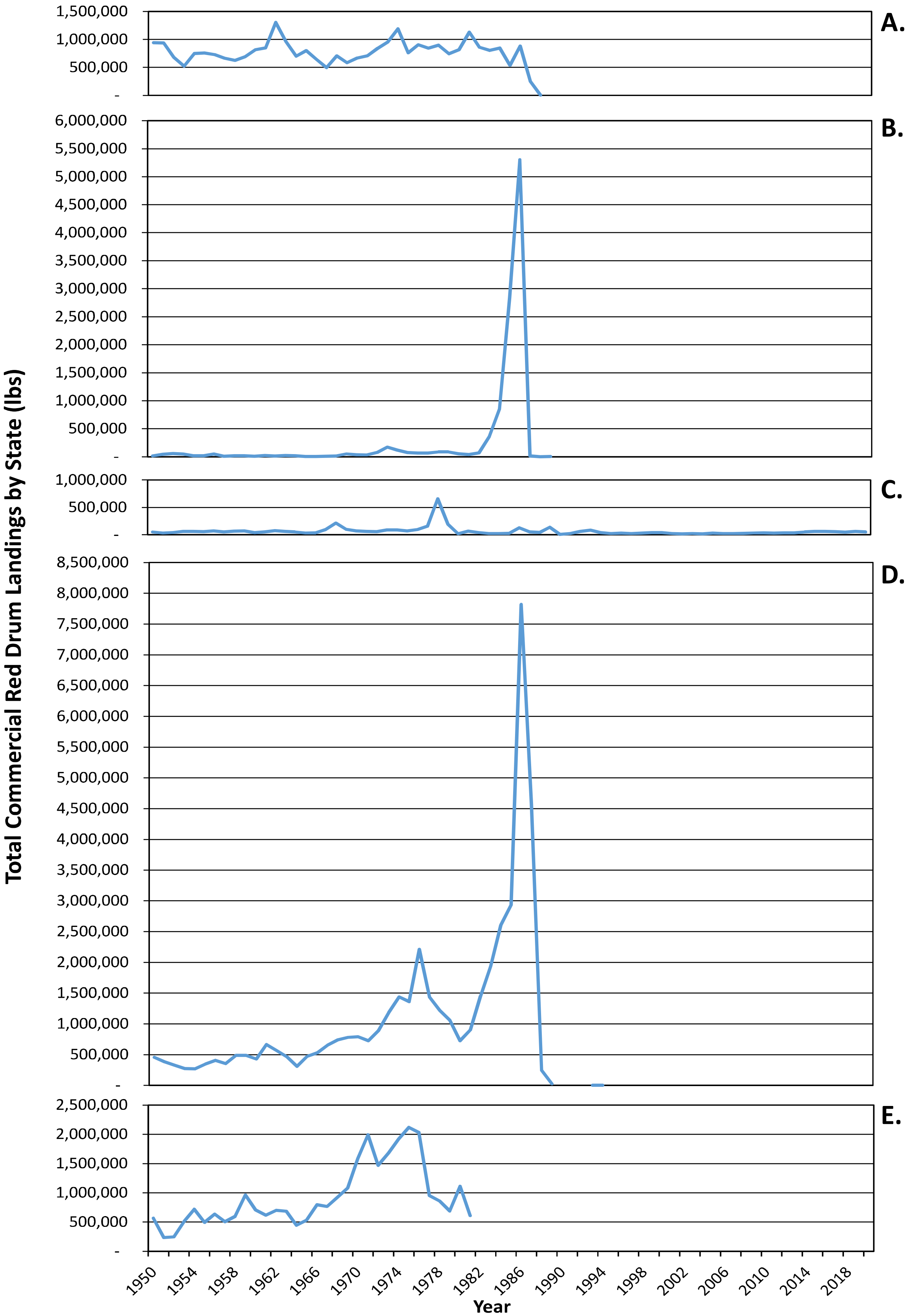



Figure 6.5 Commercial landings (lbs) of Red Drum in A). West Florida, B). Alabama, C). Mississippi, D). Louisiana, and E). Texas from 1950-2020 (NOAA and FWC unpublished data).

Table 6.1 Brief history of regulations affecting commercial harvest, including prohibitions on nets and commercial sales of Red Drum in the Gulf region.

| Year | Regulatory Actions | | | | |
|---|---|---|---|---|---|
| | Florida | Alabama | Mississippi | Louisiana | Texas |
| 1977 | | | | | Recreational bag limit of Red Drum reduced to 10/day; commercial bag limit reduced to 200 lbs/day |
| 1981 | | | | | Ban on commercial sale of Red Drum and Spotted Seatrout (via gillnet ban) |
| 1985 | | Ban on commercial sale of Red Drum and Spotted Seatrout | | | |
| 1986 | | | | Prohibited to have Red Drum or Spotted Seatrout on a vessel that also has a purse seine on board | |
| 1987 | **Federal:** Commercial sale of Red Drum banned in EEZ. Incidental bycatch on shrimping boats and other commercial fishing vessels not to exceed 200,000 and 100,000 lbs, respectively. Recreational bag limit is set at 1 fish per trip. | | | | |
| 1988 | Commercial moratorium on harvest and sale of Red Drum from state waters | Net ban on south shore of Bon Secour Bay | | Moratorium on commercial fishing for Red Drum and Sportfish designation | |
| 1989 | Permanent prohibition of sale of native Red Drum | | | | |
| 1995 | Net Limitation Amendment | | Emergency regulation restricting the issuance of gillnet licenses | Ban on entangling (gill and trammel) nets | |
| 1997 | | | Gill/trammel nets must be constructed of degradable material | | |
| 2019 | | | Entangling nets (gill and trammel) must be less than 1,200 feet in length and must have a minimum 1-½ inch$^2$ mesh size. Ban on nets within ½ mile of the shoreline | | |

### West Florida

The Gulf Coast of Florida produced around 800,000 lbs of Red Drum on average from 1950-1988 (Figure 6.5A). Florida was the largest contributor to commercial Red Drum in the Gulf through the 1950s and 1960s (Figure 6.6). In the 1970s, Florida landings remained fairly level but Louisiana and Texas began to increase their own commercial production which reduced Florida's contribution. Throughout its history, the majority of Florida's commercial catches came from entanglement nets and haul seines with a smaller portion derived from lines (NOAA unpublished data). By the late 1980s, Florida's Red Drum landings fell significantly due to restrictions put in place by Florida to address overfishing. Specifically, commercial Red Drum landings were reduced to a five-drum limit per vessel in 1987, followed by a ban on all commercial Red Drum fishing and sales from Florida waters in 1988 and then permanently in 1989.

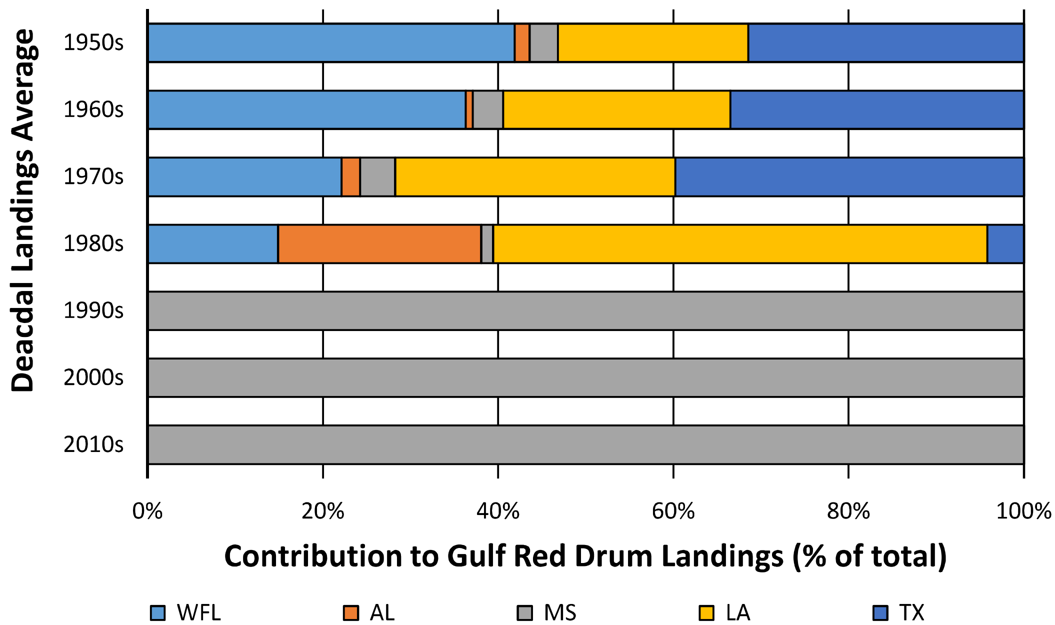



Figure 6.6 Decadal contribution by state to the commercial Red Drum landings in the Gulf of Mexico from 1950 to 2019 (NOAA and FWC unpublished data).

### Alabama

Commercial Red Drum landings in Alabama rarely exceeded 30,000 lbs until the early 1970s and began to increase in 1972 (Figure 6.5B). There were a couple of peaks in 1973 and 1974 but landings remained around 70,000 lbs on average through the early 1980s. To this point, Alabama was the smallest contributor to the total Red Drum landings in the Gulf (Figure 6.6). In 1983, landings from offshore in Alabama rapidly increased to 900,000 lbs possibly due to the regulation making it illegal to possess Red Drum with the intent to sale (83-MR-12). Subsequently, landings increased in 1985 and spiked to 5.3M lbs in 1986 primarily as a result of purse seines targeting large schools of fish in federal or adjacent state waters. Alabama regulation (85-MR-1) allowed for Red Drum harvested in other state or federal waters to be landed in Alabama. Legislation was passed in late 1986 restricting the Red Drum fishery and the landings fell to less than 6,000 lbs by 1987 and zero after 1990. Due to confidentiality issues, the gear breakdown for Alabama is not available, but Gulf-wide, purse seine and gillnet landings increased at the beginning of the 1980s (Figure 6.3) and were virtually eliminated by the late 1980s. Porch (2000) notes anecdotal reports of up to 1M lbs of Red Drum being landed by purse seines in 1981 and being transported away from the ports with no record suggesting that the official NOAA landings may be grossly underestimated during that time.

### Mississippi

Like Alabama, commercial Red Drum landings in the 1950s through the 1970s were minimal, around 62,000, with a record high of 658,000 lbs in 1978 (Figure 6.5C). Beginning in 1977, purse seiners began targeting Red Drum which contributed to the higher landings and were banned in 1979 (Porch 2000, Figure 6.6). Despite the reduction, commercial catches were further restricted to a 200,000 lbs quota beginning in 1987 which was decreased to 35,000 lbs in 1994. The quota was raised in 2014 to 50,000 lbs and then again in 2015 to 60,000 lbs annually.

With the exception of the late 1970s, the majority of commercial landings for Red Drum in Mississippi were in gill and trammel nets from the 1950s to the late 1990s. However, since the early 2000s, the use of entangling nets has declined while the use of lines (rod-and-reel and unspecified lines) has replaced them. Despite the appearance of significant changes to gears, the quota remained 35,000 to 60,000 lbs.

### Louisiana

Red Drum are no longer allowed to be landed commercially in Louisiana. Prior to 1984, no commercial regulations on Red Drum existed. Through the 1950s and 1960s, commercial landings of Red Drum in Louisiana fluctuated around 400,000 to 500,000 lbs annually (Figure 6.5D, Figure 6.6). By the late 1960s, Louisiana landings began to increase steadily to nearly 1M lbs by 1972 and 2.2M lbs by 1976 with significant numbers of juvenile taken from inshore waters. Some of the decline in landings in the late 1970s can be attributed to restricting nets to 1,200 feet in length, prohibiting the use of monofilament gillnets, and changing the allowable mesh size for gill and trammel nets. Additionally, netting was prohibited in parts of Lake Pontchartrain, parts of Lake Borgne, and within one mile of the Chandeleur Islands beginning in 1978. Then, a rapid expansion of the fishery occurred in 1980 with landings reaching 7.8M lbs by 1986.

Prior to 1960, the majority of fish landed in Louisiana were from haul seines and hook-and-line, but starting in about 1970, most of the increasing landings came from gill and trammel nets which rose to around 3.4M lbs in 1986 and 1987. An additional increase in landings after 1985 was the result of an increase in the use of purse seines, which contributed an additional 3M lbs in 1986 (Porch 2000). This increased pressure was directed at adults whereas the entangling nets were inshore and primarily targeted subadults and juveniles. Prior to the 1980s, most of the Louisiana Red Drum supplied local markets, especially New Orleans. However, the popularity of blackened redfish peaked nationwide, especially in New York markets, and led to increased demand and increased take of adult Red Drum throughout the 1980s. Given the increased demand from restaurants, commercial fishermen responded by catching Red Drum in record numbers during 1986 and 1987. Landings fell dramatically in 1988 as a quota of 1.8M lbs was established late in 1987 and reached by the end of February of 1988. In July of 1988, a commercial moratorium was established for three years through legislation and that moratorium was extended indefinitely in 1991.

### Texas

Texas landings accounted for over half the Gulf production through 1897 (GMFMC/GSMFC 1984; Figure 6.5E). Beginning in 1965, Texas commercial landings of Red Drum began increasing annually, reaching 2M lbs in 1975 and 1976 (Figure 6.5E), and this represented a removal level approximately three times higher than the annual average for the previous decade (GMFMC/GSMFC 1984). However, commercial landings began to drop sharply after this peak. The Texas fishery was dominated by various types of gillnets and trot lines and in 1981, Texas passed House Bill 1000 and declared Red Drum as a sportfish, eliminating any commercial sale and take (Porch 2000; Figure 6.6).

## Recreational Fishery

In the Gulf of Mexico and South Atlantic, Red Drum is typically one of the most sought-after species targeted by recreational anglers. Red Drum, Spotted Seatrout (*Cynoscion nebulosus*), and flounder make up the trifecta for inshore fishing. They are taken recreationally by hook-and-line with minimal skill required and are great table fare. Red Drum will actively pursue artificial baits such as plastic jigs and top water plugs or live and dead bait such as shrimp, cut fish, and squid. They can be caught by trolling, casting, or bottom fishing on set lines. Red Drum will also take live and dead crabs and are common throughout the nearshore waters.

Smaller Red Drum (rat reds) are frequently caught in the marshes and upper estuaries all along the coast. Larger adult fish (bull reds) will come inshore but are generally caught in more open water of the lower estuaries, bays, barrier islands, and offshore. In shallow water, Red Drum can be located 'tailing' as they forage for shrimp and crabs and have their heads down causing their tails to breach at the surface.

Offshore, large adults will school and can often be found chasing baitfish such as anchovies, menhaden, and sardines. Anglers will watch for feeding seabirds diving at the surface to locate bait and Red Drum schools. Often, Red Drum will feed directly on the surface creating huge disturbances in otherwise still waters that can be seen by anglers a long way off. Red Drum will also forage near shorelines seeking out burrowing organisms such as Beach Ghost Shrimp (*Callichirus islagrande*), and various mud and swimming crabs.

A wide variety of fishing gear is used to target Red Drum. Typically, medium to heavy spinning rods and reels are frequently used to take Red Drum inshore. Heavy casting rods may be used offshore for set lines and for trolling through schools with planers. Finally, many anglers target Red Drum with various weights of fly-fishing gear and most of the state agencies have adopted fly fishing records.

Red Drum could be considered an 'every person' fish in that anyone can catch them with no restrictions to access. They can be targeted from shore or dock anywhere along the estuary as well as by boat, and anyone with access to sand beaches and barrier islands can surf fish, wade fish, or float and find Red Drum. No special gear or bait is required making Red Drum one of the most common species in state surveys and creels. According to NOAA's MRIP data, the number of directed trips with Red Drum as the primary or secondary target was 9,867,547 in the South Atlantic and 6,709,317 in the Gulf in 2020 (NOAA unpublished data).

Tournament fishing for Red Drum has been around since the earliest recreational angling competitions such as the Mississippi Deep Sea Fishing 4th of July Rodeo held in Gulfport which began in 1947, the Southwest Louisiana Fishing Rodeo in Lake Charles which began in 1938, the Alabama Deep Sea Fishing Rodeo held each year on Dauphin Island which began in 1929, and the International Grand Isle Tarpon Rodeo in Louisiana which began in 1928. Red Drum have always been considered a high dollar category paying from hundreds to thousands of dollars and may include prizes like fishing tackle, boats, and new vehicles. Additional categories have been instituted such as the highest number of spots regardless of the size of the fish.

In recent years, a number of catch-and-release tournaments have been developed such as the IFA Redfish Tour and the Elite Redfish Series. All boast media coverage with the level of excitement comparable to major league baseball. Payouts in 2019 were awarded to 25 teams totaling $428,000 in prize money. The live release tournaments require anglers to maintain the fish and the event organizers release the fish back into the wild. They are not necessarily released in the same region the fish was caught however, which could lead to mixing of previously isolated populations (Adriance personal communication).

Participation in saltwater fishing, in general, has increased in the Gulf annually although data on saltwater anglers in Texas is not available since 1985 (Figure 6.7). Since the beginning of NOAA collecting recreational fishing data, the West Florida Coast has led in estimated participation out of all the Gulf states followed by Louisiana, Alabama, and Mississippi. It can be assumed that Texas, with its extensive coastline, has a high number of annual participants and would likely rival the West Florida Coast numbers. License sales in each state do not reflect the actual numbers of people fishing since there are anglers who are either historically exempted from requiring a license (children and seniors) or the purchase of combination (hunting and fishing, saltwater and freshwater, etc.) or sportsman (all inclusive) licenses do not necessitate actual participation in saltwater fishing either. The availability in most states of lifetime licenses does not require purchase on a recurring basis and generates a large pool of otherwise uncounted anglers. Those individuals may fish often or rarely and there is no way to gauge their effort. In addition, many of those licenses are purchased for children who may never utilize them once issued. Finally, the death of lifetime license holder does not purge them from the potential angler rolls, therefore, latent effort is much higher than participation as measured by any NOAA angler surveys. More detail regarding saltwater angling participation will be provided on a state-by-state basis below.

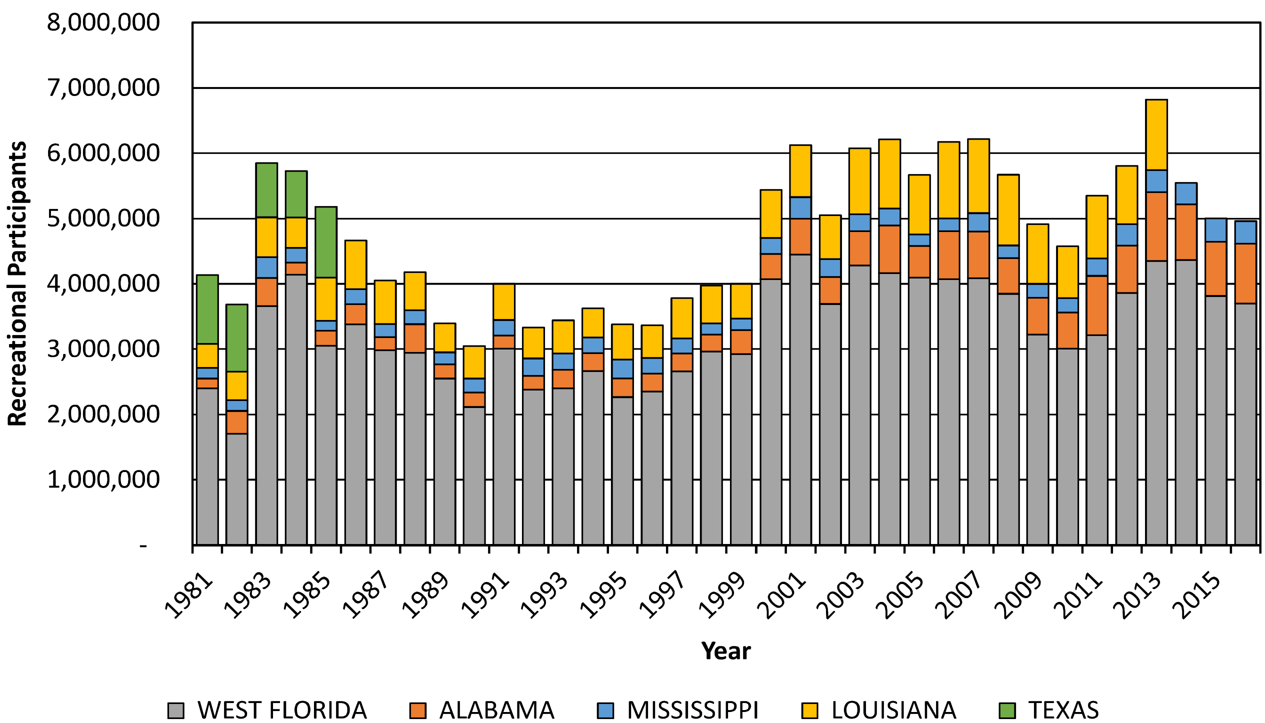



Figure 6.7 Total saltwater angler participation estimates by state as generated by the MRIP from 1981 to 2016 (NOAA unpublished data). ***Note:*** Texas participation is only included through 1985 since they began their own survey. Louisiana angler participation is not available since 2014 and is collected through the LA Creel program. NOAA ceased reporting angler participation after 2016 and the new survey has not yet been implemented.

## History

One of the earliest mentions of Red Drum was by Hallock in his 1876 book *Camp Life in Florida; A Handbook for Sportsmen and Settlers*. Hallock notes several of the Atlantic and Gulf areas where the fish could be angled. Goode (1884) describes what he terms, the Southern Red-fish, as the most important coastal species along the Atlantic and Gulf of Mexico coasts. He states that from Tampa to the west, it is the most common edible fish and increases in numbers moving from the Mississippi River to Texas where it is "more abundant than any other sea-fish". Henshell (1884) recounts fishing along the Florida Atlantic and Gulf Coasts for Tarpon, mullet, and Red Drum. Murphy-Grimshaw (1897) talks of hooking numbers of large Red Drum around Punta Gorda, Florida while chasing Tarpon. Kell (1900), a sailor aboard the Confederate Steamer *Alabama* mentions supplying their vessel with large numbers of Red Drum on hook-and-line while stationed in Quintana, Texas. Turner-Turner (1902) mentions fishing for Red Drum in his summary of the fishes of Florida. He notes that while they can reach very large sizes, 40-50 lbs, most anglers did not fish the surf where Red Drum are common and speculates that a fear of sharks may keep most fishermen onshore, docks, or boats (Turner-Turner 1902). Bradford (1908) provides a very short description of Red Drum in his book *The Angler's Guide*. He indicated that Red Drum preferred menhaden or clam as bait and could be caught in the surf with relatively heavy gear all along the Atlantic Coast to the Gulf from summer to fall.

Recreational saltwater fishing effort and harvest records do not exist prior to 1981, but anecdotal reports and published literature speak of increasing interest and effort in the United States really taking off after World War II as reported by de Sylva (1969). This report indicated that in 1955, there were about 4.5M saltwater anglers in the U.S. and by 1965, they had nearly doubled to 8.3M. de Sylva (1969) further comments

> "And the miraculous availability of leisure time following World War II, with the once-undreamed-of promise of a five-day week now come true and predictions of a four- and even three-day work week for the future, makes it understandable how our colleagues 50 or 100 years ago could not have envisioned armies of over 10 million anglers scampering to the sea. In the past 15 years, sport fishing has qualified for the title of an industry, but an unusual industry in that it shows all profit and no loss, and a motivation for the need for sport fisheries research could now be found."

In Texas state waters beginning in 1965, commercial landings of Red Drum began increasing annually, reaching around 2M lbs in 1975 and 1976 (GMFMC/GSMFC 1984, Auil-Marshalleck et al. 2002). Commercial landings began to decrease after this peak and recreational anglers began voicing concerns over what they perceived as unsustainable levels of commercial take. The management of Red Drum became an inflammatory and divisive topic as recreational and commercial anglers began to place blame on each other for declines in Red Drum abundance. The Texas Parks and Wildlife Department (TPWD) began standardized gillnet surveys in 1975, and these surveys indicated that Red Drum populations were indeed in a state of decline. Recreational anglers began to mobilize, and an organized lobbying effort resulted in the formation of the Gulf Coast Conservation Association (GCCA) in 1977. The declining population trends along with growing concern from the recreational angling sector resulted in the passage of the Red Drum Conservation Act, and subsequently the Texas Parks and Wildlife Commission adopted regulation changes in an effort to protect Red Drum from being overfished in Texas waters. House Bill 1000, or the "Redfish Bill" became law in Texas in 1981 which gave Red Drum and Spotted Seatrout gamefish status, thereby making harvest by commercial fishing illegal. This action further divided the recreational and commercial sectors, pitting one against the other in a battle for harvesting rights to the popular fish. Commercial finfish fishermen attempted to overturn the law in federal court, but the attempt was unsuccessful.

Additional actions were taken in a number of states to designate Red Drum as "Sportfish" or some other non-commercial status, effectively eliminating the entire commercial harvest with the exception of Mississippi as noted above.

## State Recreational Fisheries

Recreational fishing data for harvest are derived using the NMFS Marine Recreational Information Program (MRIP) and the Texas Recreational Harvest Monitoring Program. The Texas program has been in place since 1974 while the Marine Recreational Fisheries Statistics Survey (MRFSS) was used to sample anglers from Florida to Louisiana from 1979 until 2011. With the implementation of MRIP in 2012, the previous MRFSS catch estimates have been calibrated to MRIP estimates and are reported below. Since 2014, Louisiana has employed its own recreational survey, the LA Creel program, to generate recreational harvest estimates. Together, these programs provide the best estimates of harvest by recreational anglers in the Gulf of Mexico and southern Atlantic regions.

MRIP is currently composed of two surveys to assess catch and effort. The Access Point Angler Intercept Survey (APAIS) is the dock side component. The reported recreational catch in the MRIP include both retained fish observed dockside (type 'A'), fish reported caught but not observed by samplers ('B1') and fish released alive (type 'B2'). The 'B1' fish include those caught and used for bait, discarded dead, and those preyed upon at release. The recreational harvest presented in the figures and tables are type A+B1 combined with the effort and this expansion estimate represents total harvest, as designated by the NMFS. The APAIS survey asks anglers where the majority of their fishing took place which can lead to inshore species being included with a predominantly offshore fishing event (e.g., Red Drum can be reported as landed from the EEZ when they were not). The second part of MRIP is the Fishing Effort Survey (FES). FES is a mail survey that asks anglers to report saltwater fishing trips from shore and by private boat over the past two months and twelve months. The combination of landing and effort is done by two-month intervals (or waves) to generate the recreational harvest estimates. *It should be noted that the recreational angler estimates produced by NOAA historically and used in the state's portion of the following sections are not consistently agreed upon by each partner.* The overall trends observed in the figures can be used, but the magnitude of point estimates is typically greater than that observed in each of the state's license counts and should be used with caution.

All recreational harvest estimates from NOAA include a measure of percent standard error (PSEs) which measures precision of the estimates. PSEs are derived, in part, based on the occurrence of the species in the APAIS. A low rate of intercept (or a rare species) prevents reliable estimates of harvest when expanding over the whole recreational fishery (NOAA personal communication). High or low reports of effort during a two-month period also contribute to reliability of harvest estimates. According to NOAA, estimates with PSEs above 50% indicate high variability around the estimate (therefore low precision) and should be viewed cautiously. Gulf-wide, the average PSEs for Red Drum recreational harvest have been below 50% for most of the 40 years of data provided. Each state varies in the PSEs with the higher contributing states having substantially better precision estimates (NOAA unpublished data).

The following sections describe the state recreational efforts and contributions to the total Red Drum harvest.

### West Florida

Records of recreational anglers targeting Red Drum in Florida can be found in the literature for more than a century. Hensell (1884), as noted above, traveled all around Florida with rod and reel and mentioned hooking a 40-pound Red Drum which surprised the area settlers who only fished with cast nets. Norris (1865) noted that Red Drum were highly abundant along most of the West Florida Coast, especially in the shallow waters around Charlotte Harbor where Red Drum were speared. The accessibility of this large Sciaenid, along with the great sport provided and reward as a food source, made it a common target for anglers. The ability for anyone to fish for Red Drum from shore, dock, boat, or even wading makes them a primary target in most of the recreational survey data. Common baits reported for Red Drum fishing in the Old Tampa Bay region included Pinfish (*Lagodon rhomboides*), shedder-crabs (*Callinectes* spp.), Gulf Killifish (*Fundulus grandis*), and fiddler crabs (*Uca* spp.) (Railey 1933, 1935, 1936).

West Florida Red Drum harvest is small in comparison to Louisiana but higher than Alabama and Mississippi in part due its long coast (Figure 6.9). The percentage of recreational trips in Florida that largely target Red Drum is also less than Louisiana, but similar to that of Alabama and Mississippi. The percentage of these trips increased from the time NOAA started collecting effort data from recreational anglers with the average being 5% in the 1980s and 13% in the 2010s (Figure 6.8). Although Red Drum is a popular fish in Florida, the state boasts other highly prized recreational species that are less available as

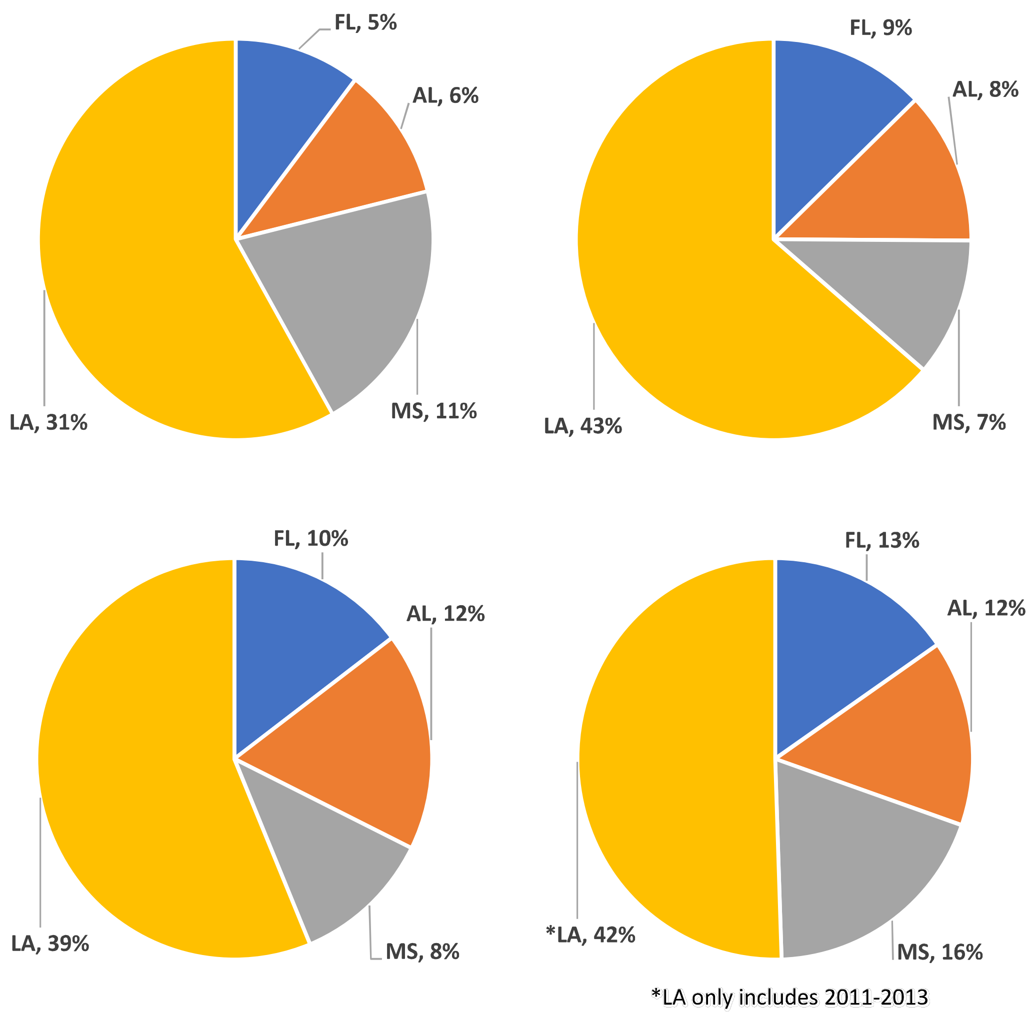



Figure 6.8 Decadal average percent of total recreational trips by state targeting Red Drum as primary or secondary preferred species from 1981-2019 (NOAA unpublished data). **NOTE:** Directed trips in LA in 2010s only includes three years of data because of LA Creel and do not participate in MRIP. Texas collects its own data which is not available through MRIP.

one moves west. Some examples include Tarpon (*Megalops atlanticus*), Common Snook (*Centropomus undecimalis*), and Bonefish (*Albula vulpes*) – species that associate with mangroves which are found in abundance throughout most of West Florida (Cedar Key and south).

One of the biggest changes in recreational harvest of Red Drum in Florida occurred in the late 1980s when concerns of overfishing prompted a series of regulations, including the permanent closure of commercial harvest in 1989. More restrictive recreational regulations were implemented simultaneously beginning in early 1987 followed by an emergency closure for all Red Drum harvest until the Fall of 1987. A prohibition on harvest occurred in 1988 as requested by the NMFS to allow for the Gulf states to implement management plans that would allow a recommended rate of juvenile escapement at 30%. Recreational fishing was opened again in 1989 with a bag limit of one (1), an 18 - 27-inch slot, and a closed fishing season in March and April. Prior to 1989, there was no daily bag limit. Staff analyses suggested that the combination of commercial and recreational harvest would not meet the escapement goal, and because recreational fishing was believed to offer a more positive economic impact, commercial harvest was banned (FWC unpublished data). As a result of the regulatory changes, the harvest by recreational anglers fell from an average of about 3.3M lbs prior to 1987 to about 1 M lbs in 1987 and only 11,000 lbs in 1988. Since 1988, the total harvest (recreational only) of Red Drum along the Florida Gulf Coast is around 2.9M lbs on average (Figure 6.9).

In Florida, Federal waters (EEZ) in the Gulf of Mexico were closed to all Red Drum fishing in 1988 and remain closed today, however, due to reporting the area where anglers spent the most time, there are some Red Drum attributed wrongly to the EEZ (Figure 6.10). There seems to be a slight decline in the number of residents participating since 2007 with the last two years that NOAA estimated participation representing the lowest in the time series (Figure 6.11).

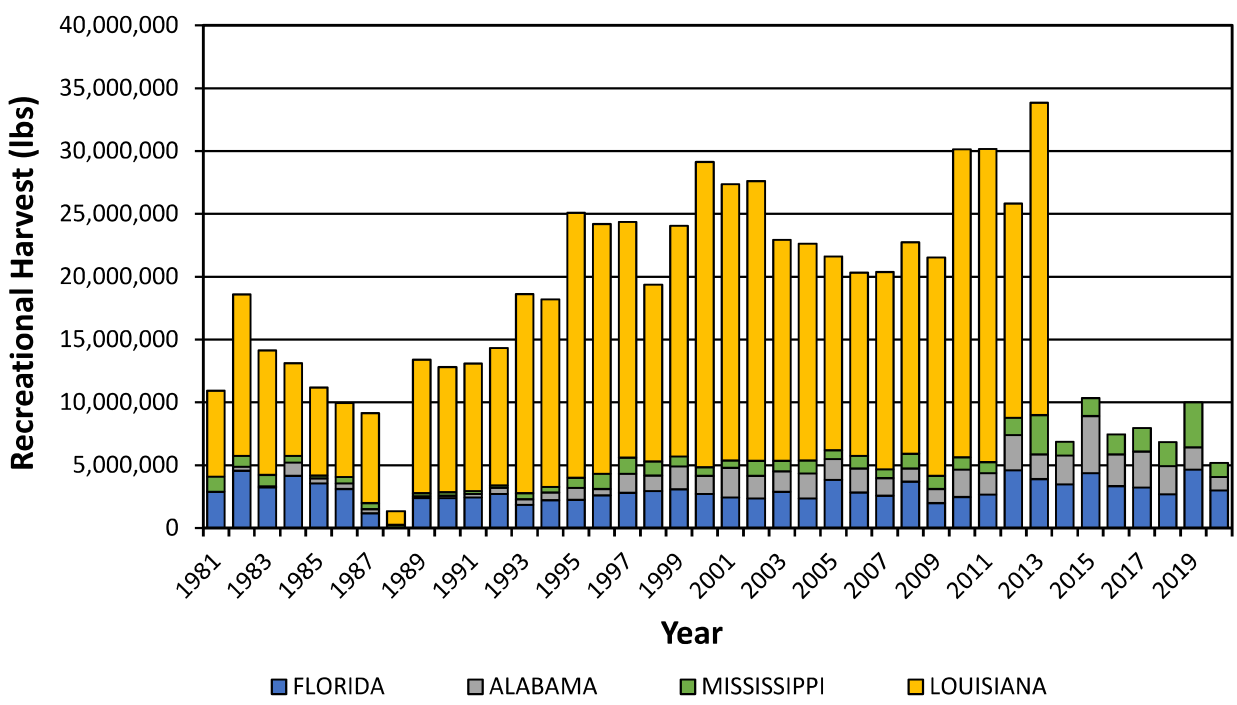



Figure 6.9 Total recreational harvest (lbs) by state from 1981-2020 (NOAA unpublished data). ***Note**:* Texas harvest is not included since they do not participate in MRFSS and MRIP. Louisiana harvest is not available since 2014 and is collected through the LA Creel.

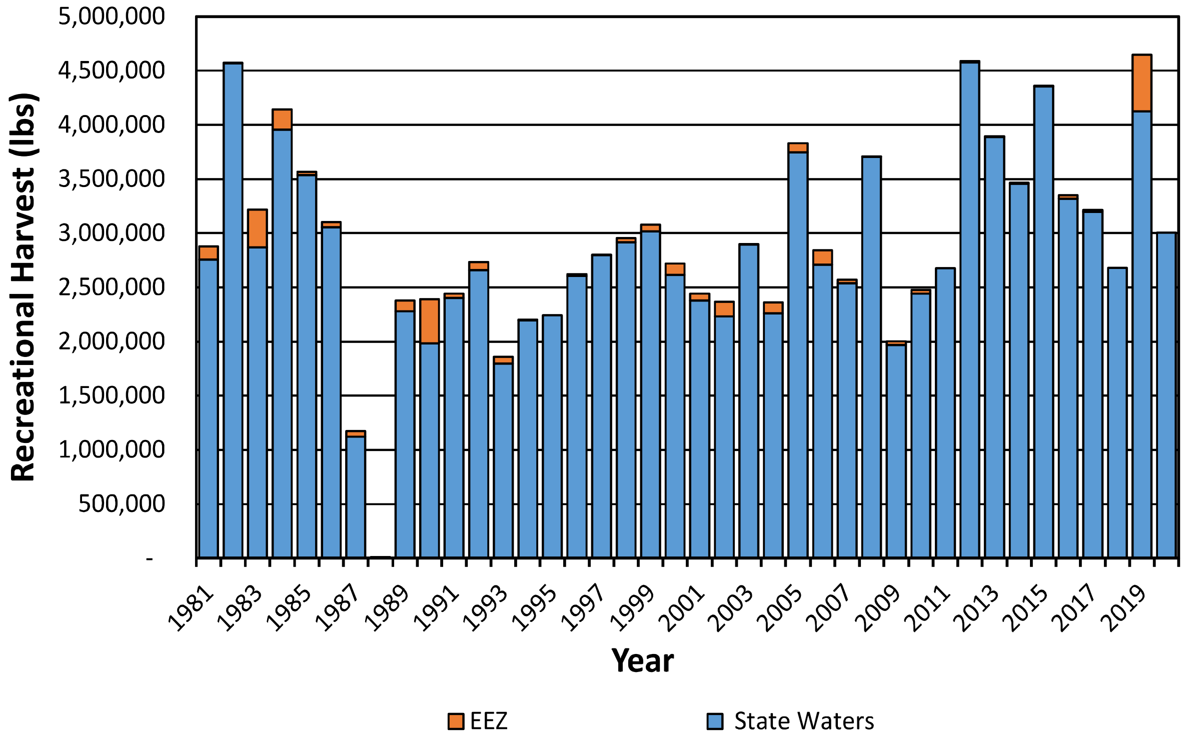



Figure 6.10 Total recreational harvest (lbs) of Red Drum from Florida state and Federal (EEZ) waters from 1981-2020 (NOAA unpublished data).

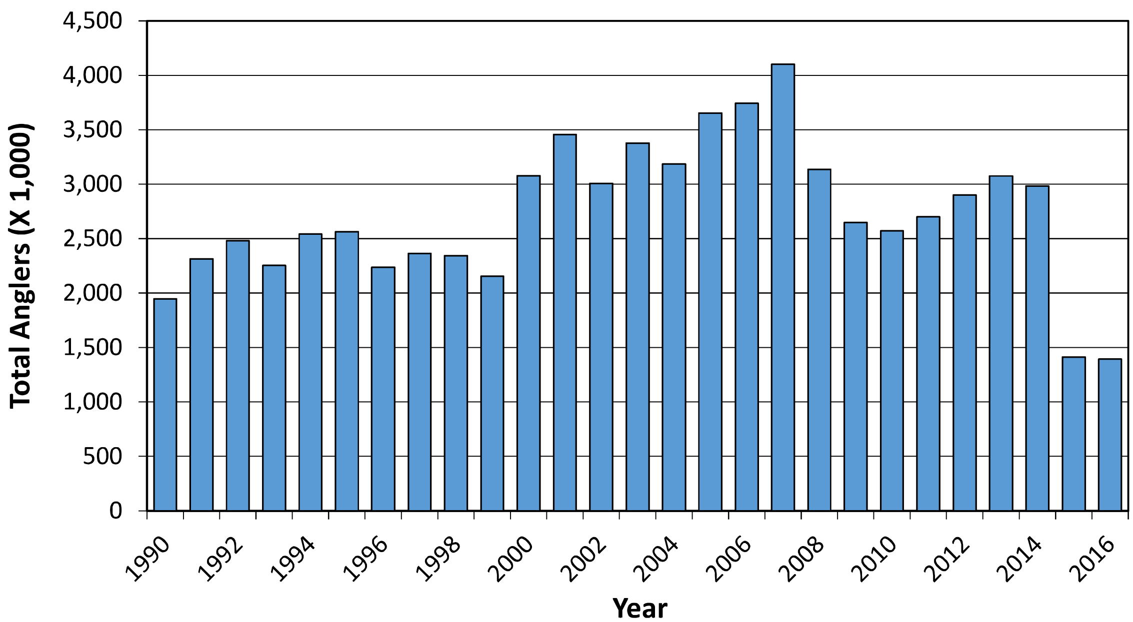



Figure 6.11 Trends of Florida resident anglers participating in saltwater fishing from 1990-2016 as estimated by NOAA (NOAA unpublished data).

## Alabama

There is not much written about recreational fishing for Red Drum in Alabama before the 1980s, although there are numerous mentions of catches throughout the newspapers from Montgomery, Birmingham, and the Mobile areas (VanderKooy personal observation). Most anglers who target Red

Drum in Alabama are likely similar to most of the other states in the region and also target other nearshore species like Spotted Seatrout and flounder together. More recent fishing articles indicate that anglers in Alabama can capture Red Drum on nearly any bait offered from plastic to live. Topwater plugs are equally noted, especially over fish that are actively feeding (Mashburn 2018). Red Drum can be found all year in Alabama waters throughout the bay and flats and sand bars around the islands in the spring and summer (Thompson 2010) and in deeper holes up the smaller bayous and creeks in Mobile Bay in the fall and winter (Mashburn 2017, Jordan 2018).

The monitoring of the recreational Red Drum fishery in Alabama (2003-2007) was accomplished through three separate programs. The Alabama Marine Resources Division (ADCNR/MRD) roving creel survey collected effort and catches from anglers while they were still fishing, providing incomplete trip information. The ADCNR/MRD creel survey intercepted anglers launching from personal, private and public access points. MRFSS collected angler effort and catch from completed trips at public access ramps and marinas. Additionally, a biological sampling program collected length, weight, sex and otoliths from catches to assess age structure at public access points.

Recreational harvest of Red Drum has been steadily increasing since NOAA began collecting data on fishing effort and participation in Alabama. Participation, as measured by NOAA, was steady throughout the 1980s and 1990s, around 250,000 anglers, and began to increase in the 2000s, topping 1.0M in 2013 (Figure 6.12). The majority of recreational fish have come from state waters with the exception of a couple of years (1984, 1995, and 2000) which is due to the NOAA survey design asking primary area fished (Figure 6.13). The increase has been around 30% every five years on average since the early 1990s. There was a slight decline in 2008 and 2009 following a number of significant hurricanes and tropical systems, but the trend has continued since. The higher harvest of Red Drum reported in 2015 (4.47M lbs) is not well understood and is not likely due to sampling since the associated PSEs are fairly low indicating reliability in the estimate (NOAA unpublished data). The overall harvest of Red Drum from Alabama is still low relative to Louisiana which averages around 18M lbs annually over the last 20 years (Figure 6.13).

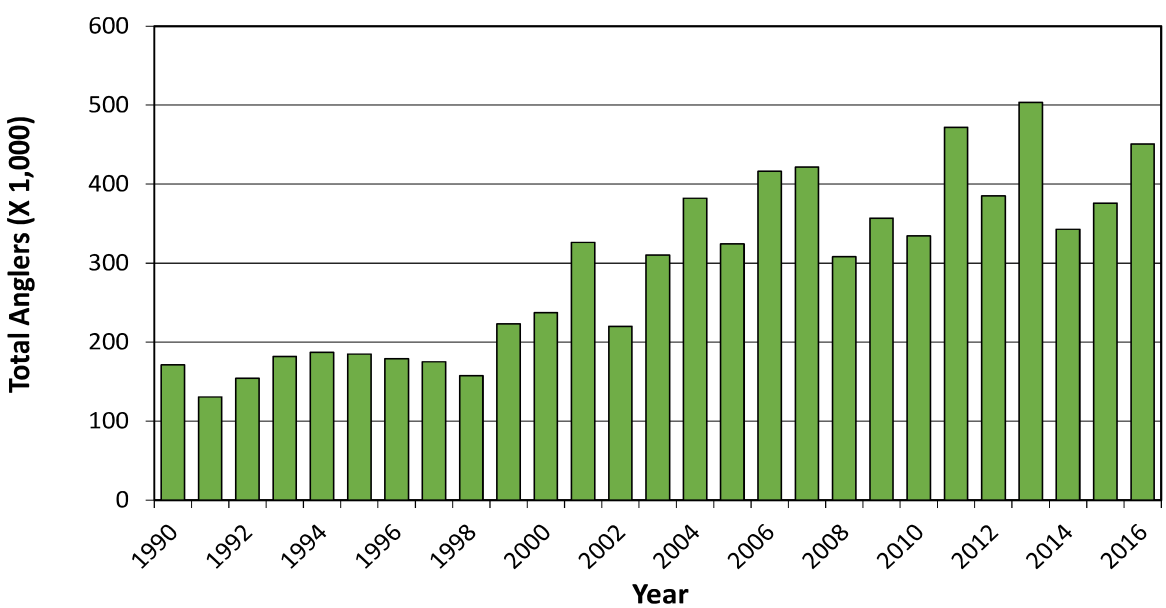



Figure 6.12 Trends of Alabama resident anglers participating in saltwater fishing from 1990-2016 as estimated by NOAA (NOAA unpublished data).

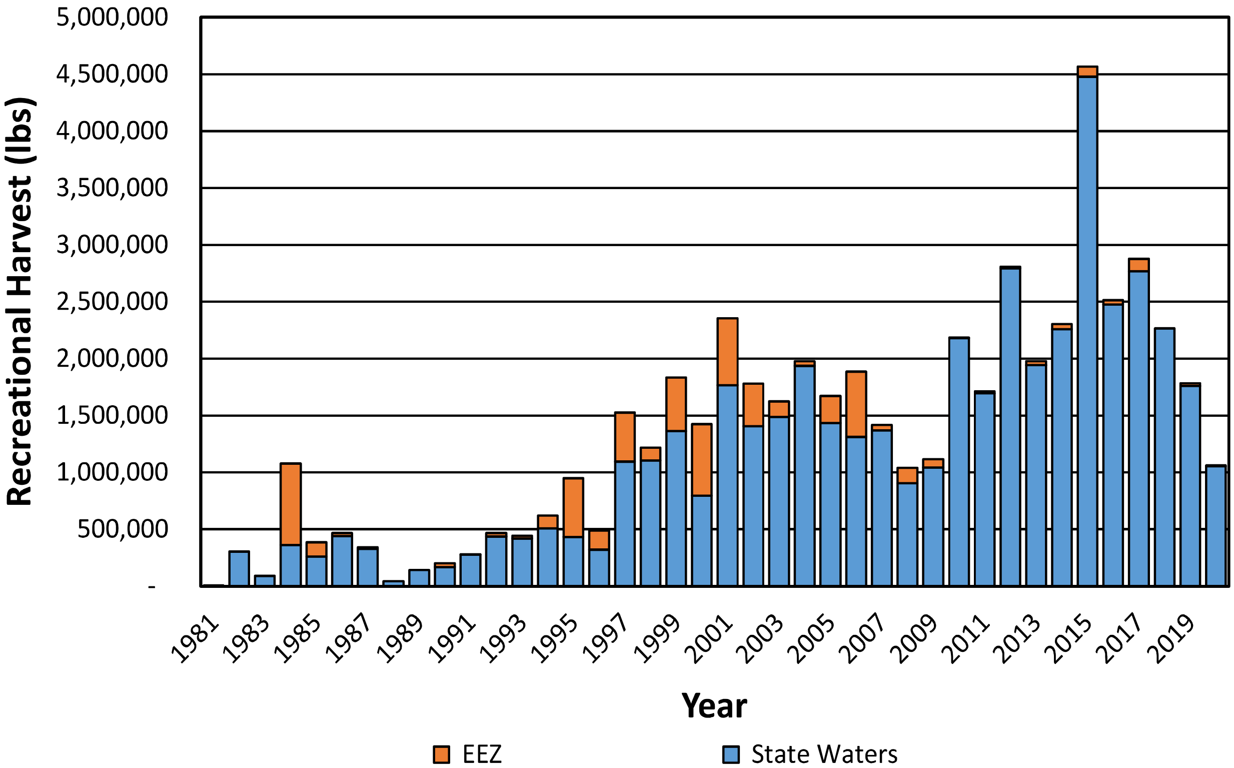



Figure 6.13 Total recreational harvest (lbs) of Red Drum from Alabama state and Federal (EEZ) waters from 1981-2020 (NOAA unpublished data).

When asked about targeted species, Alabama anglers state that they have doubled the number of trips in which Red Drum were their first and second target species from around 6% in the 1990s to about 12% since the early 2000s (Figure 6.8). In Alabama, Red Snapper are still the highest targeted species, but with regulatory changes in the reef fish species, Red Drum have remained a preferred alternative. Results of the MRFSS survey (N=447), from 2003-2007, indicated that approximately 11% of saltwater anglers were targeting Red Drum. Percent of anglers targeting Red Drum had been very consistent over the five years with a range of 10 to 12.2%. For those anglers targeting Red Drum, they were successful 24% of the time. Only 1.5% of surveyed anglers during the five-year period were successful in keeping the daily creel limit of three fish. Results from the ADCNR/MRD roving creel (N=668) (Figure 6.14) demonstrated a variation in the catch over the 2003-2007 period while the MRFSS indicated a decline in catch rates over the same time frame. Data collected during 2005 were affected due to the numerous tropical storms and hurricanes.

Length frequencies from MRFSS and otolith dock side collections indicate fish greater than 26 inches TL comprise a large percentage of the catch, 37% and 34%, respectively (Figure 6.15). Results from the ADCNR/MRD incomplete trip creel survey indicated that Red Drum greater than 26 inches TL were 6% of the catch and 16-18 inches TL fish comprised the majority of the catch (49%). The age structure from the dockside otolith survey (N=250) showed that 33% (N=82) of all the Red Drum sampled were age-0 to age-1. Age-0 to age-1 comprised mean total lengths of 16-20 inches. Age-2 and up were greater than 24 inches TL and the number of dockside samples by length for otolith samples is greater than MRD creel lengths beginning at 23 inches and up (Figure 6.15). Results indicated that incomplete trips showed a smaller average size for harvested fish and anglers of completed trips were more likely to participate in dock side surveys (prestige bias) when they had captured a trophy fish.

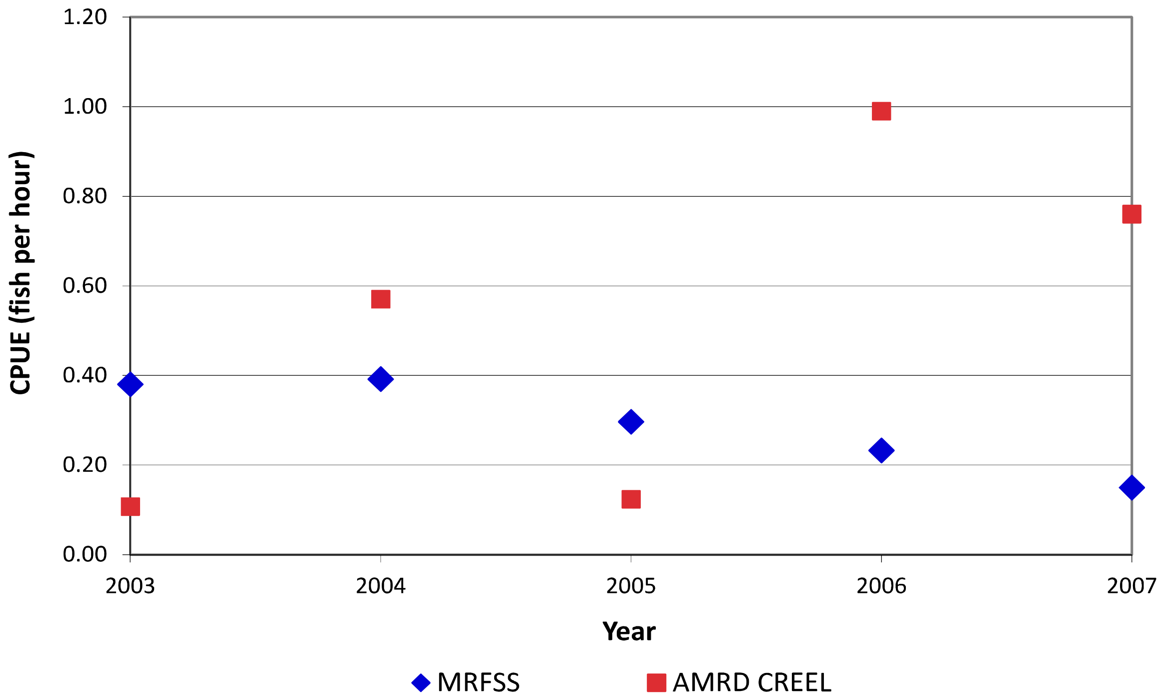



Figure 6.14 Estimated catch rates of Red Drum from Alabama waters 2003-2007 (NOAA unpublished data, ADCNR/MRD unpublished data).

## Mississippi

Red Drum can be caught year-round in Mississippi waters with large fish schooling offshore and around the barrier islands in the summer and lots of smaller fish lurking in the shallows inshore. A preference has always been high for Red Drum in Mississippi since their occurrence throughout Mississippi Sound and the three major bay/river systems is high. Deegan (1990) conducted a state-wide survey of about 2,000

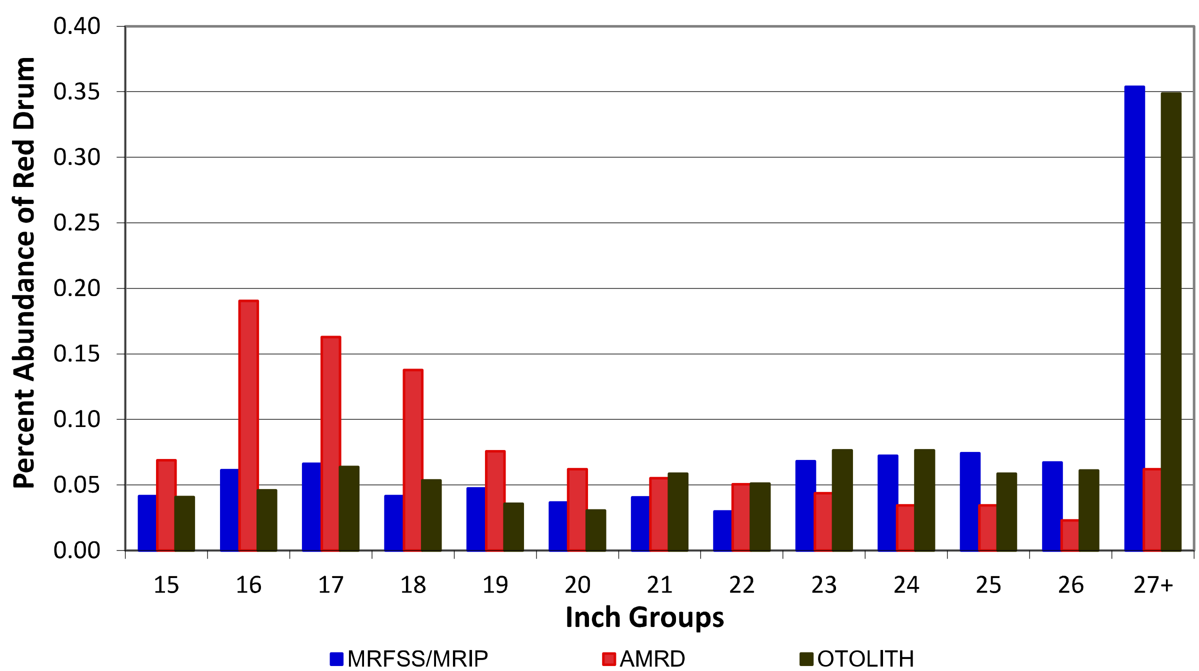



Figure 6.15 Red Drum length frequency from MRFSS, Alabama creel and otolith surveys for 2003-2007 (N= 643, 298, and 358, respectively; NOAA unpublished data, ADCNR/MRD unpublished data).

saltwater anglers in Mississippi. Of the 1,000 who responded, 30% indicated a preference for Spotted Seatrout followed by 25% who indicated Red Drum was their target species. More recent information has been collected by NOAA through the MRFSS/MRIP survey. Mississippi anglers report Red Drum as a primary or secondary target on about 16% of their trips in the current decade (Figure 6.8). In the late summer, large schools will begin moving on their spawning run to nearshore waters around the barrier islands and passes (Leon 2002, Felsher 2019). In the fall and winter, the water clears up and fish may be targeted in the bayous on both artificial or live/dead bait (Broom 2017).

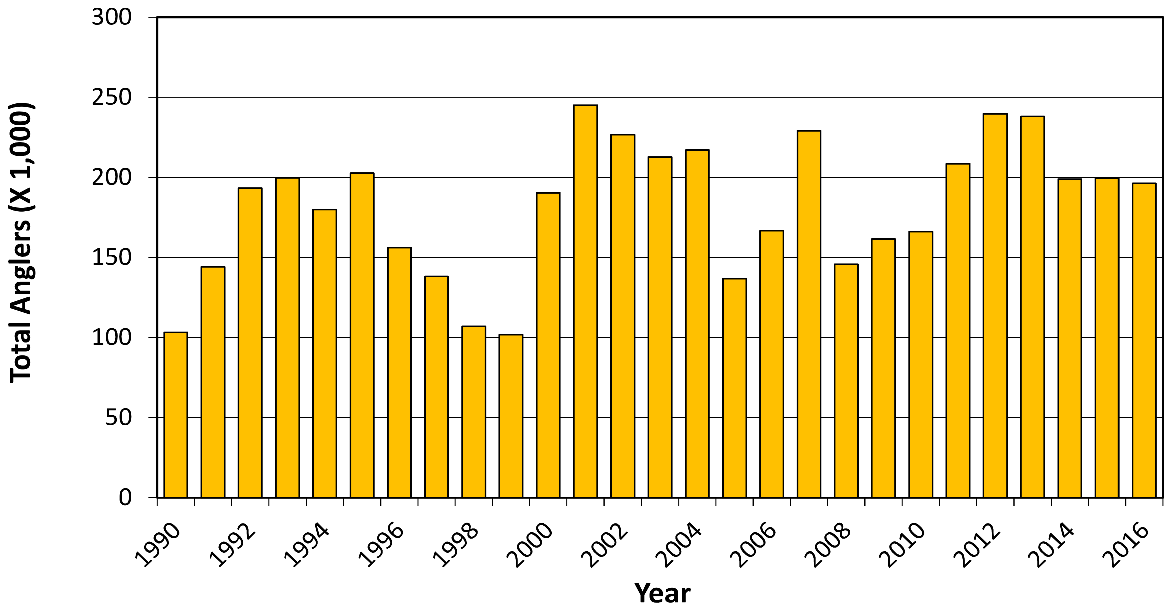



Figure 6.16 Trends of Mississippi resident anglers participating in saltwater fishing from 1990-2016 as estimated by NOAA (NOAA unpublished data).

Similar to the other states in the region, Mississippi participation in saltwater angling has been stable despite a decline in the late 1990s (Figure 6.16). The number of anglers estimated by NOAA increased slightly in the 2000s and increased again in the last couple years of the survey (2015-2016). The decline in 2005 and 2006 were likely a result of the after-effects of the hurricanes of 2005 (Cindy, Dennis, Katrina, and Rita).

Recreational harvest of Red Drum in Mississippi was relatively flat for much of the late 1990s through the late 2010s at around 750,000 lbs but has been increasing over the last decade (Figure 6.17). The amount of Red Drum designated as EEZ is due to the NOAA survey design and which area the majority of the effort took place, not where each fish was actually captured. The nearly threefold spike in recreational harvest in 2013 and 2019 are attributed to the influence of two single wave specific estimates. The shore mode landings for the months of May/June in 2013 totaled 1.7M lbs, and the private/rental boat mode for the months of July/August for 2019 totaled 1.7M lbs. These two single point estimates largely drive the observed trend and should be used with caution as there is little evidence that they are reflective of the actual fishery.

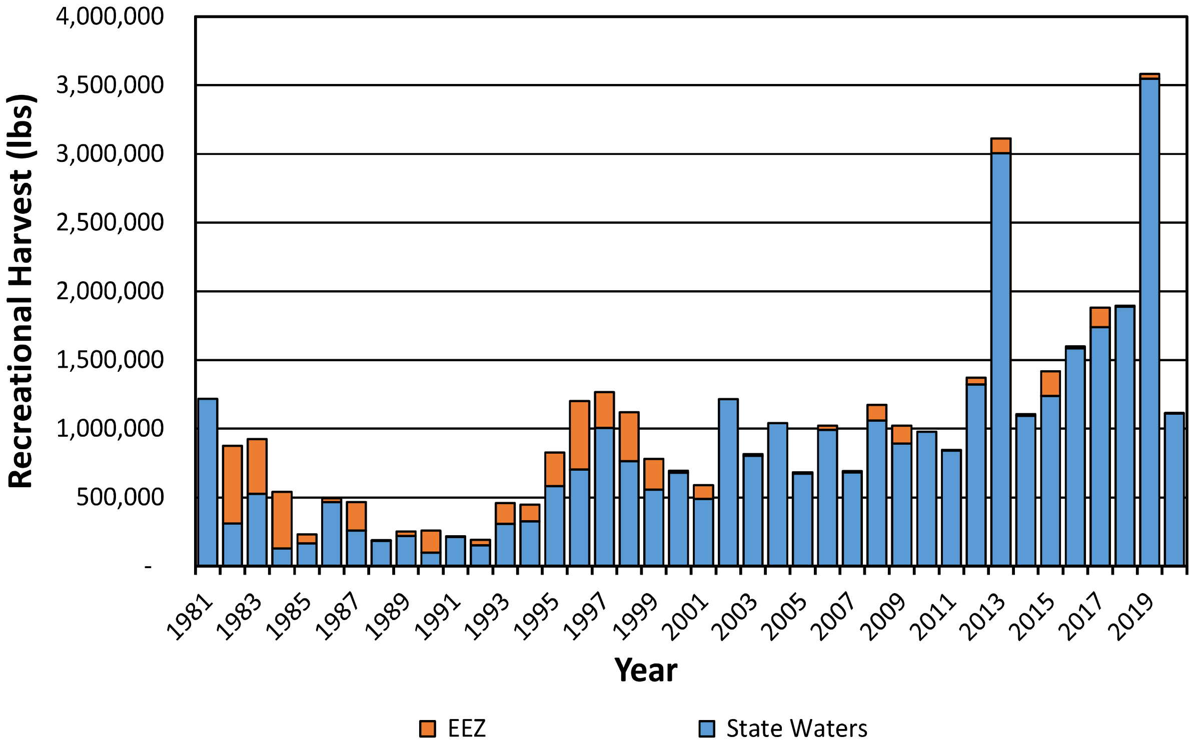



Figure 6.17 Total recreational harvest (lbs) of Red Drum from Mississippi state and Federal (EEZ) waters from 1981-2020 (NOAA unpublished data).

The number of Mississippi residents participating in recreational saltwater fishing has remained relatively stable since about 2000 (Figure 6.16). While there was some variability following major events such as the hurricanes of 2004 and 2005 and the BP Deepwater Horizon disaster in 2010, the number of anglers has been around 180,000 annually (NOAA unpublished data).

## Louisiana

Red Drum has always been one of the most popular fish with anglers in Louisiana. There are numerous mentions of people targeting them along the extensive marsh coastline since the mid-1800s and early 1900s (Daily Picayune 1892, Meise 1930). Norris (1865) mentioned Red Drum in the northern Gulf as a fish that will "…afford fine sport. They strike boldly, and run off thirty or forty feet of line at the first dash; as the mouth is fleshy, they are seldom lost when fairly hooked."

An article in the Morning Advocate (1950) summarized fishing for Red Drum in Louisiana well.

> "Probably no fish typifies the expression of power and durability, more than the redfish or as it is officially called, the channel bass. It takes the bait or lure with deliberation, but the minute the hook is set, you find yourself tied to a raging bulldog. They are mostly taken during the winter time or fall, in fairly shallow water. They move up into the bays and over the oyster reefs and shell bottoms. Sometimes though, when schooling, the water is a copper red when the school is near. Then they can be taken by trolling with a spoon, but most are caught with heavy slaughter poles and big shrimp. Some use casting rods and service reels however. They are excellent eating -- especially baked with a tomato sauce."

In 1984, the LDWF conducted a recreational angler survey of nearly 13,000 individuals at various access points Coast-wide (Adkins et al. 1990). Red Drum and Spotted Seatrout were overwhelmingly preferred species of most anglers at 49.3% and 63.8%, respectively. Their results indicated that, seasonally, Red Drum catches were lowest in the late spring and peaked in the fall (October-December). In an earlier survey in Barataria Bay (1975-1977) published by Guillory and Hutton (1990), Louisiana recreational anglers caught Red Drum primarily with live bait (38.4%) and dead/cut bait singly (29.1 %) or in combination with artificial bait (18.2%). NOAA participation data collected through MRFSS/MRIP confirms the number of recreational trips in Louisiana are dominated by Red Drum as the first or second species targeted by anglers throughout the data from 1981-2013 (Figure 6.8). LA Creel data (2016-2020) confirms this previous trend as Red Drum is currently the second most targeted species statewide, second only to Spotted Seatrout in Louisiana. The areas of the Atchafalaya, Vermilion, Mermentau, and Teche basins do not conform with this trend as Red Drum is the first target of anglers in those areas of Louisiana. The estimated participation by saltwater anglers in Louisiana fluctuated widely though the 1980s and 1990s between a low of 370,000 in 1981 up to 740,000 in 1986 but averaging around 540,000 annually (Figure 6.18). Since 2000, the total number of anglers has been around 1.0M with a high in 2006 of 1.17M.

Participation by Louisiana residents in saltwater recreational fishing reached a peak in 2006 and 2007 then fell to just below 800,000 until the NOAA MRFSS/MRIP survey was replaced by LA Creel in

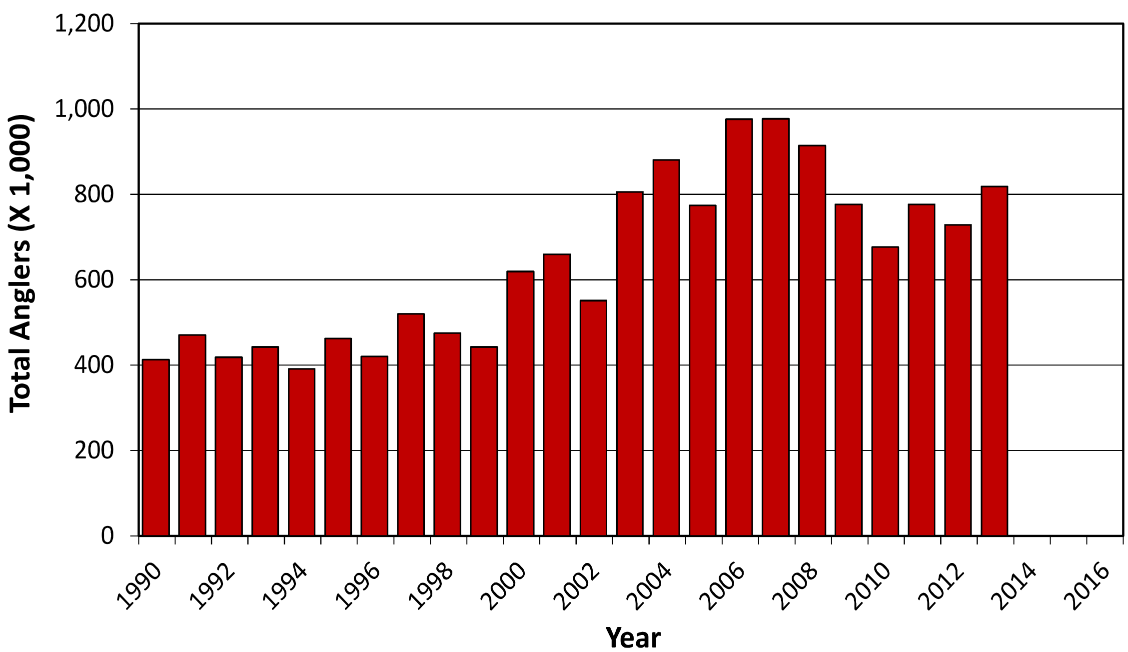



Figure 6.18 Trends of Louisiana resident anglers participating in saltwater fishing from 1990-2013 as estimated by NOAA (NOAA unpublished data). **Note:** LA Creel began in 2014 and NOAA no longer estimated participation in Louisiana.

2014 (Figure 6.18). Recreational harvest of Red Drum during the time period followed a similar pattern, increasing for the most part until the elimination of the NOAA survey in Louisiana. Participation since 2014, the inception of the LA Creel survey, has averaged 2.2M angler trips with the highest participation occurring in 2020 at 2.5M angler trips and the lowest participation of 1.9M angler trips in 2021. Estimated targeted angler trips for Red Drum have averaged 1.1M angler trips from 2018 to 2021 with a high of 1.4M in 2018 and a low of 0.8M in 2021.

Kelso et al. (1994) surveyed saltwater anglers and found similar results to Adkins et al. (1990) with 183 respondents (56.1%) preferring Spotted Seatrout and an additional 118 respondents (36.2%) indicating a preference for Red Drum. The results were reversed when asked about night fishing with the majority (53.1%) preferring Red Drum over Spotted Seatrout. Flounder was preferred third behind in either day or night fishing (Kelso et al. 1994).

There were no regulations on the recreational harvest of Red Drum in Louisiana prior to 1984 (see Chapter 5) when a recreational bag limit was set at 50 total Red Drum and/or Spotted Seatrout per day in combination with no minimum size but a limit of two fish ≥36 inches. After their popularity increased as blackened redfish (noted above) in the mid-1980s, the Louisiana legislature granted gamefish status to Red Drum in 1988 and in 1995, passed the Louisiana Marine Resources Conservation Act, which restricted use of gillnet and other entangling nets in state waters.

The trends in the recreational harvest since 1981 generally follow the enacted regulatory changes during the time period. There is a gradual reduction through 1987 under new bag and possession limits and a sharp decline in 1988 with the closing of all Red Drum fishing from February through June and a new daily bag of five fish/angler starting in July 1988. Harvest then increased steadily since the establishment of gamefish status, with the exception of a few years following the hurricanes of 2004 and 2005 and the BP Deepwater Horizon oil disaster in 2011. Total recreational harvest exceeded 15M lbs annually, which has been more than triple the harvest by Florida, Alabama, and Mississippi combined for the same years (Figures 6.9). Harvest estimates have been generated by LDWF through LA Creel since 2014 and only total numbers of harvested fish are available for comparison to previous years data collected through the NOAA MRFSS/MRIP programs (Figure 6.19). However, it should be noted that MRFSS/MRIP harvest estimates do not compare directly to LA Creel harvest estimates and calibration of landings is needed to establish one time series. Louisiana Red Drum recreational harvest from 2014 through 2020 has averaged 1.35M fish

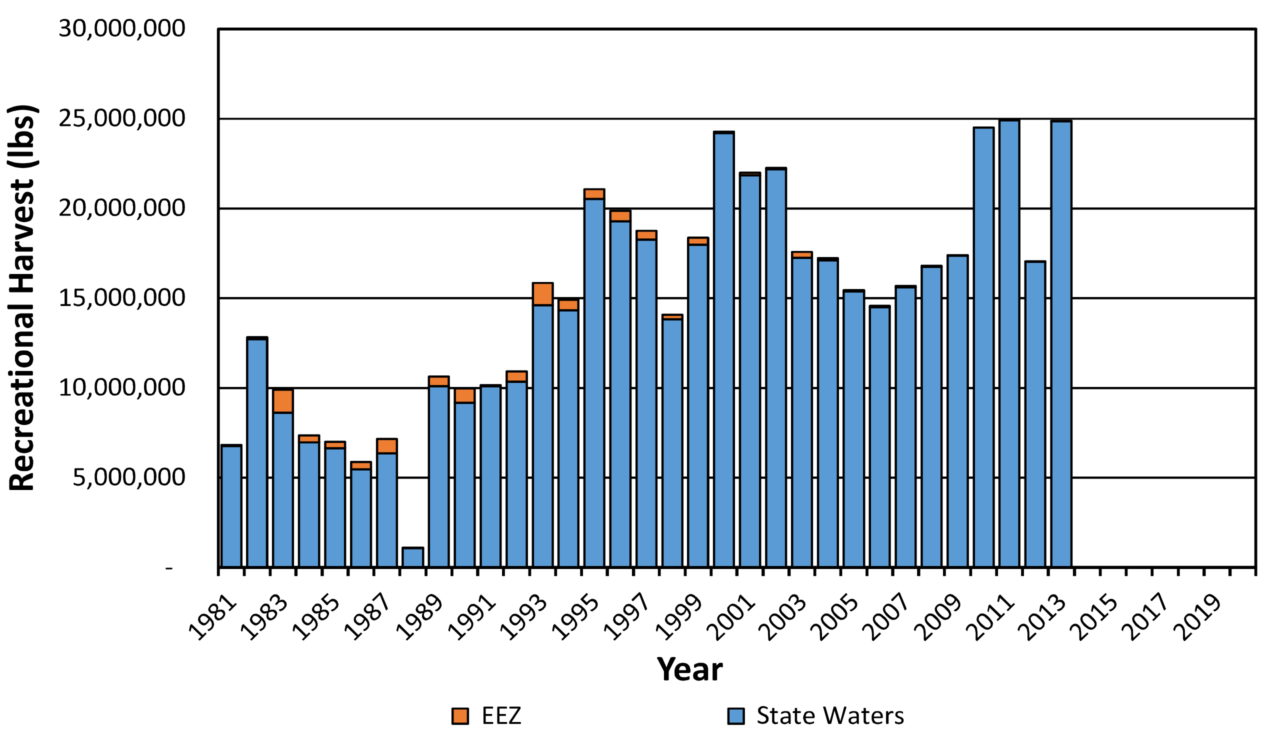



Figure 6.19 Total recreational harvest (lbs) of Red Drum from Louisiana state and Federal (EEZ) waters from 1981-2013 (NOAA unpublished data). **Note**: Comparable Louisiana harvest is not available since 2014 and is collected through the LA Creel.

with a high of 1.98M fish in 2018 and low of 1.05M fish in 2016 and 2020. Recreational harvest, in recent years, has ranged from an estimated low of 4.8M lbs in 2020 to a high of 8.3M lbs in 2018.

### Texas

Goode (1884) provided notes on Red Drum throughout the Atlantic and Gulf Coasts of the U.S. He noted the range of Red Drum in Gulf of Mexico waters that

> "…west of the Mississippi River it [Red Drum] is more abundant than any other sea-fish, evidently increasing in numbers as the Texas coast is approximated. On the Texas coast it is more abundant than all other food-fishes together. West of the mouth of the Rio Grande the species has not been recorded, chiefly, no doubt, for the reason that no explorations have been made along the shores of Mexico."

Kell (1900) noted that the sailors on the Confederate Steamer *Alabama* frequently caught Red Drum to pass the time and to add to their food supplies when they were shoreside around Freeport, Texas. A newspaper article in the 1837 Weekly Houston Telegraph describes Harrisburg County, Texas and Galveston Island and notes that great quantities of Red Drum exist along the island's beaches along with oysters, referring to Red Drum as the "Cod of the Gulf".

Early on, people outside the region recognized Texas' efforts to manage Red Drum in Heilner's 1940 book *Salt Water Fishing*. The author applauded the state for its proactive laws protecting Red Drum. Heilner quotes his friend Philip Mayer, a veteran angler from Texas, saying

> "Taking fish during spawning season is killing the goose that lays the golden egg. Sportsmen can solve the problem by releasing all fish in roe - unless the hook has been gorged. I have seen many thousands of fish gutted and cleaned. In no instance have I ever seen a female channel bass (redfish) in roe that would weigh under 25 pounds. So, even in spawning season, redfishing can go on simply by releasing the large fish."

As noted earlier (Texas Commercial above, Chapter 5 Texas), the state legislature moved on banning commercial fishing for Red Drum in Texas waters before any of the other states, providing them a Gamefish status in 1981. NOAA recreational harvest estimates do not exist prior to 1981 and Texas does not participate in the MRFSS/MRIP programs. The Texas Recreational Harvest Monitoring Program estimates daytime annual fishing pressure (effort in man-hours), landings (number of fish harvested), catch rates (harvest per unit effort as an indicator of resource availability or fishing success), species composition, and size compositions (mean lengths and mean weights of fish harvested) for sport-boat anglers on trips lasting 12 h or less in Texas marine waters (Green and Campbell 2010). This monitoring program records numbers of fish so a direct comparison between the states using NOAA generated numbers is probably not recommended but may be informative (Figure 6.20). Total recreational harvest in Texas is still small compared to the NOAA estimates for Louisiana, but the trend is a slight increase through the 1990s to around 230,000 fish, plateauing throughout the 2000s, and then averaging 295,000 annually for the last 10 years (Figure 6.21). There were a few notable high years including 2010 and 2011 when much of the Gulf was closed due to the Deepwater Horizon disaster with the exception of Texas waters. Oil did not approach the western Gulf and therefore did not limit fishing in Texas and the number of Red Drum harvested actually increased to a record high in 2011 (Figure 6.21). The most recent peak in 2020 can likely be attributed to the effect of the COVID-19 Pandemic and the recruitment of new anglers into the recreational fishery.

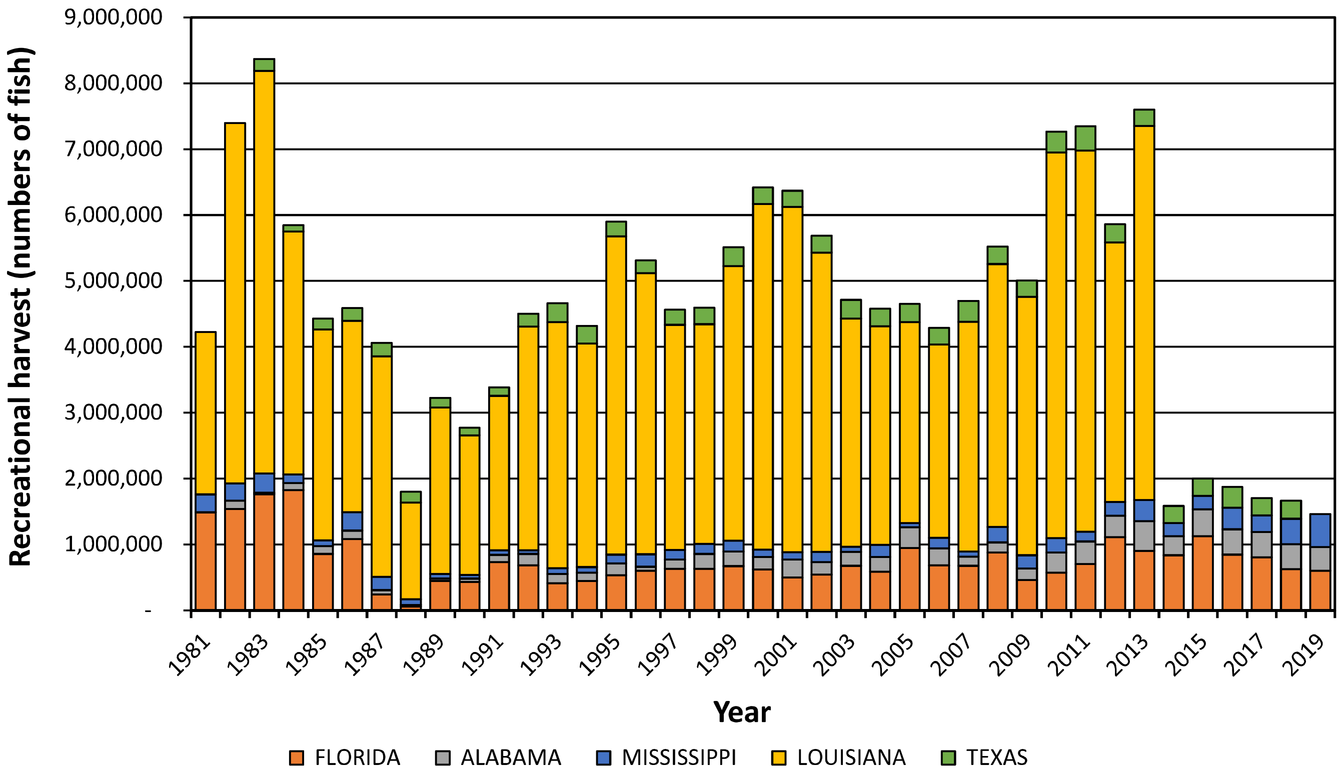



Figure 6.20 The total number of recreationally harvested Red Drum in the Gulf of Mexico from 1981-2019 (NOAA unpublished data and TPWD unpublished data). **Note**: LA Creel began in 2014 and comparable numbers of Red Drum in Louisiana are not available.

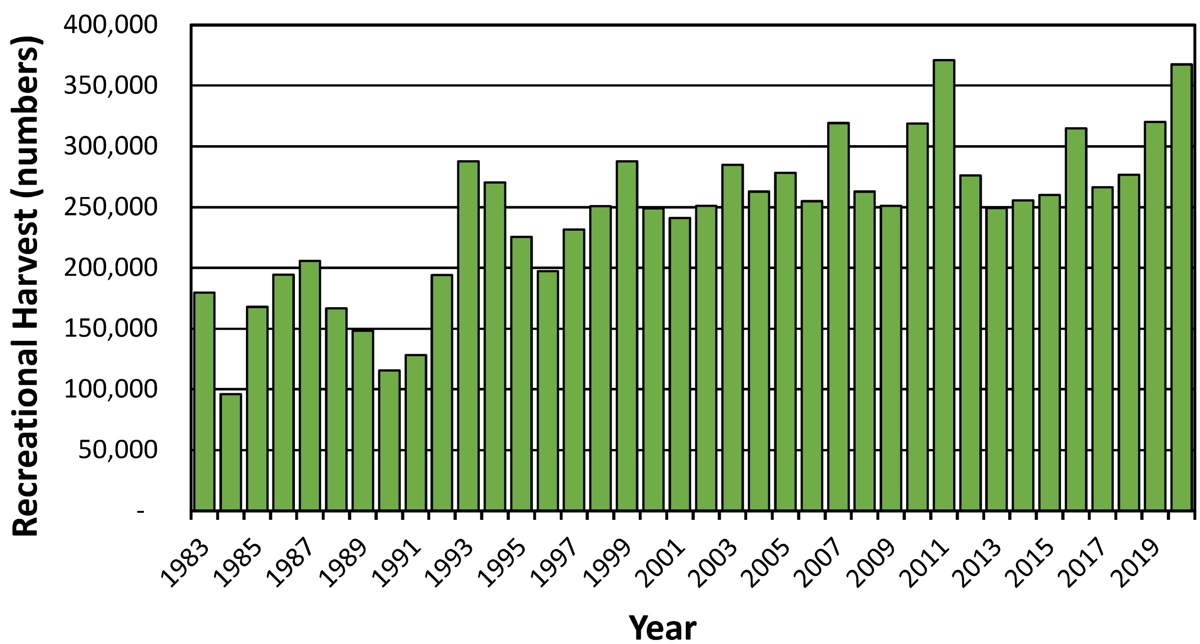



Figure 6.21 The total number of recreationally harvested Red Drum for all Texas waters (included bays, TTS, and EEZ from private and party boats) from 1983-2020 (TPWD unpublished data).

Saltwater fishing in Texas has steadily grown in popularity over the past few decades. Since effort in Texas is estimated in man-hours of effort and not by individual angler, license sales may serve as a proxy to angler participation, with an assumption that a licensed saltwater angler may target Red Drum. In 2005, there was a significant change in the licensing structure and types of licenses offered in Texas, so license sales from 2005 to present will be examined. It should be noted that anglers have the option to purchase lifetime licenses but because they are one-time sales, obtaining a cumulative total of active licenses is not practical so only annual sales are considered here. Sales also include resident and non-resident as well as a variety of combination licenses (salt and freshwater, hunting and fishing, seniors, and super combos).

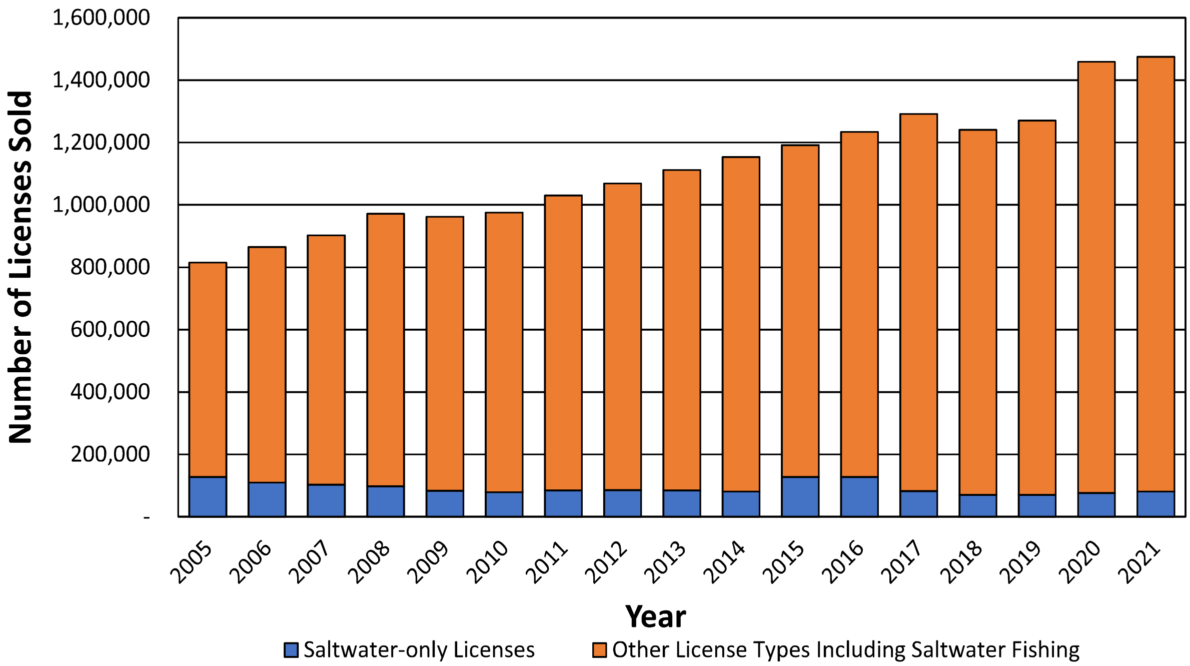



Figure 6.22 The number of annual saltwater licenses sold in Texas from 2005 to 2021. This includes combination licenses and both resident and non-resident saltwater (TPWD unpublished data).

The total annual sales indicate that there has been a steady increase since 2005 in potential saltwater anglers in Texas and the number of licenses sold have almost doubled from 2005 through 2021 to just over 1.45M (Figure 6.22). Again, this does not include lifetime license holders which would make the total anglers slightly higher. Participation is measured through the Texas monitoring program through an access point (boat ramp) creel which looks at boat-based angler effort as well as species targets.

The TPWD creel has estimated that since the early 1990s, 54% of all the trips made by saltwater anglers were targeting Red Drum or Red Drum and Spotted Seatrout annually and the majority of the Red Drum landed (over 98%) were from the inshore bays and Gulf passes (Figure 6.23). Considering the longer state boundary and rough EEZ waters, this is not surprising. Similar results were reported by Kyle et al. (2013) which summarized angler attitudes in Texas (Figure 6.24). The first species preferred by anglers was Red Drum at around 35% followed by Spotted Seatrout at around 20%. However, the authors noted a significant increase in their study compared to previous work in preference for Spotted Seatrout which nearly matched Red Drum. These numbers match reasonably well with the TPWD data of about 54% of trips including Red Drum as the primary target.

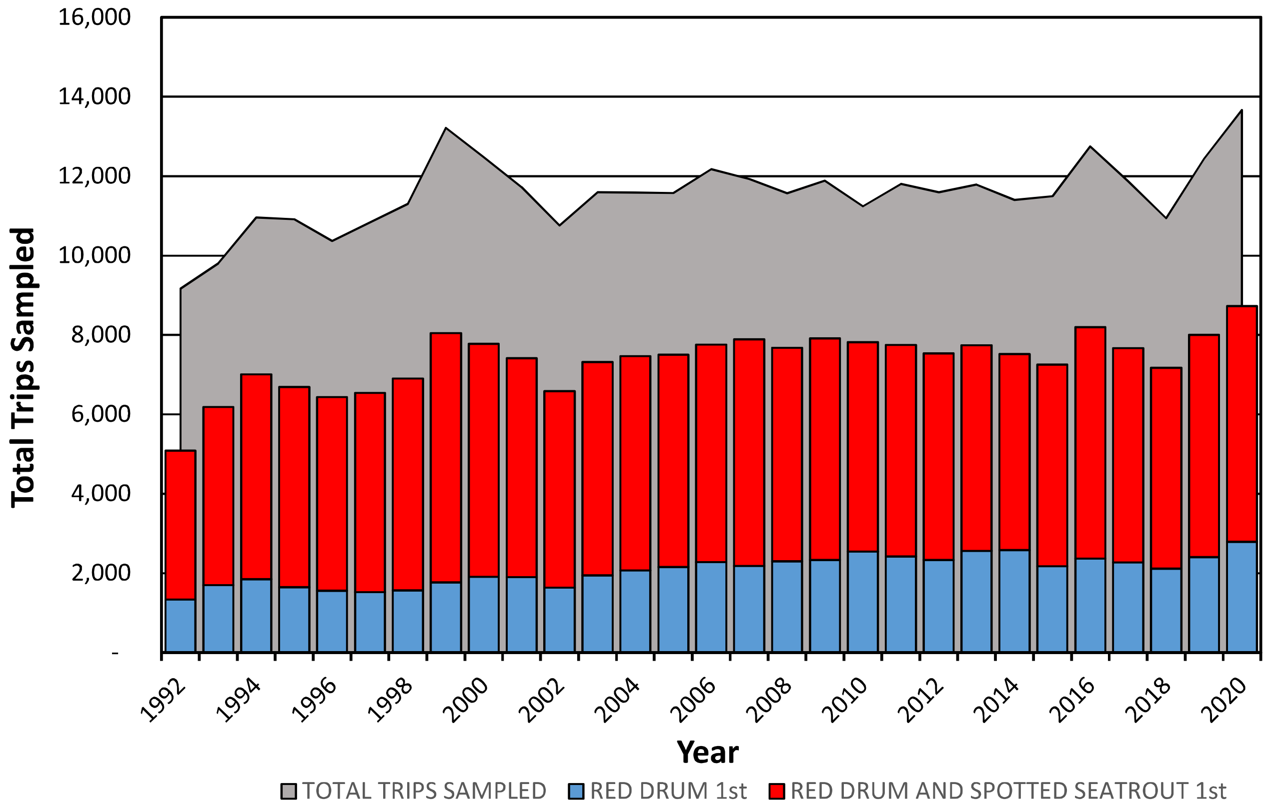



Figure 6.23 The total number of trips sampled by the TPWD creel survey (blue area) targeting Red Drum or a combination of species with Red Drum (red and gray bars) from 1992 to 2020 (TPWD unpublished data).

The bay systems of Texas vary greatly in terms of the habitat types present in each. There is also a north to south salinity gradient which increases as one moves south, resulting in drastically different ecosystem characteristics when comparing Sabine Lake at the Texas-Louisiana border to the Lower Laguna Madre at the United States-Mexico border. While Red Drum are tolerant of a wide range of salinity and can successfully forage in a variety of habitat and substrate types, anglers must employ different techniques to be successful depending on location. In the brackish waters of Sabine Lake, anglers may target the edges of the marsh. Mid-coast, Red Drum can be found in the vicinity of oyster reefs. In the clear waters of the lower coast in the Laguna Madre, anglers can drift over grass flats in specialized tower skiffs while sight casting to Red Drum loafing in potholes.

The bay systems closest to urban centers receive the majority of the recreational fishing pressure, and this is reflected in the recreational harvest when viewed by bay system. These include Galveston Bay with its proximity to the Houston metroplex area, Corpus Christi Bay situated by the city of its namesake, and the Lower Laguna Madre next to Brownsville. Other locales, such as Rockport, are considered vacation destinations by anglers and Red Drum harvest from neighboring Aransas Bay is the highest on the Texas Coast (Figure 6.25).

## Pier and Jetty Fishing in Texas

Since Red Drum occupy a variety of inshore habitats, this makes them a very accessible species to the shore bound angler. Throughout much of the year, bank anglers and wading anglers target juvenile Red Drum in shallow water habitats of inshore bays. But from September through November, anglers will crowd Gulf piers and jetties in Texas in search of mature Red Drum participating in the annual Red Drum

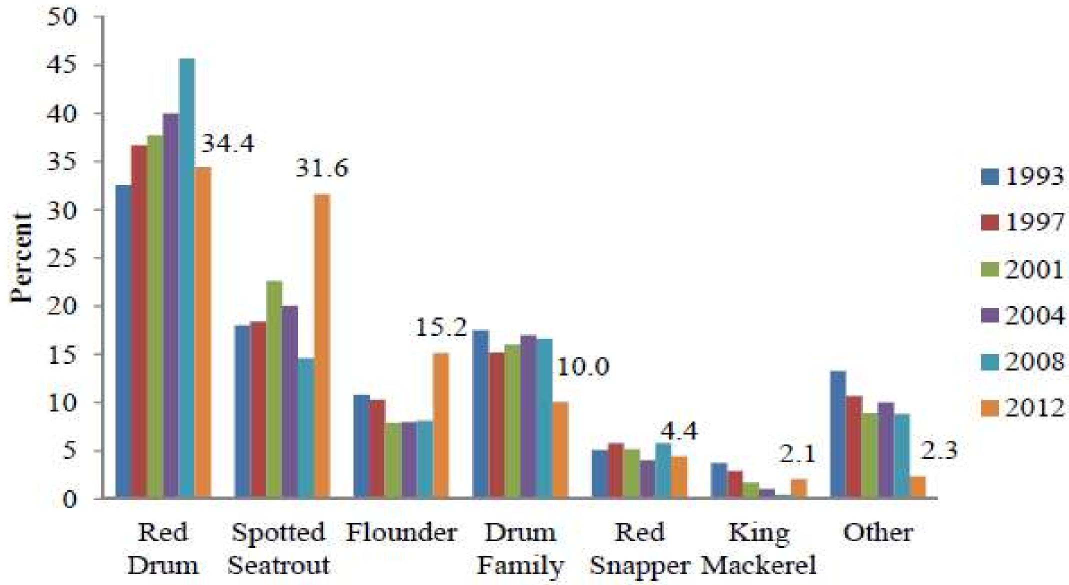



Figure 6.24 Trends in percent of licensed resident saltwater anglers by their first-choice preference of species they would like to catch in salt water in Texas (Figure 27 *from* Kyle et al. 2013. Sources: Ditton and Hunt 1996; Bohnsack and Ditton 1999; Anderson and Ditton 2004; Tseng, Wolber, and Ditton 2006; Landon, Jun, Kyle, Yoon and Schuett 2012).

"run", or spawning event (Weixelman 1982). Juvenile Red Drum that have spent their early years in the bays and estuaries reach sexual maturity around four years of age and head out to the Gulf passes to join other mature "bull" Red Drum that have come in from offshore haunts to spawn. This annual event peaks in September and October, as the first frontal systems of the fall season start making their way to the Texas coast and photoperiod begins to shorten. Anglers will typically use large chunks of cut or whole bait fish, fished on the bottom, with heavy tackle to target these large fish. For many, this offers the best chance of catching a Red Drum over 40 inches. Specialized landing gear is used to land fish from the tall

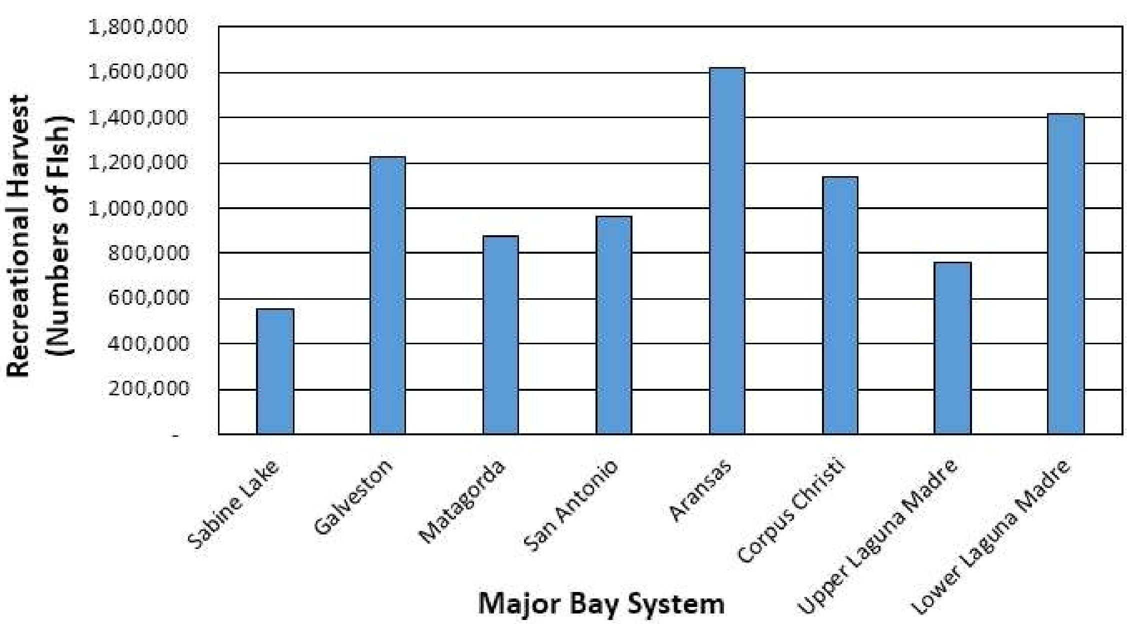



Figure 6.25 Red Drum harvest by recreational anglers by bay system in Texas from 1987-2020 (TPWD unpublished data).

Gulf piers. Anglers use drop nets which are net hoops that can be lowered down with ropes to land bull Red Drum. While many of these fish are caught and then released due to poor quality of the meat, anglers can retain two bull Red Drum (greater than 28") per license year.

## Bycatch

Bycatch in a fishery can be classified into two different types: 1) incidental catch and 2) discarded catch. Incidental catch refers to retained or marketable catch of non-targeted species. Discarded catch is the portion of the catch returned to the sea because of regulatory, economic, or personal considerations. When possible, these terms will be used in this section; otherwise, the overall catch of non-targeted species will be described as bycatch.

### Commercial

Unwanted fish caught in commercial harvests, or bycatch, is not a new problem to the U.S. fishing industry. Efforts to find a solution resulted in a 1907 report published by the U.S. Bureau of Fisheries, suggesting that the only practical solution was to develop the utilization of those species having no market (Field 1907). In the U.S., Red Drum were captured by many of the net fisheries from trawls to gillnets (Figure 6.3) and supported local markets as a species that had a good value in most local markets but were not highly valuable (Figure 6.4). Red Drum were generally considered incidental in most fisheries until the 1980s when the demand increased for them in the wider U.S. markets and a number of fisheries began to target them directly.

Prior to the increased market demands for Red Drum, gillnets typically targeting inshore species such as mullet, Spotted Seatrout, and flounder, contributed to higher mortalities and potential discards of Red Drum. Mortality in soaked gillnets is high because of the nature of how the nets are fished, being placed and retrieved hours later resulting in the death of captured fish. Strike nets, a gillnet that is not anchored or secured to the water bottom and is actively worked while being used, may have had lower mortalities. Red Drum captured in a strike net were typically retained and therefore incidental catch unless undersized, and therefore returned to the water immediately. Latour et al. (2001) observed an average mortality of 19.1% for adult Red Drum caught with trammel nets fished in water temperatures above 28.8°C in South Carolina but no mortality at lower temperatures.

Bycatch in the menhaden fishery has been quantified as percentages of total bycatch by several researchers in the past (Knapp 1950, Miles and Simmons 1950, Guillory and Hutton 1982, Condrey 1994, de Silva and Condrey 1998). However, the amount of Red Drum encountered during fishing activities has not been well-quantified due to releases of larger fish from the purse seine both before and after pumping. Therefore, Red Drum mortalities are not easily determined from those studies. The menhaden fleet in the Gulf continues to encounter some Red Drum while purse seining but tries to eliminate them from the catch with a number of bycatch excluder devices when pumping from the net and when dewatering before they reach the hold (Rester and Condrey 1999). After the ban on purse seine fishing for Red Drum, a zero tolerance for incidental catch was placed on the menhaden fleet. Mississippi and Louisiana have complete bans on Red Drum on board purse seining boats (MS Code §49-15-71, LA Rev Stat §56:322) and violations can result in fines and potential confiscation of gear.

Sagarese et al. (2016) explored the various reported bycatch estimates in an effort to quantify the contribution to total removals (bycatch plus recreational and commercial harvest) by converting numbers and percentages to estimates of weight. They found that at the height of the purse fishery in the mid-1980s, the menhaden fleet may have impacted nearly one-third equivalent to the total recreational and

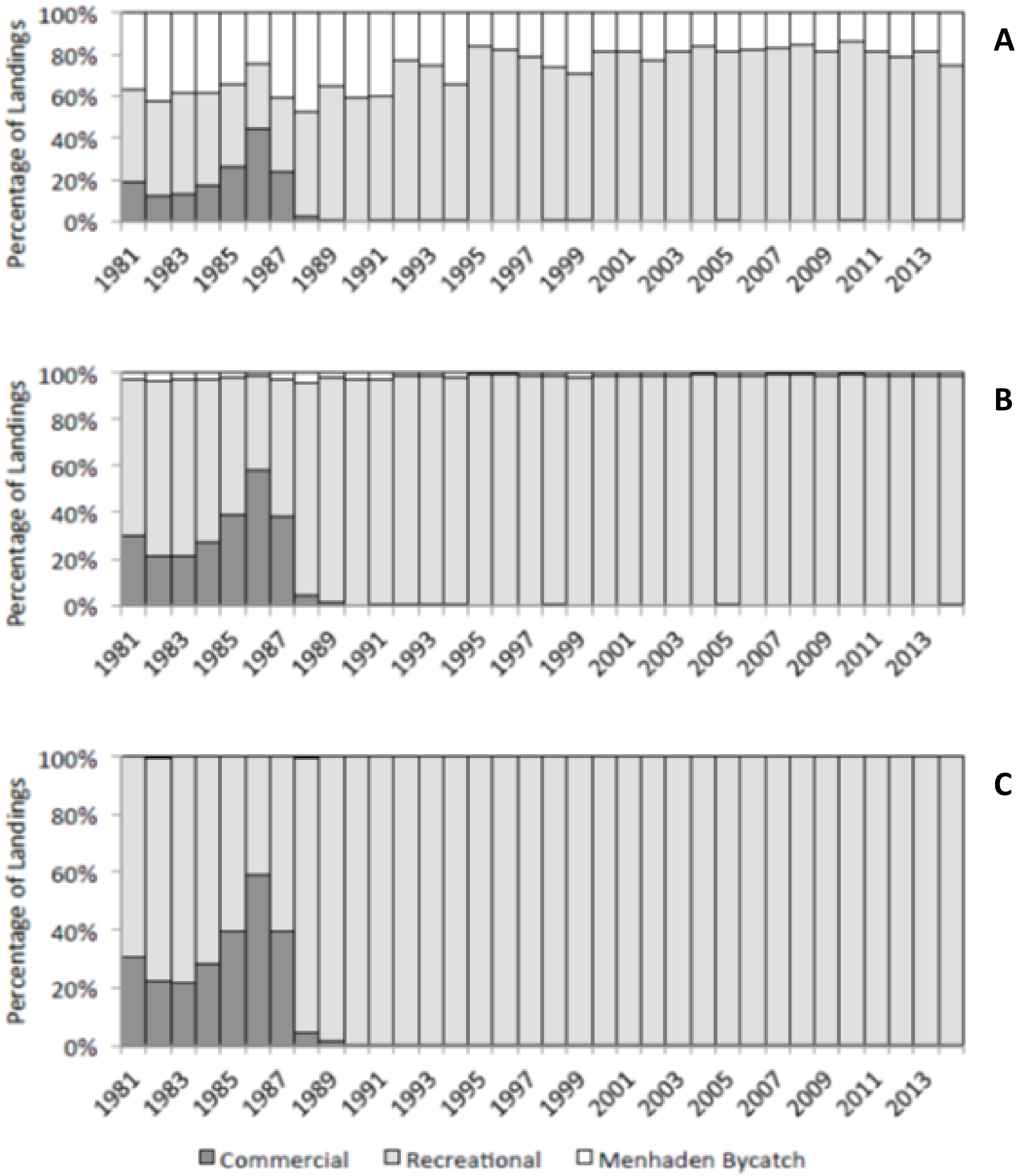



Figure 6.26 Comparison of commercial landings and recreational harvest of Red Drum in the Gulf of Mexico (preliminary estimates from SEDAR49) with estimated bycatch in the Gulf Menhaden reduction fishery. Results for A) the highest estimate of total bycatch (3.1%) in conjunction with the highest (21.6%N, of which 65.4% discarded dead), B) moderate (0.63%N), and C) lowest percent by number for Red Drum (0.046%N) (Figure 5 *from* Sagarese et al. 2016).

commercial harvest combined at the highest estimated bycatch level (Figure 6.26A). In contrast, the total impact from menhaden fishing at the lowest estimated bycatch level resulted in negligible Red Drum mortalities compared to the combined recreational and commercial harvest (Figure 6.26C).

In Porch (2000) and SEDAR 49 (SEDAR 2016), bycatch of Red Drum in the Gulf of Mexico was included when determining the stock status. In the description of discards for the various commercial fisheries, it was noted that, in regards to the menhaden reduction fishery, “Due to the paucity of Red Drum bycatch in the fishery, no analyses were conducted” (Porch 2000).

The shrimp fishery has been evaluated as an additional source of mortality in most of the recent Red Drum assessments (Goodyear 1996, Porch 2000). Despite the changes in the commercial and recreational fisheries in the mid-1990s, management of Red Drum did little to affect the incidental harvest by the Gulf Shrimp fleet (Goodyear 1996). Bycatch prior to 1988 may have contributed to the commercial landings for Red Drum in the Gulf, but the total number of fish killed since the closing of the commercial take adds to total mortality. The estimated bycatch from the offshore shrimp fleet from 1972-1998 is provided in Figure 6.27. In addition, it was noted by Porch (2000) that the contribution to Red Drum bycatch in the inshore shrimp fleet was not quantifiable but "may be substantial".

Observer program data from 2011-2016 were examined for their utility in estimating total discards by species in the various offshore shrimp fisheries in the Gulf and South Atlantic (Scott-Denton et al. 2020). The Federal Observer Program began in 2007 and primarily focuses on endangered and threatened marine species but also includes all other species encountered by the shrimp fleet. Over the six years reported by Scott-Denton et al. (2020), the Gulf observers were at sea 10,420 days which comprised 2.5% of the fleet's total days at sea and witnessed 19,260 tows by the Gulf penaeid fishery. Red Drum comprised 21,276 lbs of the total bycatch or 0.2% of the total by weight for the observed tows (Scott-Denton et al. 2020). By comparison, Red Drum commercial landings in fish and shrimp trawls from 1968-1990 averaged around 18% of all the landings in Mississippi, 59.9% in Alabama, and 1.5% in Louisiana (Goodyear 1991). The implementation of turtle excluder devices (1987) and bycatch reduction devices (1997/1998) in the various trawl fisheries as well as a reduction in overall participation and effort in the offshore fleet, likely contributed to a substantial reduction in incidental catches of Red Drum in the last decades (Porch 2000, Gallaway et al. 2003, Nance et al. 2008, Scott-Denton et al. 2012).

Red Drum have not been recorded in the trotline fishery in Texas since commercial take of Red Drum was banned in Texas in 1981. However, Red Drum appear to be a significant source of bycatch according to a study by McEachron et al. (1988) examining methods to reduce bycatch in the commercial trotline fishery. This may not necessarily translate to high mortality, as survival of released Red Drum caught

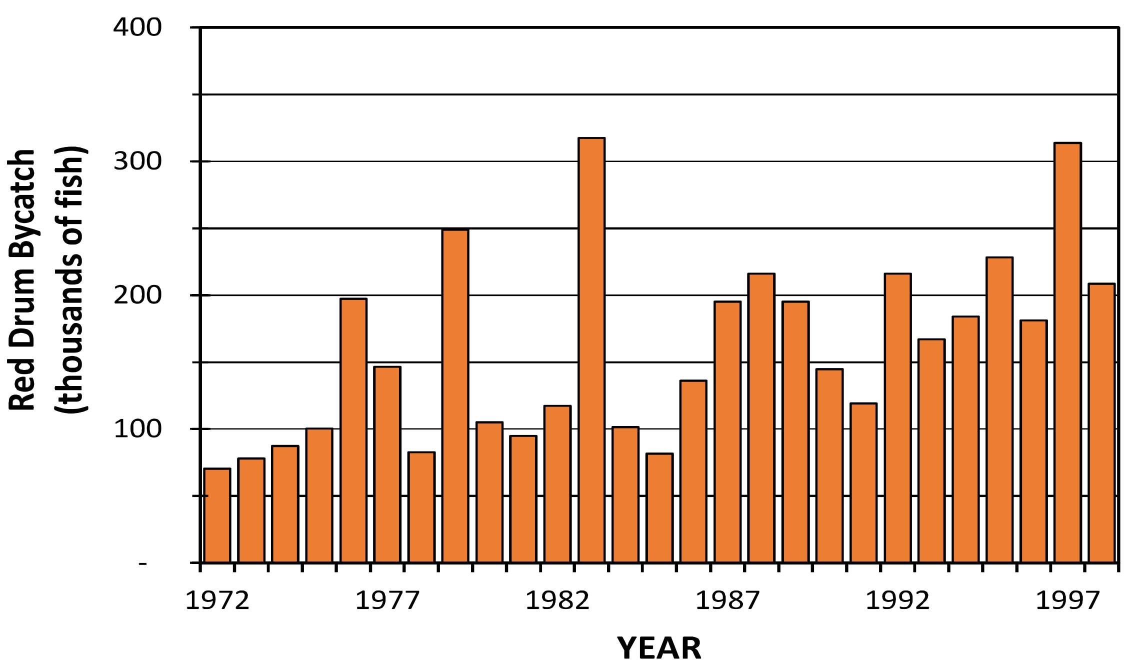



Figure 6.27 Estimated bycatch of Red Drum from the offshore shrimp fishery, 1972-1998 (*Recreated from* Figure 7 in Porch 2000).

on trotlines in winter and summer was 100% according to another study (Martin et al. 1987). However, modern day trotliners use wooden dowels (soaked in attractant) to target Black Drum in Texas, and anecdotal evidence suggests Red Drum mortality as bycatch is low. This is next to impossible to document as numbers of dead bycatch are not reported by trotliners (Bartram personal communication).

### Recreational

It is difficult to examine 'bycatch' of Red Drum in the recreational fisheries in the Gulf of Mexico since it is one of the species targeted by anglers. A large number of Red Drum are released in part due to the state bag and slot limits. Those fish are reported by MRIP as released alive (type 'B2' in the catch data) but may not actually be considered bycatch by anglers.

Red Drum could be considered as bycatch when considering hooking mortality as a result of catching fish outside the slot or releasing fish once a limit is filled. Studies by the LDWF (Thomas 1995) examined both Red Drum and Spotted Seatrout survival post hooking with both single and treble hooks. Their data indicated that Red Drum have a very high survival rate, around 97%, even for deeply hooked fish where they left the hooks in place for release. Matlock et al. (1993) found similar results in Texas waters with about a 4.1% mortality rate for Red Drum angled on either a single or multiple hook. Vecchio and Wenner (2007) found similar results in juvenile Red Drum off the South Carolina coast testing release from variations on circle hooks and traditional J-style hooks. The mortality associated with both were relatively low and dependent upon where the fish was hooked. Fish that were deep hooked had higher mortalities at about 7% for J-hooks, 2% for non-offset circle hooks, and 10% for offset circle hooks but most of the shallow hooked fish survived regardless of hook types. Adult Red Drum had much lower mortalities around 1.9% with non-offset circle hooks and 3.3% from J-hooks (3.3%), again, depending on how deep the fish was hooked. Additional work (Gearhart 2002, Aguilar 2003, Flaherty et al. 2013) found slightly higher morality rates associated with hooking location (mouth versus throat) and environmental variables such as lower salinities and higher temperatures. Gearhart (2002) found mortalities in North Carolina waters in low salinities (<14ppt) was 10.9% and 2.3% in higher salinites (>17ppt) with a mouth/lip hooking location. Aguilar (2003) also found North Carolina Red Drum had release mortalities around 6.7% which were related to 'deep' hooking associate with the use of J-hooks. Flaherty et al. (2013) reported a 5.6% mortality rate again associated with location of hooking and high water temperatures. J-hooks produced the deepest hooks in the throat versus circle hooks in the mouth/lip. All the studies listed since 2000 determined highest Red Drum release survival was directly tied to the use of circle hooks for live/cut bait.

## IUU Fishing

Illegal, unreported, and underestimated (IUU) fishing for Red Drum includes retention of fish from the EEZ by U.S. commercial or recreational anglers or retention of fish outside the size or bag from legal waters. However, in recent years, IUU fishing of Red Drum has become a major issue along the Texas-Mexico border. Incursions by Mexican nationals into U.S. waters to commercial fish has been a growing problem. The USCG and Texas law enforcement officials routinely intercept lanchas (a 20 to 30 feet long fishing boat used by fishermen in Mexico). They stage near the U.S. border and quickly enter U.S. waters where they set and retrieve miles of illegal nets and longlines up rivers, in the bay, and offshore in Texas. The target species for these fishermen are primarily Red Snapper and sharks in offshore waters. In 2015, the USCG detected 211 lanchas through aerial survey but were only able to reach and seize 39 vessels before they escaped back across the border. The USCG intercepts resulted in the recovery of 872 Red Snapper and 57 Sharks. In 2018, there were 179 lancha incursions detected by air resulting in 60 seizures consisting of 4,959 Red Snapper and 121 sharks (USCG 2018).

In addition to offshore, a large number of illegal gillnets are confiscated by USGC and TPWD enforcement along the U.S. side of the Rio Grande River which are routinely filled with commercially and recreationally important species such as mullet, Spotted Seatrout, flounders, and subadult Red Drum. The fishermen do not utilize these fish so much for the market as they do for bait in offshore longlines for pelagic and reef associated species which have much greater commercial value. Enforcement has reported entire longline sets of nothing but cut Red Drum as bait which originated from Texas waters. Fish which are successfully returned to Mexico are then processed and sold as imported seafood back into the U.S.

In January 2017, the U.S. government decertified Mexico under compliance rules aimed at tackling IUU fishing (NOAA/NMFS 2017). Mexico provided evidence of enforcement activities already in place to reduce the poaching of resources from the U.S. EEZ and as a result, received a positive certification determination in 2018 although incursions by fishermen from Mexico continue (USDOC 2018, NOAA/NMFS 2019).

## Mariculture

### Food Fish

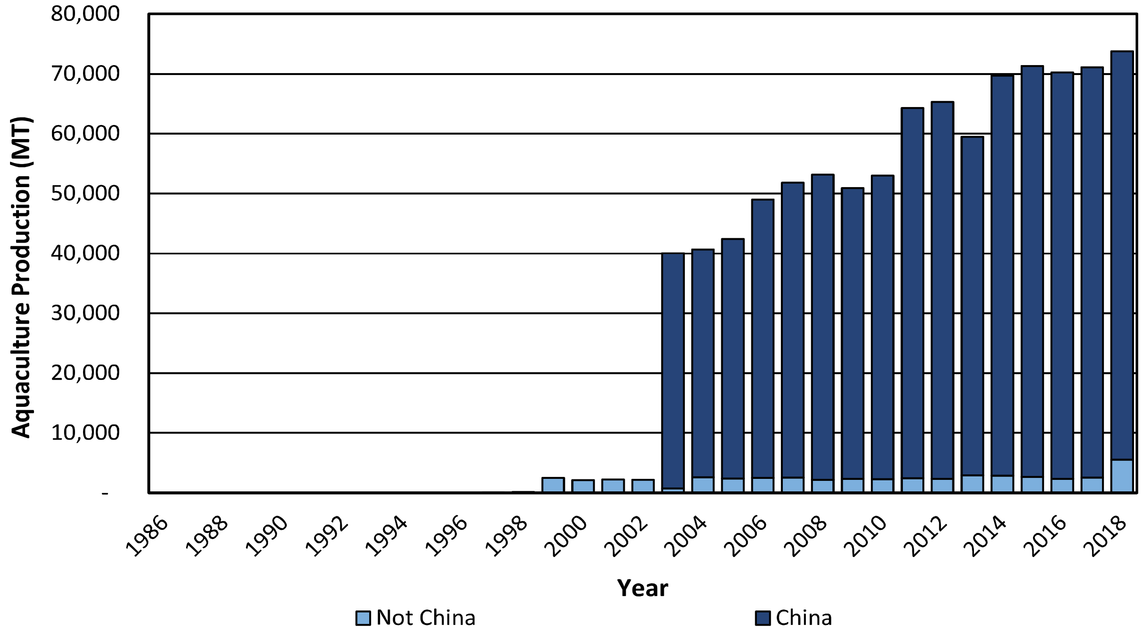
Red Drum has yet to become a significant cultured product in the U.S. commercial food fish market. At least three facilities in Texas are successfully growing them in captivity, however, the market demand has not been strong enough to make it a profitable venture. The cost for cultured Red Drum in the U.S. market is simply too high to sustain large volume operations and other species which are readily available such as Black Drum (*Pogonias cromis*) and Sheepshead (*Archosargus probatocephalus*) that are excellent substitutes (Pearce personal communication).

According to the FAO aquaculture statistics, the U.S. began reporting production around 1,500 MT of Red Drum annually starting in 2004 (Figure 6.28). A number of other countries also began Red Drum culture around the same time but not in very large numbers. China began reporting production in 2003 at just under 40,000 MT and increased to almost 70,000 MT in the last four reporting years through 2017. Total Red Drum production in all other countries combined have averaged around 2,500 MT in comparison (FAO unpublished data).

Red Drum aquaculture products are primarily derived from China and Vietnam with a few coming from U.S. domestic producers. There are less significant imports originating from Mexico, Argentina, Ecuador, and Central America as well. A growing source of Red Drum is from the island nation of Mauritius in the Indian Ocean which provides an excellent, pen raised fresh product shipped directly by air to wholesalers in the U.S. (Pearce personal communication). However, due to the COVID-19 pandemic in 2020, limitations on international flights resulted in that product being unavailable at the time of this publication.

### Stock Enhancement

In order to increase the fisheries productivity of natural waters and to increase the availability of certain species for harvest, fishery managers have often utilized stocking of hatchery reared fish. In some areas of the Gulf (Texas and west central Florida), Red Drum fishing pressure became so intense in the 1960s and 1970s, that survival of juveniles became severely reduced (Perret et al. 1980). Therefore, the state agencies began looking at stocking Red Drum fry and fingerlings to increasing the availability of juveniles to support fishing effort and future harvest.



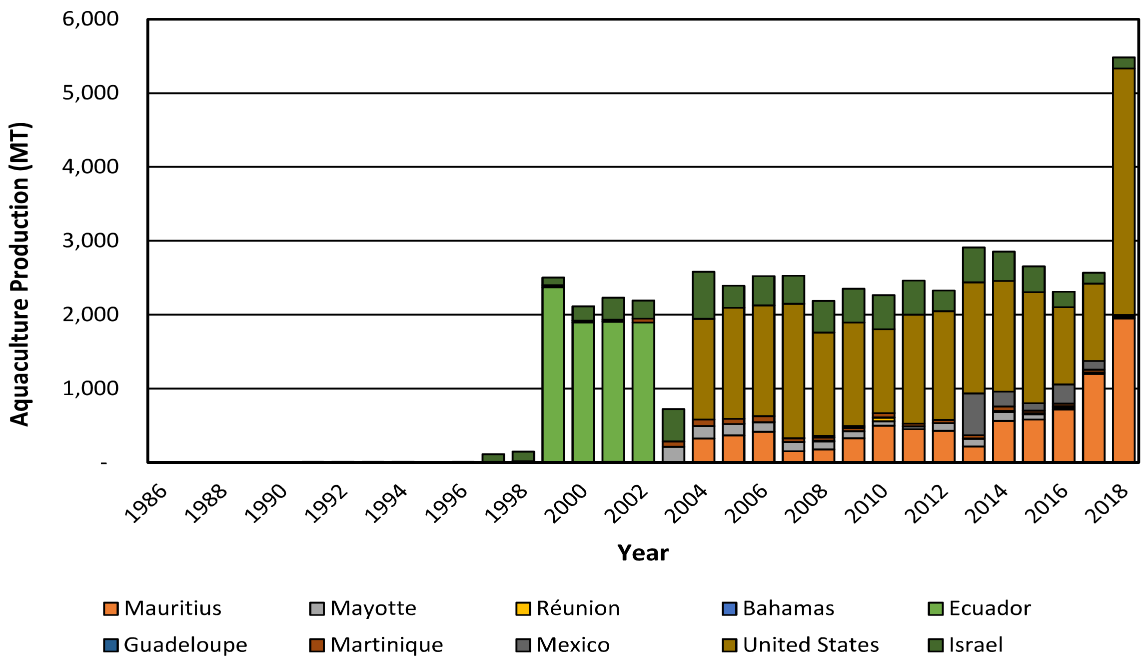




Figure 6.28 Red Drum production A) worldwide and for China and B) all countries other than China reporting aquaculture (FAO unpublished data).

### *Texas*

Biologists from Texas, Florida and Alabama have been successful in inducing Red Drum to spawn in captivity and produce large numbers of fry to fingerlings for stock enhancement in their respective waters. The largest Red Drum enhancement program has been in Texas. The TPWD began producing and releasing fish into Texas bays beginning in 1975 with over 12M fish released into four bay systems (Matlock 1986). In subsequent years (1977 and later; Figure 6.29), more fish were released to a peak of nearly 252M by 1993. Since that time, the TPWD has determined that stocks have rebounded such that

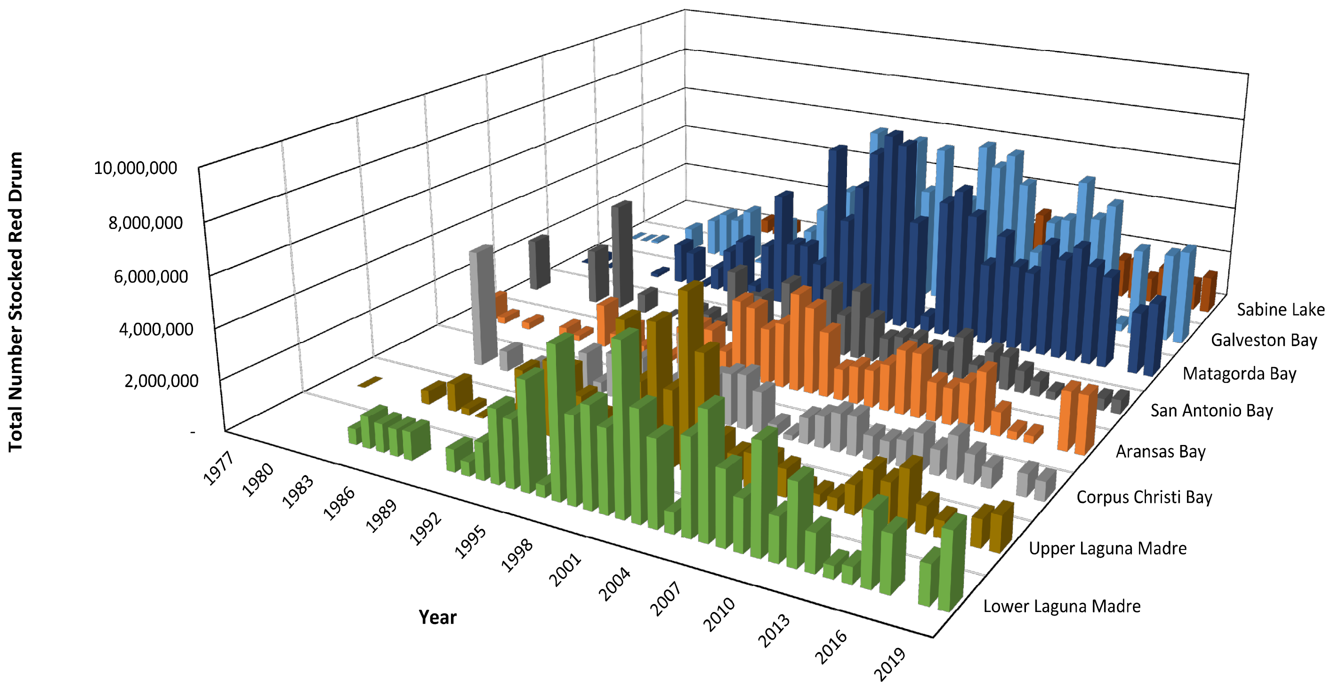



Figure 6.29 Total number of Red Drum "fingerling" stocked into Texas waters by major bay system from 1977 to 2020 (TPWD unpublished data).

by the early 2000s, around 25M fish were released. That number has further declined to around 15M annually since 2010 (TPWD unpublished data).

Red Drum propagation in Texas is conducted at two TPWD facilities; Sea Center Texas in Lake Jackson and the CCA Marine Development Center in Corpus Christi, and the Perry R. Bass Marine Fisheries Research Station in Palacios is used for Red Drum grow out only although all three hatcheries work on a number of other species as well.

### *Alabama*

In Alabama, Red Drum are produced for stock enhancement at the Claude Peteet Mariculture Center (CPMC) in Gulf Shores. Records of fry and fingerling production are scarce prior to 1987, but there are some reports suggesting that the effort began prior to 1980. Trimble (1980) and Heath et al. (1981) reported survival rates of Red Drum raised at CPMC. The CPMC began receiving larvae hatched by the Florida Department of Natural Resources (now the FWC) in 1976 and 1977 and did grow out in ponds. They received additional Red Drum eggs in 1981 from the TPWD to culture in the CPMC ponds. It is not clear if any of the fingerlings in this early work survived to be released however.

The first ADCNR/MRD stocking records were from 1988 and 1989 as part of a MARFIN funded project to improve life history information for Red Drum in Alabama (ADCNR/MRD 1988 and 1989). As a result of the project, a total of 3,623 fingerlings were tagged and released from the hatchery in 1987 and another 13,277 were released in 1988. Minutes from the GSMFC's SEAMAP Subcommittee which met in 1990 indicate that rearing, tagging, and stocking of Red Drum by the agency continued with a total of around 40,000 fish having been released back into Alabama waters by 1990 (SEAMAP Subcommittee Red Drum Work Group 1990). Despite these initial occurrences, not much effort was directed at Red Drum rearing in following years until around 2015 (Table 6.2).

Table 6.2 Stocking of Red Drum in Alabama waters from 2015-2019 (Anson and Mareska 2021).

| Year | (1-2" in TL) |
|---|---|
| 2015 | 8,452 |
| 2016 | 40,000 |
| 2017 | 76,686 |
| 2018 | 368,439 |
| 2019 | 486,847 |
| Total | 980,424 |

In 2015, the ADCNR/MRD began a large effort to enhance Red Drum populations in Alabama waters using National Fish and Wildlife Foundation (NFWF) funding. The CPMC released Red Drum fry and fingerlings totaling nearly 1M fish. The Department quit producing Red Drum after 2019 due to concerns raised by the public regarding potential predation on oysters and crabs. The CPMC redirected their effort towards flounder and Florida Pompano instead.

*Florida*

Red Drum production in Florida by FWC was initiated to investigate the potential of fish releases to aid in management and restoration of native Red Drum stocks rather than a large-scale stocking program. Red Drum production in Florida began in 1988 in Volusia County and releases of fish were spread at eight locations around the state through 1993. Stocking efforts focused primarily on stocking Biscayne Bay from 1990-1999 with a total of 1.67M Red Drum released. In 1998, the FWC initiated a Marine Stock Enhancement Board (MSEAB) which redirected stocking efforts and developed strategies for stocking efforts in the state. At that time, all Red Drum stocking research in the state focused on the Alafia River and Little Manatee River (Tampa Bay), both in an effort to determine best stocking practices for measurable success and raise the local population of Red Drum by 25% for the angling community (Tringali et al. 2008, FWC Website). FWC produced and released around 1.6M Red Drum into the Alafia River and nearly 2.4M into the Little Manatee River during 2000-2004 to identify key strategies to guide a potential stocking program (Tringali et al. 2008). Soon afterward, FWC postponed fish production and releases in search of property to build a new hatchery to intensively produce sportfish, including Red Drum. While piloting new intensive culture techniques at the original FWC hatchery at Port Manatee (Palmetto, Florida) beginning in 2008, FWC produced 190,000 Red Drum which were released into Charlotte Harbor, Sarasota Bay, and Tampa Bay estuaries in 2018 and 2019. Presently, FWC is nearing completion of its new Marine Fisheries Enhancement Center at Apollo Beach where intensive production will supply Red Drum for all stock enhancement research (Lemus personal communication).

*Mississippi*

In 1987, Mississippi State University partnered with Mississippi Power's Watson Plant in Gulfport, Mississippi and built a hatchery facility and a complex of 26 quarter-acre ponds to determine the feasibility of producing Red Drum and other species for commercial markets following the model from Texas. The primary goal was development of a commercial aquaculture industry to meet the demand for Red Drum. The Coastal Aquaculture Unit at the Watson Plant began collecting broodstock and spawning fish and produced 250,000 and 750,000 eggs in 1987 and 1988 respectively (M. Murphy personal communication). The high demand for Red Drum fillets in the restaurant industry pushed many into the potential product, but as the hatchery was beginning to succeed in producing fingerlings, NOAA closed all commercial fishing for Red Drum and the alternative species available to replace Red Drum in the market resulted in a devaluing of the fish. As a result, the hatchery ceased production of Red Drum in the mid-1990s and focused on other species such as hybrid Striped Bass (*Morone chrysops* × *M. saxatilis*) and hybrid catfish (*Ictalurus punctatus* x *I. furcatus*). Over the decade of Red Drum production, the hatchery raised and released around 1,000 tagged individuals in 1988 and again in 1990. Several of those tagged fish remained at large for as long as seven years, but all records from the hatchery and the MDMR were lost during Hurricane Katrina in 2005 (Murphy personal communication).

# Chapter 7
# ECONOMIC CHARACTERISTICS OF THE COMMERCIAL AND RECREATIONAL FISHERIES

Historically, Red Drum were an important species targeted by both commercial fishermen and recreational anglers in the Gulf of Mexico; however, regulations imposed on the commercial sector in the 1980s to protect Red Drum populations limited commercial landings and led to the Red Drum fishery predominately being a recreational fishery. Since the early 2000s, Red Drum aquaculture production has increased rapidly and is the predominate source of commercial production of the species for human consumption. Per the United Nations Food and Agriculture Organization (FAO), global aquaculture production of Red Drum has increased from 2,115 MT in 2000 to 70,242 MT in 2016 with 97% of production (67,931 MT) originating in China (FAO unpublished data).

In the following economic discussion, the term dockside price will be used to describe the price per pound received by a commercial fisherman harvesting Red Drum and the term ex-vessel value will be used to describe the landed value (dockside price per pound multiplied by the total pounds landed) at the state and regional level for the commercial Red Drum fishery. Value-added by subsequent processors, and any associated mark ups in the value of the fish as it moves through the marketing channel to consumers, are not included in the discussion due to lack of data. Values associated with Red Drum recreational fishing are generally limited, but available research on angler willingness-to-pay (WTP) for Red Drum fishing opportunities will be presented.

Annual nominal ex-vessel values will be discussed for the Gulf and Atlantic Coast states. Atlantic landings were included to provide more information on the wild capture market in light of the prohibition of commercial harvest in Gulf of Mexico federal waters and most state waters beginning in the 1980s. Information on trends in Gulf landings (lbs) is found in Chapter 6 - Fisheries.

## Commercial Sector

The Gulf commercial Red Drum fishery was moderately sized through the 1970s and experienced rapid growth during the first half of the 1980s as the species became more popular with consumers due to the popularity of blackened red fish, a dish created by New Orleans chef Paul Prudhomme that increased demand substantially for commercially harvested Red Drum (McGill 1988). The Gulf commercial fishery peaked in 1986 with 14.1M lbs landed (Figure 6.2) with an ex-vessel value of $9.3M (NOAA unpublished data).

Texas prohibited commercial fishing for Red Drum in Texas waters in 1982. Concerns were raised over stock status in the Gulf due to increased harvest and the GMFMC subsequently prohibited directed commercial harvest from federal waters in 1986. In 1987, a quota of 325,000 lbs was set for commercial fishermen in federal waters off Alabama, Mississippi, and Louisiana and all commercial harvest off of Florida and Texas was prohibited. In 1988, commercial fishing was banned in all federal waters (GMFMC 1992). Subsequent limitations on entanglement harvest and prohibition of commercial sale in Florida, Alabama, and Louisiana further decreased the commercial fishery. The commercial fishery shrank rapidly as prohibitions on landings and sales of Red Drum were quickly enacted. By 1988, Gulf wide landings were approximately 292,000 lbs with an ex-vessel value of just $392,000. Since 1990, the commercial Red Drum harvest in the Gulf has averaged only $65,000 per year (nominally) with most of the harvest occurring in Mississippi state waters (NOAA unpublished data).

## Annual Commercial Ex-Vessel Value

During the period from 1950-1989 most of the ex-vessel value generated by Red Drum commercial landings occurred in the Gulf of Mexico (Figures 7.1 and 7.2). This was due to higher landings and generally higher dockside prices in the Gulf region. Since 1990, the Atlantic states have accounted for the majority of ex-vessel value generated by Red Drum commercial landings due to the closure of the Gulf fishery. During this period, the South Atlantic produced higher landings than the Gulf in all years and Atlantic dockside prices have generally been higher than Gulf prices since 2005. Commercial ex-vessel values presented are nominal (non-inflation-adjusted) total landed values by state and/or region and by year (NOAA unpublished data).

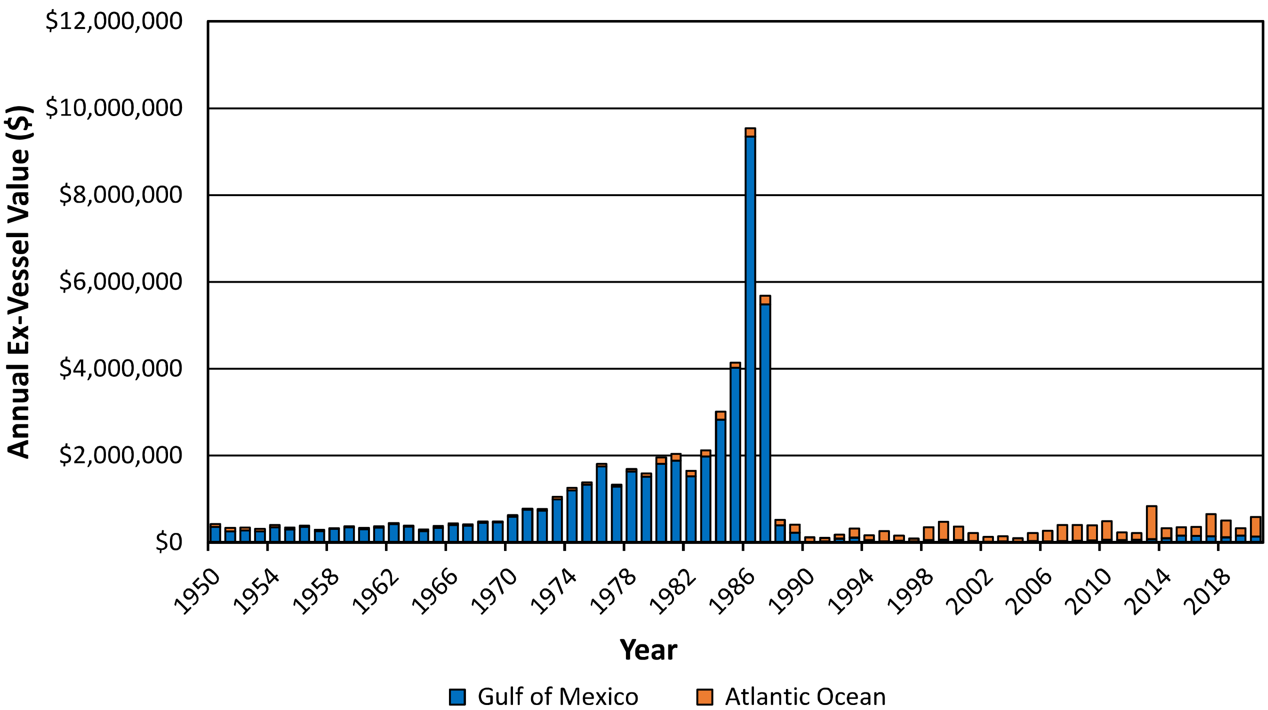



Figure 7.1. Annual Red Drum ex-vessel value by fishing area from 1950-2020 (NOAA unpublished data).

### *Ex-Vessel Values by Region*

#### Gulf of Mexico

Between 1950 and 1989, the Gulf accounted for 91% of U.S. annual commercial landings on average (Figures 7.3 and 7.4). Between 1950 and 1970, total Gulf wide ex-vessel value averaged $352,593 with Texas, Florida, and Louisiana accounting for 43%, 29%, and 24% of landings, on average, during the period (NOAA unpublished data).

While the nominal ex-vessel value of Gulf landings more than tripled from 1970-1983, most of the increase was driven by inflation. Inflation adjusted ex-vessel value only increased 29%. The Gulf commercial Red Drum fishery was marked by extremely rapid growth from 1983-1986 as ex-vessel value increased almost five-fold. This led to concerns regarding stock status and the rapid decline in ex-vessel value in subsequent years was due to closure of the federal water fishery and state-level restrictions. By 1988, the ex-vessel value of commercial landings was only 4% of the value landed just two years prior in 1986.

#### Atlantic Coast

Historically, the majority of U.S. commercial Red Drum landings, in terms of ex-vessel value, came from the Gulf of Mexico with lesser landings from the South and Mid-Atlantic regions (Figure 6.1). Through the

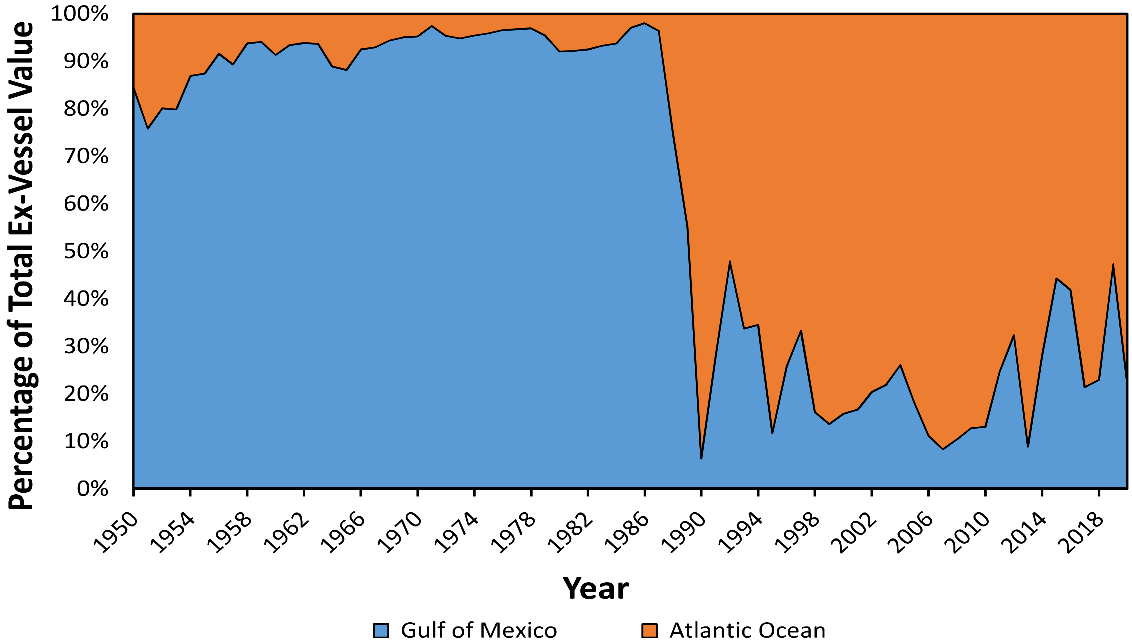



Figure 7.2 Annual percentage of total U.S. Red Drum ex-vessel value by fishing area from 1950-2020 (NOAA unpublished data)

early 1980s, most Atlantic commercial Red Drum landings were from the East Coast of Florida (Figure 7.5). On average, Florida accounted for 67% of total U.S. Atlantic Coast commercial Red Drum based on ex-vessel value (Figure 7.6). Since 1990, landings from the Atlantic have accounted for 77% of U.S. commercial average annual ex-vessel value of Red Drum with large annual variations year-to-year, with North Carolina accounting for 95% of Atlantic coast ex-vessel value on average (NOAA unpublished data).

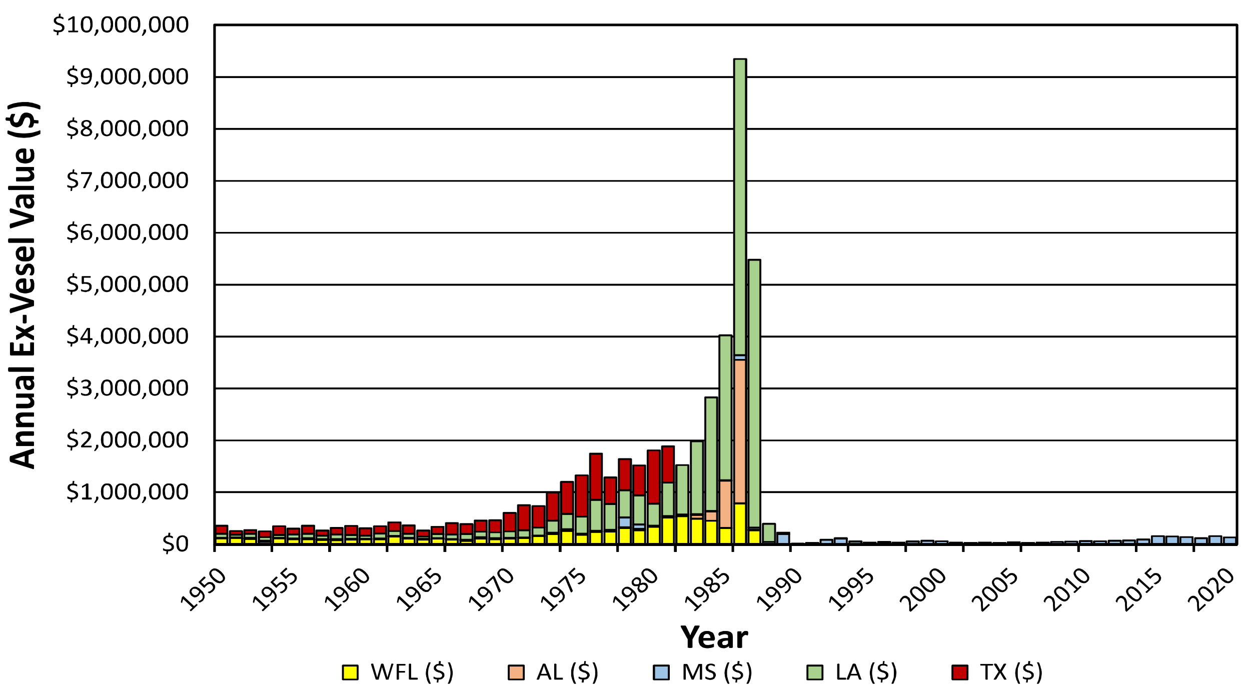



Figure 7.3. Annual Red Drum ex-vessel value by Gulf state from 1950-2020 (NOAA unpublished data.

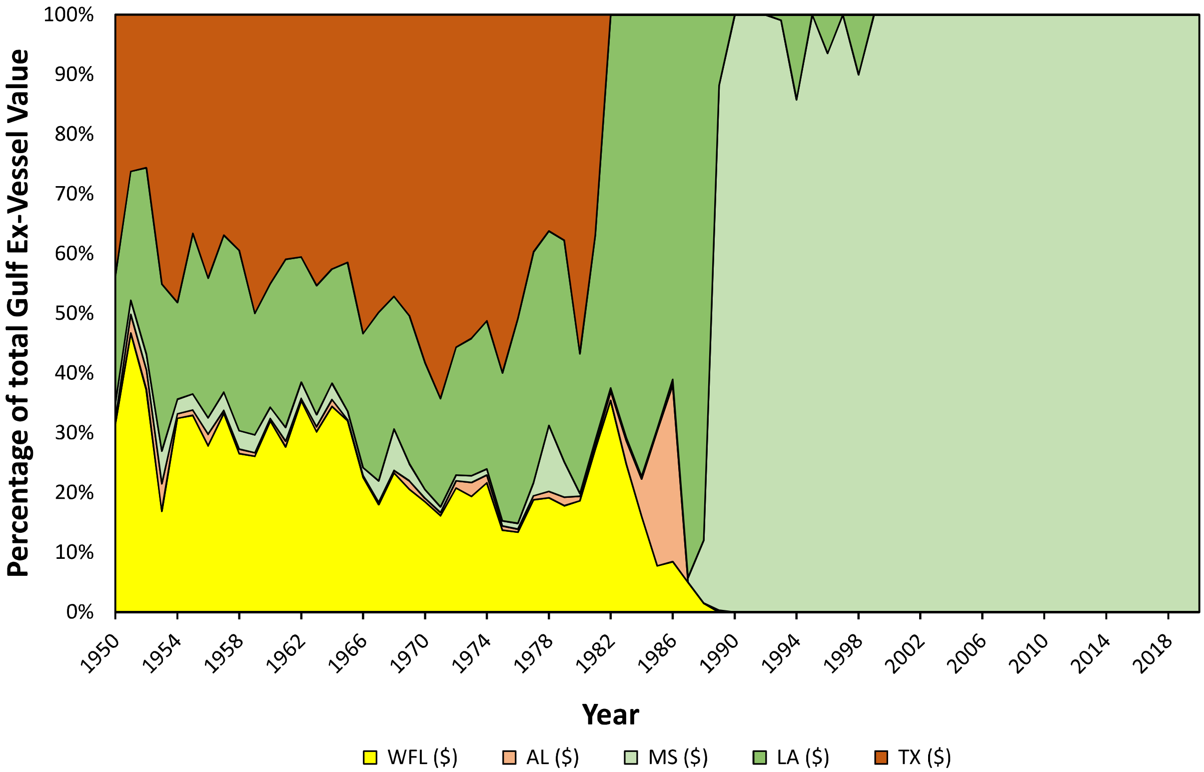



Figure 7.4. Annual percentage of total U.S. Gulf of Mexico Red Drum ex-vessel value by state from 1950-2020 (NOAA unpublished data).

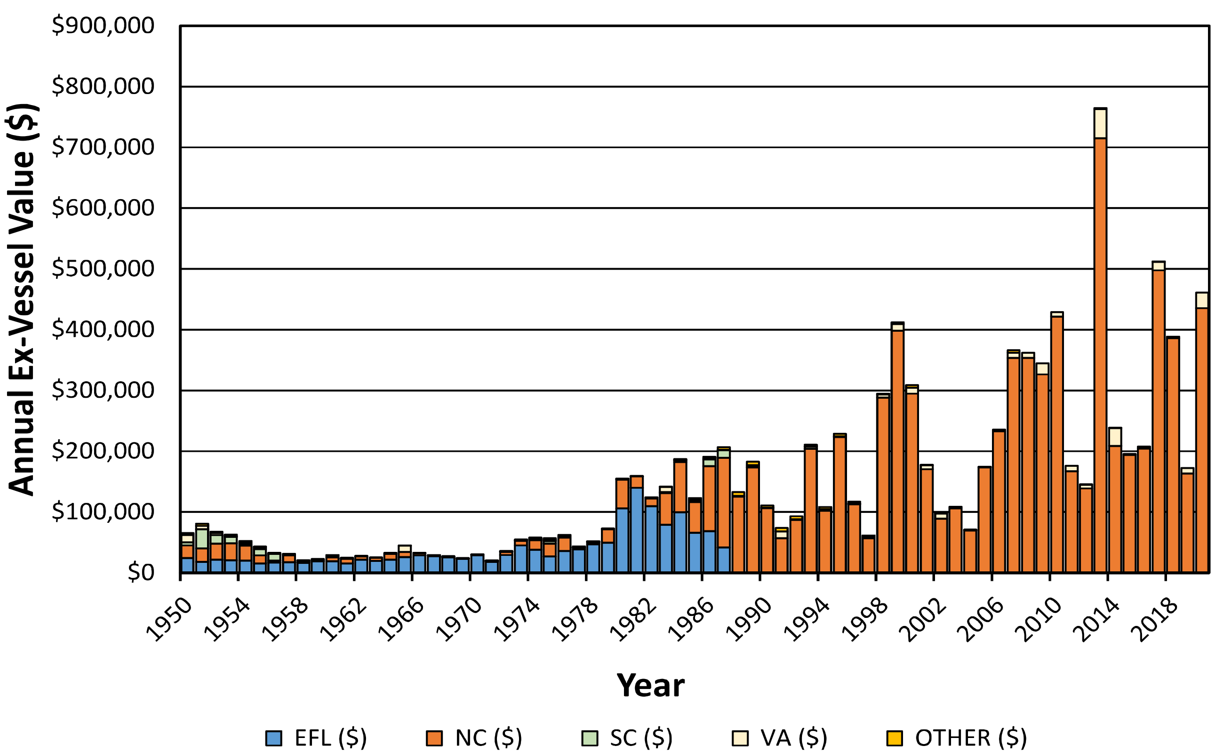



Figure 7.5 Annual Red Drum ex-vessel value by Atlantic state from 1950-2020 (NOAA unpublished data). 'Other' Atlantic landings include small and sporadic landings from Delaware, Georgia, Maryland, New Jersey, New York, and Rhode Island.

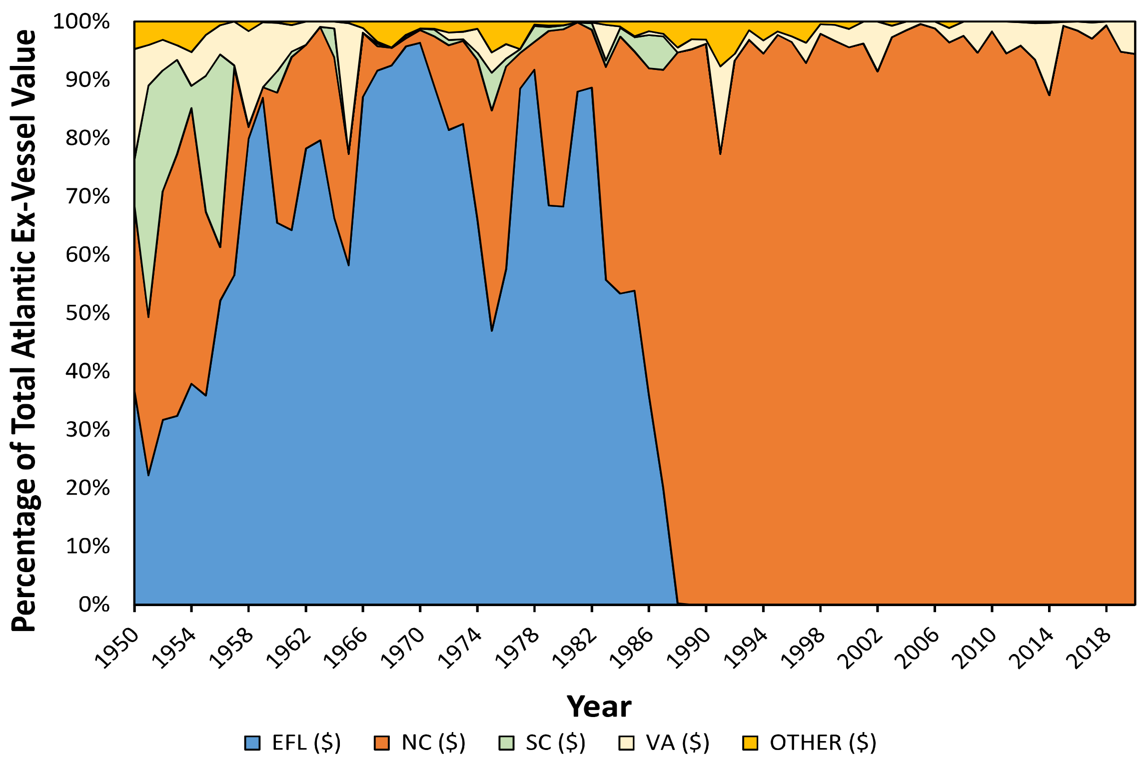



Figure 7.6. Annual percentage of total U.S. Atlantic Coast Red Drum ex-vessel value by state from 1950-2020 (NOAA unpublished data). Other Atlantic landings included small and sporadic landings from Delaware, Georgia, Maryland, New Jersey, New York, and Rhode Island.

While the North Carolina fishery has become the largest U.S. state-level commercial Red Drum fishery over the last thirty years (Figure 6.1), landings have been marked by large annual swings in landings and value over the last few decades primarily related to natural fluctuations in year class strength driven largely by environmental conditions (Kowalchyk personal communication).

In North Carolina, the commercial dockside value has shown an upward trend since the 1970s, and the elimination of Red Drum commercial harvest in other states, as well as trip limits and bycatch requirements in the state, have led to further price increases. Currently, market conditions do not vary greatly, and fish house prices are sufficiently high to make Red Drum a desirable fish for harvest which keeps fishermen interested in harvesting Red Drum when available (Kowalchyk personal communication).

### *Ex-Vessel Values by State*

#### Florida (East and West Coasts)

From 1950 to 1987, Florida commercial Red Drum landings, on average, accounted for 26% of total Red Drum ex-vessel value. The West Florida fishery was substantially larger than the East and from 1950-1987 the West Coast of Florida accounted for 84% of commercial Red Drum landings from the state of Florida by ex-vessel value. Regulatory closures on both coasts led to an end to commercial harvest in 1988.

#### Texas

Prior to its closure in 1982, the Texas commercial Red Drum fishery was a major component of total Red Drum landings. Texas was the first state with substantial landings to prohibit commercial harvest of

Red Drum. From 1950-1981, Texas Red Drum accounted for 42% of the Gulfs annual ex-vessel value on average.

#### Louisiana

Louisiana's Red Drum fishery decreased substantially in 1988. The landings decreased 97% compared to 1986 when the commercial fishery reached its apex of 7.8M lbs. Between 1950 and 1981, Louisiana Red Drum accounted for 23% of U.S. average annual Red Drum ex-vessel value. Louisiana was the epicenter of the commercial Red Drum fishery at its height, between 1984 and 1987, Louisiana accounted for 73% of total annual ex-vessel value on average.

#### Alabama

Between 1950 and 1982 Alabama's Red Drum fishery was relatively small accounting for only 1% of annual ex-vessel value on average. The state's fishery, like the other Gulf states, expanded rapidly in the 1980s. The 1986 ex-vessel value ($2.8M) was approximately 217 times larger than 1981 landings ($128,000). Alabama has had no commercial landings of Red Drum from federal waters since 1989.

#### Mississippi

Prior to the mid-1980s, Mississippi's commercial Red Drum fishery was rather small. Between 1950 and 1987, Mississippi Red Drum landings accounted for only 2% of the average annual ex-vessel value in the Gulf. Since the closure of the federal and other state waters, Mississippi's share of the total U.S. catch has increased dramatically to 23% of annual ex-vessel value on average since 1988; however, this is more a function of the nationwide decrease as Mississippi commercial landings have averaged just under $70,000 per year over the same period.

#### North Carolina

North Carolina was a minor contributor to the U.S. commercial Red Drum fishery prior to harvest closures in other states. From 1950 to 1987, it accounted for only 2% of the ex-vessel value annually on average. Since 1988, North Carolina commercial landings averaged 71% of total U.S. ex-vessel value with an average value of approximately $231,000 per year. While North Carolina now has the largest commercial Red Drum fishery in the U.S., it is largely a result of decreased commercial Red Drum fishing elsewhere in the U.S.

#### Other Atlantic States

All other Atlantic states had minimal commercial Red Drum fisheries historically. Since 1950, all other Atlantic states combined accounted for only 2% of U.S. total annual ex-vessel value on average.

### Annual Dockside Prices for Red Drum

Dockside price is the price received by commercial fishermen upon sale to a first buyer, usually a dealer or wholesaler. This analysis measures dockside prices as the total value of landings for a state or region divided by the total pounds landed in the state or region.

### Gulf States Dockside Prices

Nominal dockside prices for Red Drum have a general upward trend for the analysis period (1950-2020; Figure 7.7). From 1950-1970 average nominal Gulf wide dockside prices hovered between $0.15 and $0.21/lb; at the state level, Texas had the highest dockside prices during the period on average at $0.24/lb. From 1970-1986, nominal dockside prices more than tripled from $0.19 to $0.66/lb, and the large increase in landings and ex-vessel value in 1987 coincided with a 70% year-over-year increase in

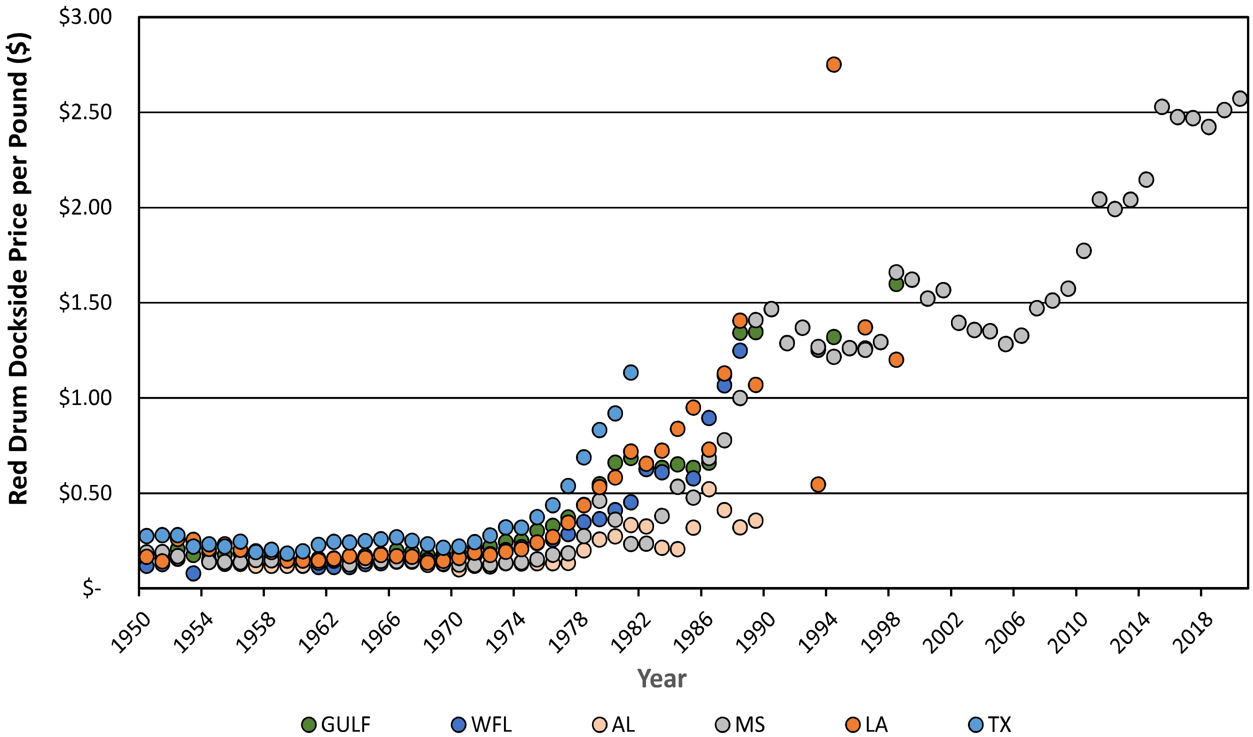



Figure 7.7 Annual average Gulf of Mexico Red Drum nominal dockside price-per-pound by state and region from 1950-2020 (NOAA unpublished data).

nominal dockside prices as the price jumped from $0.66 to $1.12/lb (NOAA unpublished data). Dockside prices continued a general upward trend from 1987-2020 with nominal prices more than doubling, albeit at much lower production levels after the end of commercial fishing in all Gulf states except Mississippi.

### *Atlantic States Dockside Prices*

Atlantic states Red Drum nominal dockside prices followed a trend similar to the Gulf (Figure 7.8). From 1950 to 1970 regionwide prices hovered between $0.10 and $0.19/lb on a nominal basis with South Carolina and east Florida fishermen, on average, receiving higher prices. Nominal dockside prices generally rose from the 1970s through 2020. Since 2000, Atlantic nominal dockside price increases have exceeded the trend noticed in the Gulf (NOAA unpublished data). While nominal Gulf (Mississippi only) dockside prices only increased 69% from 2000-2020, Atlantic dockside prices increased 145% and now generally exceed the Gulf prices.

## Commercial Aquaculture

The global supply of Red Drum is now dominated by aquaculture production with the vast majority produced in China (Figure 7.9). Since 2003, China has accounted for 95% of Red Drum aquaculture production on average. During the period from 2003-2020, aquaculture production increased from approximately 88M to 170M lbs (FAO 2022). Figures 7.10 and 7.11 provide Red Drum aquaculture production in metric tons (MT) and as a percentage of total global production excluding China, respectively. Unfortunately, very little data on Red Drum prices associated with global aquaculture production is available.

While U.S. aquaculture production of Red Drum only accounted for 3% of global annual Red Drum aquaculture production on average from 2004-2020, it was the second largest producer globally behind China (Figure 7.12). Red Drum production in the U.S. generally ranged between 2M to 4M lbs between

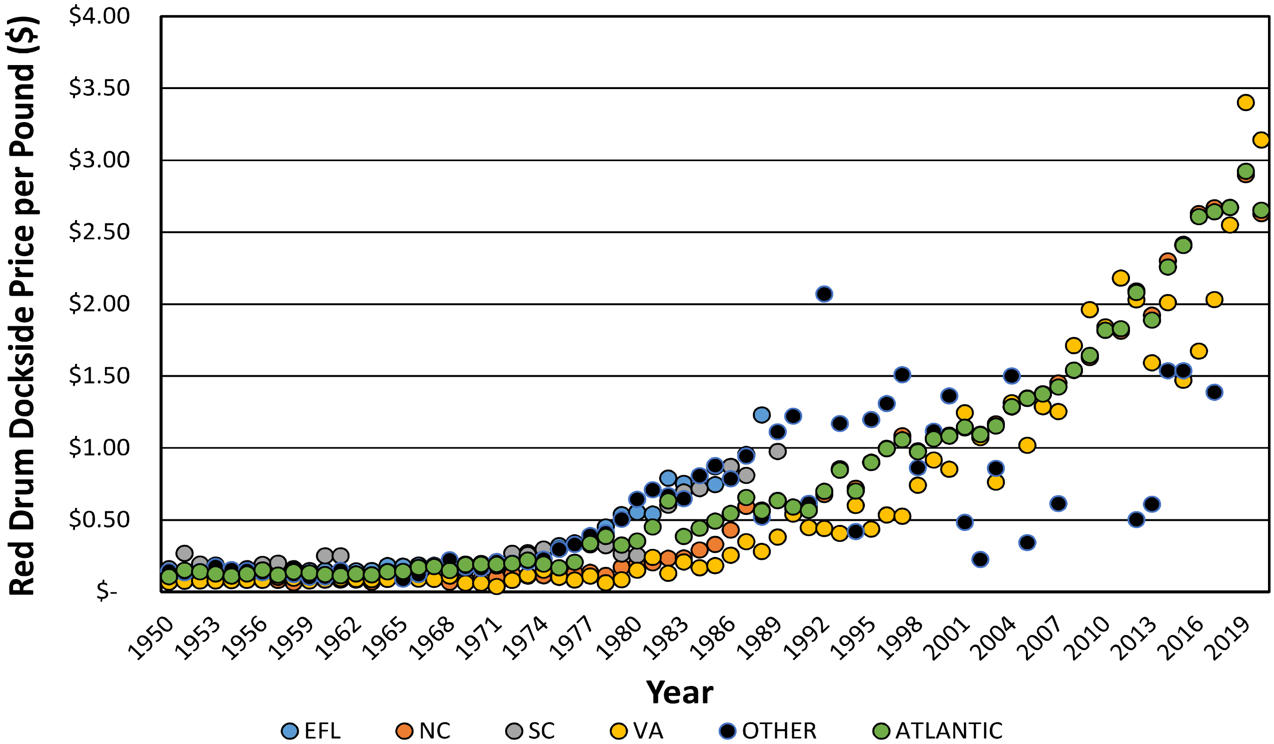



Figure 7.8 Annual average Atlantic Red Drum nominal dockside price-per-pound by state and region from 1950-2020 (NOAA unpublished data).

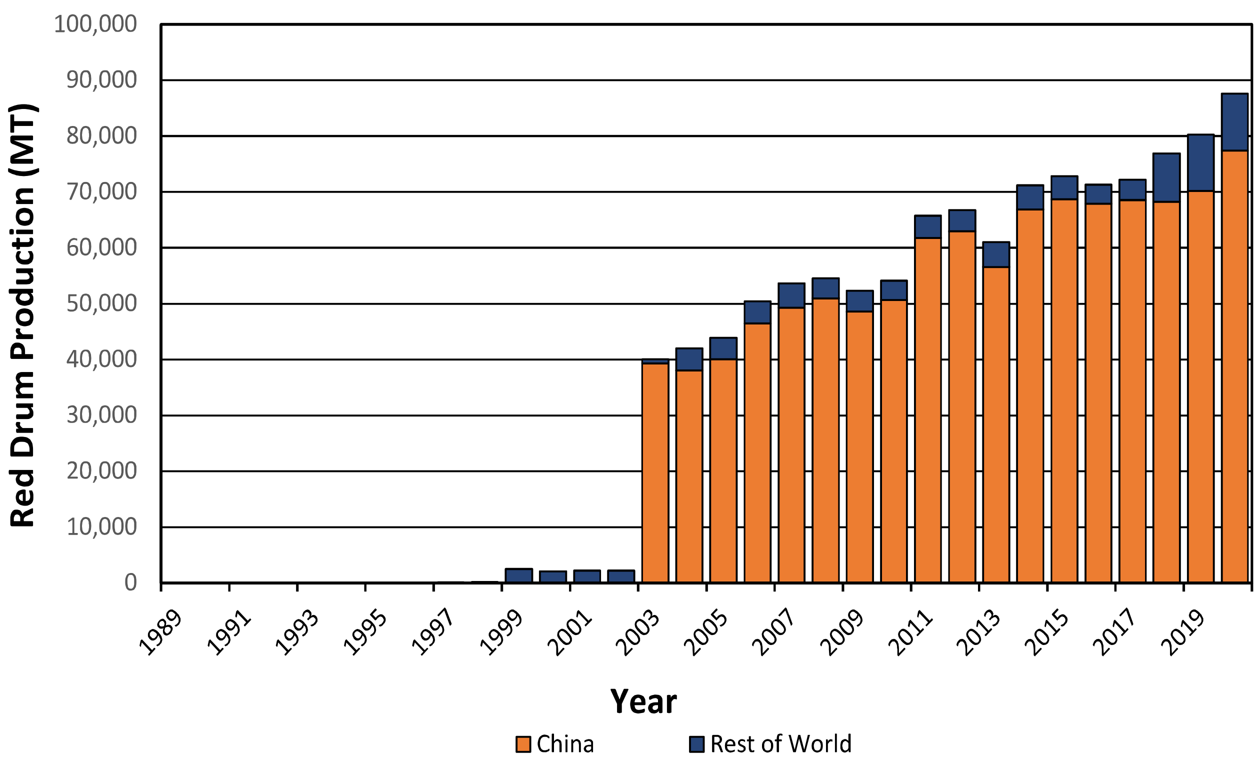



Figure 7.9 Red Drum aquaculture production by year from 1989-2020 for China and the rest of the world (FAO unpublished data)

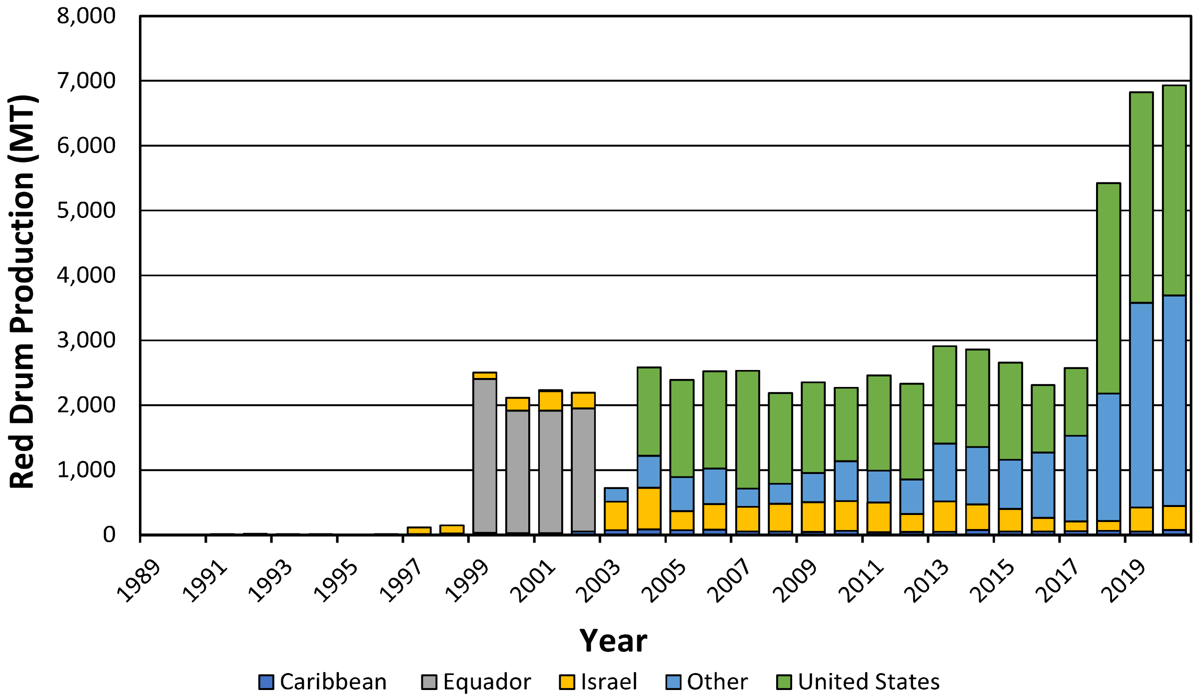



Figure 7.10 Red Drum aquaculture production by year and region outside of China from 1989-2020 (FAO unpublished data). Data has been aggregated at the regional level for Caribbean nations and smaller producers from other parts of the world have been aggregated into an ‘other’ category.

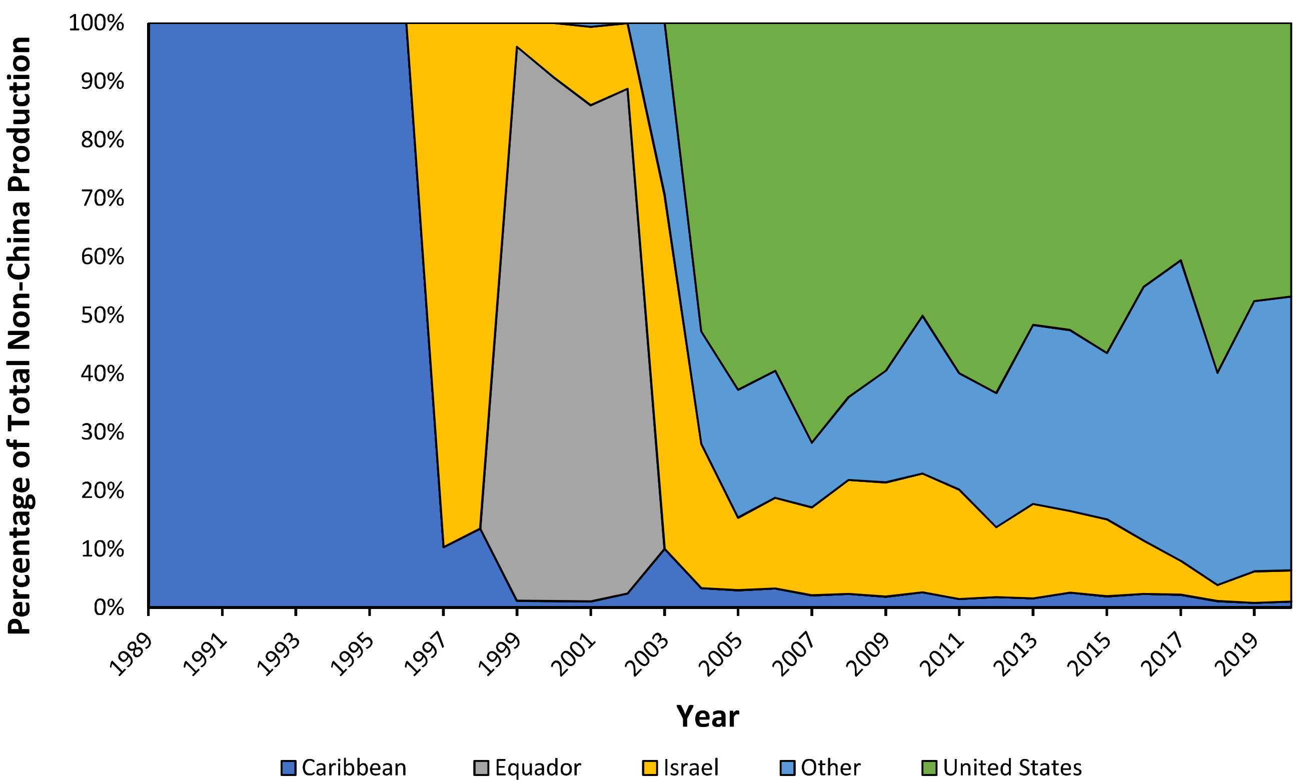



Figure 7.11 Percentage of non-China Red Drum aquaculture production by year and region from 1998-2020 (FAO unpublished data). Data has been aggregated at the regional level for Caribbean nations and smaller producers from other parts of the world have been aggregated into an ‘other’ category.

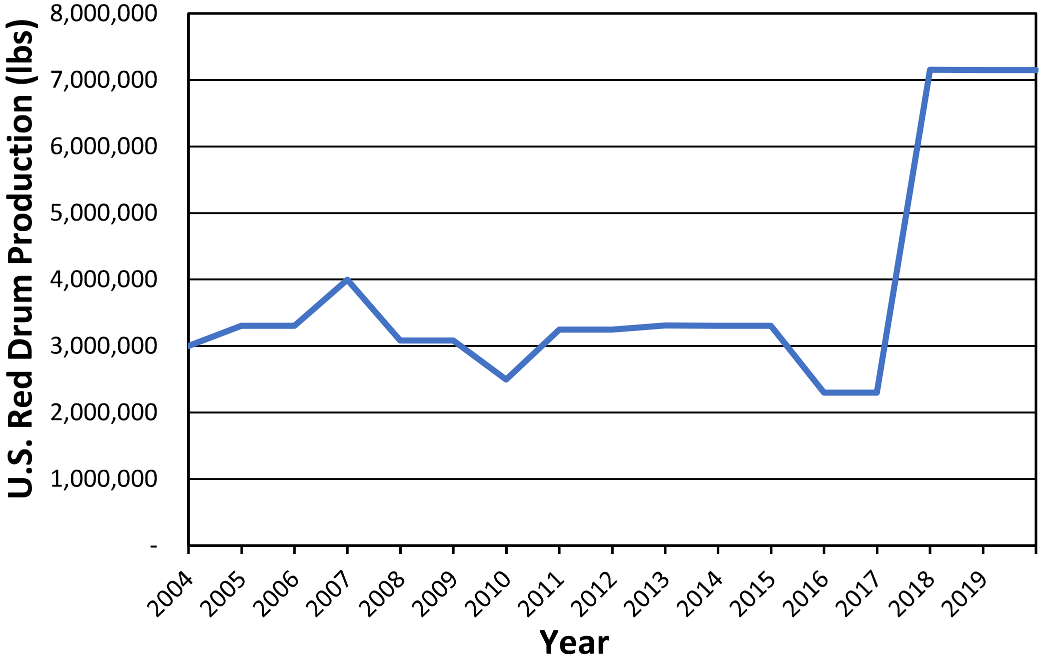



Figure 7.12 Total U.S. Red Drum aquaculture production by year from 2004-2020 (FAO unpublished data).

2004 and 2017 but increased substantially in 2018 to over 7M lbs and has remained at this level of production. According to the USDA Census of Aquaculture, U.S. farmed Red Drum production was accomplished by 12 farms located in Texas (8), Florida (2), and South Carolina (2) (USDA 2019). Texas Red Drum production uses outdoor ponds and while price data is limited, a 2017 report indicated Texas whole fish prices received by growers have increased from \$2.30-\$2.40/lb in 2008 to \$2.78/lb in 2009 and to a range of \$2.78-\$3.15/lb in 2016 (Treece 2017).

## Processing and Market Chain

### *Marketing*

The marketing of Red Drum in the United States and globally is driven by aquaculture since it accounts for the vast majority of Red Drum production. Limited information is available on the marketing of Red Drum. The FAO indicated that fresh or frozen fillets and steaks in the 0.375-0.750 lb (170-340 grams) are the primary wholesale product form, although whole, gutted fish are also marketed wholesale (FAO unpublished data). As of 2016, the largest U.S. marketer of aquaculture Red Drum, Ekstrom Enterprises in El Campo, Texas, indicated that all of its Red Drum is sold fresh (Eardley 2016). U.S. farm-raised Red Drum is primarily consumed in the U.S. with a small amount exported to Canada. In addition, the U.S. purchases Red Drum imported from Taiwan and China, but import statistics specific to Red Drum are not available (Eardley 2016).

### *Other Sources of Red Drum Supply*

The FAO lists the United States as the only country with wild capture production of Red Drum since 1950 and aquaculture production of Red Drum is discussed earlier in this chapter. Therefore, there are no other documented sources of Red Drum entering the Gulf market.

## Recreational Sector

### Angler Expenditures in the Gulf of Mexico

Saltwater recreational fishing is a key economic driver of many Gulf of Mexico coastal communities. The economic importance of recreational fishing is derived from both consumptive (harvest) and non-consumptive (enjoyment from spending time fishing regardless of harvest) use of the resources. In 2019, saltwater recreational anglers, targeting all species, spent $620.9M on trip expenditures in Alabama, $429.5M in Louisiana, $104.5M in Mississippi, $308.6M in Texas, and $1,815.1M in West Florida (NMFS 2022). The Texas estimate does not include estimated expenditures for shore-based marine recreational fishing trips, all other state level estimates include estimated expenditures on for-hire, private boat, and shore-based marine recreational fishing trips.

#### *Red Drum Angler Expenditures and Preferences in the Gulf*

Red Drum is an important species for Gulf recreational saltwater anglers. According to NOAA (unpublished data), Red Drum was the third most commonly caught species by Gulf anglers from 2011-2020 behind Spotted Seatrout and Gray Snapper (*Lutjanus griseus*). A total of 18.6M individual Red Drum were estimated to have been caught by anglers in Alabama, Florida, and Mississippi. The estimated number of fish caught includes both harvested and released fish across all recreational fishing modes (for-hire, private vessel, and shore-based). Texas and Louisiana do not take part in MRIP so the numbers provided do not include these states. Although Red Drum was not the most caught species by Alabama, Florida, and Mississippi anglers, it was the most frequently targeted. NOAA estimates that approximately 6.7M state-based recreational fishing trips targeted Red Drum in 2020, more than any other species. The second most targeted species was Spotted Seatrout (5.1M trips). At the state level, Red Drum was the most commonly targeted species in both Alabama and West Florida waters and was the second most commonly targeted species in Mississippi waters behind Spotted Seatrout from 2018 to 2020.

The popularity of Red Drum as a target species for recreational anglers extends to Texas and Louisiana as well. Kyle et al. (2013) found that 34.4% of Texas recreational anglers selected Red Drum as their first-choice preferred species to catch when saltwater fishing. While Red Drum was the most popular saltwater species targeted, Spotted Seatrout was a close second (31.6%). Previous studies have similarly indicated that Red Drum is the most preferred species among Texas saltwater anglers (Ditton and Hunt 1996, Bohnsack and Ditton 1999, Anderson and Ditton 2004, Tseng et al. 2006, Landon et al. 2012). Red Drum is highly prized by Louisiana recreational anglers and important to Louisiana's coastal economy. A recent survey of Louisiana saltwater anglers found that Red Drum was the sole target on 31.2% of fishing trips, second only to Spotted Seatrout (52.6%) (Smith et al. 2022). Similarly, Louisiana access point surveys during 2020 found that 31.0% of marine recreational fishing trips targeted Red Drum (LDWF unpublished data). Smith et al. (2022) estimated average per trip expenditures across all Louisiana marine recreational fishing trips, including Red Drum trips, at $242/trip (Smith et al. 2022).

#### *Economic Activities Associated with Red Drum Angler Expenditures in the Gulf*

While information specific to the economic contributions of Red Drum recreational fishing trips is not available, NOAA Fisheries gathers state level data on general recreational saltwater fishing trip expenditures every five years (Lovell et al. 2020). The trip expenditure data is used to estimate the economic contributions of saltwater fishing associated with direct expenditures by the anglers themselves, indirect effects associated with purchases of goods and services by impacted industries (grocery stores, bait stands, hotels, etc.), and induced effects associated with general spending by employees of impacted businesses in coastal communities. Common metrics examined include number of jobs created, total sales of goods and services, labor income from those employed due to recreational fishing, and value-added which measures regional gross domestic product (GDP). In 2019, saltwater anglers in the Gulf spent an estimated $2.497B on 49.97M fishing trips. The trip expenditure estimate only includes trip level expenditures and does not include durable goods expenditures such as boats, vehicles, and other long-lived equipment. These trip expenditures led to 23,301 jobs, $849.282M in labor income, and $1.577B in value added (NMFS 2022).

### *Economic Valuation of Recreational Red Drum Fishing in the Gulf and Southeastern United States*

Even though recreational fishing for Red Drum is extremely popular in the Gulf of Mexico, only a few studies have estimated the economic value of fishing for Red Drum in the Gulf region or more broadly in the southeastern United States. Smith et al. (2022) estimated a consumer surplus of $327/trip in Louisiana using the travel costs method. Combining this estimated consumer surplus with estimates of the number of trips targeting Red Drum, the authors calculated the annual value of Louisiana saltwater fishing trips solely targeting Red Drum at $212M and those trips targeting multiple species including Red Drum at $498M (Smith et al. 2022). Haab et al. (2012) used MRFSS data for recreational trips from Louisiana to North Carolina to estimate angler willingness-to-pay (WTP) to catch and keep one additional fish for several different species. Their analysis estimated a mean WTP range from $12-$22 to catch and keep an additional Red Drum.

## Civil Restitution Values and Replacement Costs

While states generally enforce criminal penalties for fishing violations, some states also require civil restitution for the value of the loss or damage to wildlife resources. In essence, these civil restitution values are placing a monetary value on fish lost due to negligence or illegal activity. Civil restitution values vary by state with some states using a single rate for all illegally harvested fish regardless of size and others basing the restitution on the size of the fish. The Florida Administrative Code (62-11.001) assigns restitution for Red Drum at $33.60 each. In Louisiana, the civil restitution value for an illegally harvested Red Drum is $26.47/fish (Louisiana Code Title 76, Chapter 3, Section 315). In Texas, the value is based on the size of the fish, with larger fish requiring more restitution (TPWD unpublished data; Table 7.1). Mississippi and Alabama have no values assigned for Red Drum. These values provide at least some means for assessing the damage to stocks of Red Drum.

Table 7.1 Texas Red Drum civil restitution costs by fish size (inches) (TPWD unpublished data).

| Fish Size (Inches) | $ Value Per Fish | Fish Size (Inches) | $ Value Per Fish |
|---|---|---|---|
| 1 | $0.14 | 33 | $795.57 |
| 2 | $0.14 | 34 | $833.14 |
| 3 | $0.27 | 35 | $871.63 |
| 4 | $0.42 | 36 | $911.07 |
| 5 | $0.95 | 37 | $951.45 |
| 6 | $24.36 | 38 | $992.82 |
| 7 | $47.66 | 39 | $1,035.24 |
| 8 | $70.74 | 40 | $1,078.69 |
| 9 | $94.53 | 41 | $1,123.22 |
| 10 | $118.56 | 42 | $1,168.85 |
| 11 | $142.81 | 43 | $1,215.60 |
| 12 | $167.38 | 44 | $1,263.54 |
| 13 | $192.23 | 45 | $1,312.64 |
| 14 | $217.43 | 46 | $1,362.97 |
| 15 | $242.98 | 47 | $1,414.54 |
| 16 | $268.93 | 48 | $1,467.40 |
| 17 | $295.26 | 49 | $1,521.53 |
| 18 | $322.08 | 50 | $1,577.03 |
| 19 | $349.33 | 51 | $1,633.85 |
| 20 | $377.09 | 52 | $1,692.06 |
| 21 | $405.39 | 53 | $1,751.70 |
| 22 | $434.22 | 54 | $1,812.78 |
| 23 | $463.63 | 55 | $1,875.33 |
| 24 | $493.64 | 56 | $1,939.37 |
| 25 | $524.31 | 57 | $2,004.96 |
| 26 | $555.61 | 58 | $2,072.08 |
| 27 | $587.61 | 59 | $2,140.80 |
| 28 | $620.31 | 60 | $2,211.12 |
| 29 | $653.76 | 61 | $2,283.10 |
| 30 | $687.99 | 62 | $2,356.74 |
| 31 | $723.02 | 63 | $2,432.07 |
| 32 | $758.87 | 64 | $2,509.14 |

# Chapter 8
# SOCIAL AND CULTURAL DIMENSIONS OF RED DRUM

Red Drum are among the most iconic coastal fish species along the Gulf coast. Red Drum fishing is important for a diverse spectrum of fishers - commercial to recreational and novice to avid. With local folk nomenclature including redfish, reds, channel bass and spottail bass, Red Drum are among larger coastal species accessible from shore. Chef Paul Prudhomme's "Blackened Redfish" popularized Red Drum as a seafood dish from local seafood shacks to fine dining restaurants nationwide. Among recreational anglers, Red Drum are prized for their beauty and fight. This chapter focuses on a few fisheries-related key issues and milestones for understanding the social context of Red Drum fishing and fishing communities.

## Commercial Fishery

With the closure of commercial harvest for most Red Drum in the Gulf, the various fisheries are essentially extinct at this point, however, there are historic accounts of the commercial Red Drum fishing community. These will be summarized briefly and the published resources which provide more detail are provided.

As noted in Chapter 6 – Commercial Fishery; History, the majority of Red Drum landings prior to the 1970s were to meet local consumption and demand (GMFMC 1986). After 1970, the rise in landings and eventual popularity explosion by 1986 was directly tied to the creation and promotion of blackened redfish nation-wide. Entangling gear (gill and trammel nets) were the principle source of Red Drum throughout the commercial era (Figure 6.3) as most of the fish were found inshore and most people preferred a smaller fish (GMFMC 1986). There were some Red Drum taken with lines (rod and reel, trotlines) but in much fewer number, at least for the commercial market. Since the closure of nearly all the fishery in Gulf waters, lines have been the primary source for commercial Red Drum. A history of regulations impacting the commercial harvest of Red Drum in the Gulf of Mexico is summarized in Table 6.1.

The GMFMC (1986) summarized the limited information available at the time for participants in the commercial Red Drum fishery prior to its elimination. Social demographic data for the commercial fishery since that time is absent and the few who still participate in that fishery have not been characterized.

## Social Impacts of the Gill Net Ban on Fishing Communities

The Red Drum Conservation Act, passed by the Texas legislature in 1977, set the recreational bag limit at 10 red drum per day with a possession limit of 20 per day and the commercial daily bag limit at 200 pounds of red drum per day. The same year, the Texas Parks and Wildlife Commission prohibited the use of nets and trotlines on the weekends. The new stricter regulations likely contributed to a decrease in commercial fishing boat licenses from 1977-1978. This gear restriction represented a shift to focus on the gear used in the fishery rather than focusing on commercial vs. recreational angling effort. Managers recognized that extended recovery periods to rebuild over-harvested or otherwise depleted populations can be extremely detrimental to coastal communities that are economically dependent upon fishery products (Heffernan and Kemp 1980).

Texas completely banned gillnets in 1981 in response to overfishing as well as very harsh winters in the late 1970s, which led to declines in Red Drum and Spotted Seatrout populations (Harrison 1995). This ban set the precedent for other states in the Gulf of Mexico to pass their own gillnet restrictions in the

1990s. Proponents of these bans included conservation/environmentalist organizations and recreational fishermen, while commercial fishermen strongly opposed them. TPWD attempted to predict the economic impact of the pending ban on the sale of Red Drum and Spotted Seatrout in TX (Ferguson 1986). Social characteristics and economic dependence on Red Drum and Spotted Seatrout were analyzed. Over 1,000 fishermen were licensed and/or reported sales of the species from 1979-1981, and approximately 300 had a significant economic dependence on either species' landings. Statewide economic impacts as a result of the ban were predicted to be minimal as sales from Red Drum/Spotted Seatrout were only approximately 0.1% of disposable income. Economic impacts in Corpus Christi and lower Laguna Madre bay were predicted to be the greatest as most landings were recorded and many fishermen lived in these areas. The public generally knew little about these issues but voted for the bans, despite the fact that scientific evidence was inconclusive in showing that overfishing was occurring in the Gulf of Mexico.

Around the same time, legislation also classified Red Drum as a game fish in Texas, Louisiana, Alabama, and Florida state waters as well as Gulf of Mexico federal waters. As a result, Mississippi accounts for all commercial landings of the species in the Gulf and about 19 percent of total domestic landings (NOAA unpublished data). The gillnet bans/restrictions had a significant impact on fishing communities throughout the Gulf of Mexico. Many fishermen were forced to take a second job or left the industry completely. Those who entered other fisheries added additional pressure on already fully exploited stocks, such as blue and stone crabs, grouper, and other reef fish (Adams et al. 2001). In Florida, fishermen and their wives experienced mental health impacts, such as increases in perceived stress, depression, anxiety, and anger following the net limitations in 1994 (Smith et al. 2003). A study conducted in Monroe County, Florida showed that 55% of net fishers in the Florida Keys left the fishing industry by 1996. Those that remained changed to higher effort methods, such as netting in offshore waters or switching to hook-and-line gear (Shivlani et al. 1998). While fishing buyback programs and direct assistance were developed, the programs were generally described as unsuccessful at mitigating the widespread social impacts (Harrison 1995)

Red Drum fisheries represent a long history of management conflict between state and federal governments (Goodell 1988). The state of Louisiana passed a size limit and prohibited Red Drum possession on a boat that also had a purse seine in response to the sudden rise in popularity of Red Drum on the market in 1986. A federal rule created by the Secretary of Commerce (under Mag-Stevens) was subsequently passed limiting net harvest of Red Drum in the EEZ. The state's attorney general filed suit against the Secretary, believing that the preemption of state laws goes against the procedures of the Mag-Stevens. Under the Commerce Clause, federal laws can supersede state laws so long as it can be concluded that the regulated activity affects interstate commerce, which in this case it did.

## Conflict and Conservation

The collapse of the Red Drum stocks and subsequent policies leading to its recovery sparked a successful conservation movement, as well as an intense debate between recreational and commercial fishermen. The "Redfish Wars," as they were known in Texas, began in 1977 when the Gulf Coast Conservation Association (GCCA, later changed to the Coastal Conservation Association, CCA) was formed in Houston after fourteen anglers met and voiced their concerns with overfishing of Red Drum and Spotted Seatrout (CCA Texas). The sport anglers of GCCA began to lobby for restrictions on commercial harvest of Red Drum in the Gulf. Their first victory came later in the year after the Texas Legislature passed the Red Drum Conservation Act of 1977, which limited the recreational bag limit of Red Drum to 10 fish per day and the commercial bag limit to 200 lbs per day (Heffernan and Kemp 1980, Table 6.1). The Act had little impact on the Red Drum population, and GCCA began pushing for more legislation, including a ban on gillnets and the designation of Red Drum as a sport fish (both passed in 1981, Table 6.1).

Similar organizations in other Gulf states followed. Save Our Sealife (SOS), a coalition of recreational fishermen and environmental organizations, formed in Florida and launched a multi-million dollar campaign arguing for a constitutional amendment to ban gillnets. SOS, while concerned with the depleted Red Drum population, was also concerned with the impact that gillnets had on endangered species, as well as their contribution to marine debris (Harrison 1995). In response, the Organized Fishermen of Florida (OFF), a commercial fishing interest group formed. OFF filed suit against multiple television stations across the state claiming that they ran misleading ads supporting the net ban. The ads appeared to show a commercial shrimping vessel causing harm to fish and a sea turtle when it dumped its net onto the deck. It was revealed that the video was actually part of a turtle excluder device (TED) study conducted in the 1970s (Harrison 1995). Despite this, Florida citizens voted for a gillnet limitation, which was passed in 1995 (Table 6.1). OFF was later denied their request for an emergency injunction on the limitation.

In the mid-1990s, the Mississippi CCA insisted that Red Drum stocks were still overfished and therefore the state should implement tighter restrictions. They believed that the emergency regulation passed by the Mississippi Commission on Marine Resources restricting the issuance of gillnet licenses passed in 1995 was not enough to help recover the population. The Mississippi CCA claimed that they had unsuccessfully attempted to work out a compromise with commercial fishermen on gillnet restrictions. The proposed law consisted of limited entry into the fishery requiring proof that fishermen made at least 51% of their income from commercial fishing, declaring Red Drum a game fish, increasing penalties for violations, and other reporting requirements (Harrison 1995). While the Mississippi CCA's proposed restrictions were not adopted, the MDMR restricted the size and total length of gillnets and banned the use of gillnets within a half mile of the shoreline in 2019 (Chapter 5 - Enforcement).

## Dealers and Processors

Dealers and processors in the Gulf of Mexico are multi-species operations but there has been no effort to characterize this sector and other than Mississippi and Alabama, there are no dealers that handle commercial Red Drum in the Gulf. According to the MDMR, there were 23 active fish dealers/wholesalers across Mississippi who processed Red Drum in 2021 (MDMR unpublished data). Most of these businesses are concentrated in the coastal counties of Hancock, Harrison, and Jackson. Red Drum commercially caught in other states are landed in Alabama each year. However, due to the small number of dealers in the state (less than 3 as of 2021), Alabama landings data are considered confidential and cannot be disclosed.

## Recreational Fishery

Like most of the Sciaenids, Red Drum are a highly accessible species to target inshore by all recreational anglers in all fishing modes; shore, private boat, or for-hire. In general, every saltwater angler could be included as a 'Red Drum angler'. Red drum in the recreational sector are caught almost exclusively with hook-and-line gear (NOAA unpublished data). Conventional rod and reel is common, but fly fishing for "bull reds" is becoming increasingly popular, especially along the marshes of Louisiana.

The Gulf of Mexico Fishery Management Council (GMFMC unpublished data) analyzed recent catch data of Red Drum using recreational effort. Recreational effort from the MRIP database can be characterized in terms of the number of trips in three ways:

- Target trips - The number of individual angler trips, regardless of duration, where the intercepted angler indicated that the species, or a species in the species group, was targeted as either the first or the second primary target for the trip. The species did not have to be caught.
- Catch trips - The number of individual angler trips, regardless of duration and target intent, where the individual species or a species in the species group was caught. The fish did not have to be kept.
- Total recreational trips - The total estimated number of recreational trips in the Gulf, regardless of target intent or catch success.

Table 8.1 shows the average target and catch effort for Red Drum by state from 2016-2018. Florida has the greatest average number of target trips, accounting for about 41% of trips for this time period. Louisiana has the greatest average number of catch trips, accounting for about 43% of trips for this time period. Table 8.2 shows the average target and catch effort for Red Drum by mode from 2016 to 2018. Private boat angling was the dominant mode for target and catch trips, accounting for about 83% and 88% of all trips, respectively for this time period. In 2020, recreational anglers landed over 5.1M lbs of Red Drum in Florida, a 30.9% decrease from the previous five-year average (2015-2019) while 58.5% of the poundage was harvested on the West Florida Coast (NOAA unpublished data).

Table 8.1 Average recreational target effort and catch effort for Red Drum in the Gulf of Mexico by state across all modes, 2016-2018 (GMFMC 2021).

| | State | | | | | |
|---|---|---|---|---|---|---|
| | Alabama | Florida | Louisiana* | Mississippi | Texas* | Total |
| Red Drum Target Effort | 858,637 | 5,311,119 | 2,561,804 | 906,160 | 196,089 | 6,781,523 |
| Red Drum Catch Effort | 481,541 | 2,197,319 | 2,909,725 | 608,110 | 314,107 | 5,184,508 |

*Effort estimates for Texas are from the TPWD's Marine Sport-Harvest Monitoring Program and assumed equivalent to MRIP-FES estimates. Effort estimates for Louisiana are from the LDWF Recreational Creel Survey and were adjusted to MRIP-FES equivalents using the ratios in NMFS (2020). Headboat estimates are unavailable.

## Regional Demographics and Recreational Angler Preferences

Milon (2001) utilized the Marine Recreational Fisheries Statistics Survey (MRFSS) to examine demographic data of recreational anglers which included 'add-on' questions in the telephone portion of the survey from 1997-1998 (Table 8.3). As noted in VanderKooy (2015), most marine anglers live in urban or metropolitan statistical areas adjacent to the coast (USFWS 1996, Ditton and Hunt 1996). Recreational anglers travel to coastal communities to use the fishing-related infrastructures. These include facilities and services provided by state fisheries management agencies such as piers, boat ramps, and access areas, and those provided by the private sector: guides, boat rentals, marinas, private launch facilities,

Table 8.2 Average recreational target effort and catch effort for Red Drum in the Gulf of Mexico by mode across all states combined, 2016-2018 (GMFMC 2021).

| | Mode | | | |
|---|---|---|---|---|
| | Shore | Charter | Private | Total |
| Red Drum Target Effort* | 1,001,484 | 177,289 | 5,602,750 | 6,781,523 |
| Red Drum Catch Effort* | 332,452 | 312,249 | 4,539,807 | 5,184,508 |

*Effort estimates for Texas are from the TPWD's Marine Sport-Harvest Monitoring Program and assumed equivalent to MRIP-FES estimates. Effort estimates for Louisiana are from the LDWF Recreational Creel Survey and were adjusted to MRIP-FES equivalents using the ratios in NMFS (2020). Headboat estimates are unavailable.

retail stores, restaurants, hotels, motels, campgrounds, and the rest of the tourism support system. There are a number of studies which provide historical descriptions of the recreational fishing community throughout the Gulf such as USFWS (1996), Ditton and Hunt (1996), LDWF (1997), and Milon (2001).

Milon (2001) reported that the majority of saltwater angler respondents in the Southeast Region (excluding Texas) were middleclass (<$60,000 annual income), Caucasian males between the age of 26-55 (47%). About 90% of all anglers surveyed were Caucasian, 7.5% were African-American, and only a few participants (4.5%) identified themselves as Hispanic. Additionally, about 73% of all the respondents were male. During the same time period (1998), Floyd et al. (2006) conducted a phone survey of 3,000 Texas anglers in an effort to generate a profile of residents that participate in outdoor recreation in Texas and for fishing in general (not just saltwater). The study essentially found that those most likely to participate in fishing as a recreational activity were Caucasian males with higher incomes, of middle-age or younger.

Table 8.3 Participation rates for ethnicity, gender and age cohorts by state in the Southeast Region* from 1997-1998 (Table 3-1 *from* Milon 2001).

| State | Alabama (%) | Florida (%) | Georgia (%) | Louisiana (%) | Mississippi (%) | North Carolina (%) | South Carolina (%) |
|---|---|---|---|---|---|---|---|
| **White-Male** | | | | | | | |
| 16-25 | 9.01 | 8.86 | 9.23 | 9.73 | 9.34 | 7.44 | 7.45 |
| 26-45 | 26.47 | 29.3 | 28.44 | 34.01 | 29.98 | 24.97 | 26.52 |
| 46-64 | 20.89 | 19.86 | 16.2 | 17.04 | 18.3 | 20.23 | 18.2 |
| 65+ | 6.58 | 9.09 | 5.65 | 4.65 | 5.9 | 6.04 | 6.67 |
| Total | 62.95 | 67.11 | 59.52 | 65.43 | 63.52 | 58.68 | 58.84 |
| **White-Female** | | | | | | | |
| 16-25 | 2.86 | 2.74 | 2.82 | 2.97 | 3.32 | 2.55 | 2.69 |
| 26-45 | 10.59 | 11.83 | 12.62 | 12.14 | 12.04 | 11.75 | 11.7 |
| 46-64 | 7.44 | 7.54 | 7.16 | 6.38 | 7.62 | 7.73 | 6.59 |
| 65+ | 2.72 | 2.01 | 3.01 | 1.05 | 1.47 | 2.77 | 1.73 |
| Total | 23.61 | 24.12 | 25.61 | 22.54 | 24.45 | 24.8 | 22.71 |
| **Non-White Male** | | | | | | | |
| 16-25 | 2.15 | 1.15 | 0.94 | 1.55 | 1.6 | 1.55 | 2.6 |
| 26-45 | 4.15 | 2.95 | 4.71 | 4.4 | 4.42 | 5.64 | 5.89 |
| 46-64 | 1.43 | 1.7 | 3.01 | 3.04 | 1.97 | 3.09 | 3.81 |
| 65+ | 0.57 | 0.64 | 1.88 | 0.74 | 0.37 | 1.19 | 0.87 |
| Total | 8.3 | 6.44 | 10.54 | 9.73 | 8.36 | 11.47 | 13.17 |
| **Non-White Female** | | | | | | | |
| 16-25 | 0.29 | 0.26 | 0.56 | 0.74 | 0.25 | 0.72 | 0.52 |
| 26-45 | 2.72 | 1 | 1.51 | 0.74 | 1.23 | 2.19 | 2.08 |
| 46-64 | 1.57 | 0.8 | 1.32 | 0.62 | 1.6 | 1.58 | 1.73 |
| 65+ | 0.57 | 0.26 | 0.94 | 0.19 | 0.61 | 0.57 | 0.95 |
| Total | 5.15 | 2.32 | 4.33 | 2.29 | 3.69 | 5.06 | 5.28 |

*Percentages may not sum to 100% due to rounding.

Using the participation rates from the 1997-1998 telephone survey and MRFSS resident participation data, combined with population forecasts from the U.S. Census Bureau, Milon (2001) also forecasted fishing participation rates in the Southeast over five-year increments from 2000-2025 (Table 8.4). Projections estimated that Florida will continue to be the state with the largest number of participants, increasing to nearly 3.5 million anglers in 2025 from only 2.4 million in 1997. Louisiana was projected to continue to have the second largest number of participants, increasing to approximately 570,000 anglers in 2025 from approximately 520,000 in 1997. In 1997, the regional participation rate for the Southeast was 11.56%. This was predicted to peak at 12% in 2010, and decrease to 11.64% in 2025 (Milon 2001; Table 8.4).

The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation conducted by the USFWS uses U.S. Census Bureau data to summarize demographics of participants in a variety of outdoor activities. In 2016, a total of 35.8M U.S. residents participated in saltwater fishing. Of those, 37% were from the four Gulf states of Texas through Alabama. Florida anglers were included in the South Atlantic region and not able to be included here. The majority of fishing population in the U.S. were males (73%) and 59% of all respondents were over the age of 45. Again, these numbers are not separated between fresh and saltwater which complicates the data. It was noted however that from the 2011 survey to the 2016, there was a 6% decline in the number of respondents who reported fishing in saltwater. In addition, there was a 24% decline in number of days fished. The last survey conducted by the USFWS in 2016 (USFWS 2018) does not specifically address state level data so only the 2011 survey can be used for our purposes. The following was summarized in the GSMFC's Gulf and Southern Flounder Profile (VanderKooy 2015).

Table 8.4. Projected number of marine recreational fishing participants by state in the Southeast, 2000-2025 (Table 4-1 *from* Milon 2001).

| State | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1997 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 |
| **Alabama** | 175,144 | 185,651 | 195,475 | 204,946 | 211,264 | 215,578 | 217,645 |
| **Florida** | 2,363,963 | 2,582,451 | 2,805,319 | 3,023,969 | 3,194,538 | 3,337,863 | 3,443,806 |
| **Georgia** | 95,786 | 104,885 | 112,484 | 118,805 | 123,711 | 127,973 | 131,358 |
| **Louisiana** | 519,840 | 527,596 | 536,155 | 549,632 | 559,242 | 566,090 | 569,894 |
| **Mississippi** | 138,071 | 146,120 | 151,889 | 156,352 | 158,551 | 159,746 | 159,547 |
| **North Carolina** | 496,013 | 546,143 | 588,865 | 622,904 | 644,575 | 660,130 | 667,359 |
| **South Carolina** | 224,327 | 239,320 | 253,442 | 267,377 | 277,634 | 258,449 | 290,319 |
| **Southeast Region** | **4,013,144** | **4,332,167** | **4,643,629** | **4,943,986** | **5,169,515** | **5,352,828** | **5,479,929** |
| **Regional Participation Rate** | **11.56%** | **11.97%** | **11.99%** | **12.00%** | **11.93%** | **11.82%** | **11.64%** |

## Florida

The USFWS (2014b) examined US Census Bureau data to generate estimates of participation in hunting and fishing for each state. The Florida survey indicated that in 2011, 1.39M residents made 25.4M saltwater fishing trips in their state. Of those who responded, 31% of the resident anglers indicated targeting Red Drum, but a large percentage also targeted seatrout, mackerel, mahi, and tuna (USFWS 2014b). The wide range of species targeted may suggest that Florida anglers have more opportunity to fish a wider number of species groups and those responding to the Census Bureau survey do not necessarily target any one particular species consistently. Interestingly, nearly 50% of the responding anglers indicated 'Another type of saltwater fish' on the survey (snapper and grouper were not offered as options). Of those who did report saltwater fishing in the state, the majority were between the ages of 35 and 55 although each age bracket 25-65+ was well represented ranging from 13-23%. Anglers responding were male (76%) and non-Hispanic (94%) who earned between $50-100K annually (modal value). Racially, the majority of respondents identified themselves as 'White' (83%), and the remainder indicated 'African American' or other (USFWS 2014b).

Camp et al. (2018) reported that Red Drum was the species with the most trips targeting a species between 2004-2015, at 34,434 trips. The number of Red Drum trips annually is generally increasing and trips ranged from 2058-3486. Spotted Seatrout was the species with the second most targeted trips at 27,652 trips. Distance traveled to these trips was lowest among Common Snook and Red Drum (40 km) indicating more localized coastal residents fishing effort. Anglers targeting Red Snapper traveled more than 125 km, indicating anglers were more widely distributed across the state rather than just coastal residents.

A summary of the almost 900,000 Florida residents who purchased a saltwater fishing license in 2013 provides basic demographics of gender, ethnicity, and age (FWC unpublished data). In Florida, not separating for Atlantic or Gulf Coast, the majority of anglers required to purchase a license are male (75%) and are dominated by those identifying themselves as 'White' (86%). An additional 10% identify as 'Hispanic' and 2% as 'Black'. The remaining 2% include 'Asian', 'Native American', and 'Other'. Among the 'White' and 'Asian' ethnic groups, females made up a little more than 25% of the anglers in those groups. 'Black' females only comprised about 13% of the 'Black' anglers and 'Hispanic' females made up about 16% of the 'Hispanic' anglers (FWC unpublished data).

Florida residents holding saltwater licenses ranged in age from 1 to over 100 years old, because the number of 'lifetime' licenses is included with annual license data (FWC unpublished data). The majority of 'White' anglers (47.6%) were in the 40-59 age bracket. However, among 'Hispanic' anglers, the majority (65.7%) were slightly younger, between 25-49 years of age. A similar pattern was observed in 'Black' anglers with 51.3% in a broader age category of 30-59 years of age. It should be noted that the state of Florida exempts children under the age of 16 and resident seniors 65 and older from being required to purchase a fishing license and are not included in the data above unless they have been issued a 'lifetime' license (FWC unpublished data).

## Alabama

Milon (2001) summarized saltwater anglers in Alabama using the MRFSS socio-economic add-on questions mentioned above. As with the other states included in the Southeast Region, Milon reported the majority of recreational anglers in Alabama were Caucasian males between the ages of 26-64 (47%). Almost 19% of the anglers were Caucasian women between the ages of 26-64 as well. Since 1997/1998, no other socio-demographic work has been conducted to describe Alabama anglers.

The USFWS (2014a) examined U.S. Census Bureau data to generate estimates of participation in hunting and fishing for each state. The census data indicated that in 2011, 69,000 residents made 1.4M saltwater fishing trips in Alabama marine waters. When asked about type of fish they targeted, 100% of resident respondents indicated 'all types of fish' while an additional 54% also included 'another type of saltwater fish'.

## Mississippi

In the MRFSS add-on for 1997/1998, Milon (2001) reported that recreational anglers in Mississippi tended to be younger than in other states in the Southeast Region with the majority of respondents indicating they were 26-45 years of age. Again, Caucasian males and females dominated those surveyed at 63% and 24%, respectively. There were more non-Caucasian males reporting in Mississippi (8.36%) than in Florida (6.44%), but the difference was negligible between Mississippi and Alabama (8.3%). There have been no further efforts to characterize the ethnic or racial makeup of recreational anglers in the state.

The USFWS (2013a) examined U.S. Census Bureau data to generate estimates of participation in hunting and fishing for each state. The 2011 census data indicated over 116,000 individuals made 2.2M saltwater fishing trips in Mississippi marine waters in 2011. While all Mississippi respondents indicated they fished for 'all types of fish', 56% also included Red Drum in their fishing preference (USFWS 2013a). All of the respondents were between 25 and 64 years of age with the majority in the 45 to 64 year-old range (56%). Unlike the other Gulf states, the gender of respondents was split 56% and 44% between males and females, respectively. Of those who responded, 100% were non-Hispanic and 65% identified themselves as 'White' while 35% indicated they were 'African American'. The majority of anglers (52%) reported their annual income as <$20-$39K with 37% in the modal value of $20-29K; the remainder could be combined in a $50-$149K group which included 29% of the anglers (USFWS 2013a).

## Louisiana

The LDWF (1997) provided limited socio-economic information on recreational anglers in general using several different surveys conducted by Kelso et al. (1991, 1992, and 1994), the USFWS fishing expenditure survey (USFWS 1993), and data available from the MRFSS from 1981-1996 (NOAA personal communication). Approximately 68% of the saltwater anglers surveyed reported targeting Spotted Seatrout and Red Drum in 1992-1996 (LDWF 1997). The LDWF report (1997) summarized that, of those residents who applied for recreational saltwater fishing licenses in Louisiana, 34% were between 35-44 years of age and an additional 27% were between 25-34 years of age. On average, Louisiana recreational anglers earn $40-$45K per year. However, none of the sources characterized the ethnicity of anglers (LDWF 1997).

Milon (2001) utilized the social and economic add-on questions to the 1997/1998 MRFSS phone interviews and determined that approximately 89% of the recreational saltwater anglers in Louisiana were Caucasian, of which 65% were males. In addition, like the other survey data by LDWF (1997), the majority of anglers (76%) were between the ages of 26-64; this included all gender and ethnic groups (Table 8.3).

The USFWS (2013b) examined U.S. Census Bureau data to generate estimates of participation in hunting and fishing for each state. In Louisiana, the census data indicated over 196,000 individuals made saltwater fishing trips in 2011, and of those, the majority (63% and 44%) indicated fishing for Red Drum and seatrout. The demographic data included in the report (USFWS 2013b) does not separate saltwater from freshwater anglers but in general, among those participating in 'fishing' in Louisiana (21,000 surveyed), 31% were 65 years or older and over 50% were over the age of 45. Almost 70% were male and nearly all respondents reported they were non-Hispanic (99%); 72% identified themselves as 'White'. A number of respondents declined to indicate their economic status but of those reporting, 34% had household incomes of $50-$150K per year. The only other reporting group was 8% in the $20-30K category (USFWS 2013b).

## Texas

A survey conducted in 2012 of the Texas saltwater fishing community showed that most (34.4%) of saltwater anglers identified Red Drum as their first preference of fish to catch, followed closely by Spotted Seatrout (31.6%) (Kyle et al. 2013). The average age of saltwater anglers was 43, with 73% of saltwater anglers between the ages of 30-59. Just over 12% of saltwater anglers were female. The median gross household income category was $80-$99K, with 44% of respondents indicating incomes over $100K annually. Half of all saltwater anglers reside in the Houston area, followed by Corpus Christi (9%), San Antonio (8%), and Austin (6%), the majority of whom (93%) were 'White'. Just over 12% were of 'Spanish/ Hispanic' origin. Based on a 1994 recreational survey of Texas anglers, 69.6% fish with hook-and-line while 11.4% use gigs for flounder; an additional 18% use both gears (TPWD unpublished data). Kyle et al. (2013) showed that just over half (57%) of all saltwater anglers fished for flounder during the 12 months preceding the 2012 survey. Of those anglers, 98% used rod-and-reel, and 28% used a gig.

The USFWS (2014c) examined U.S. Census Bureau data to generate estimates of participation in hunting and fishing for each state. The census data indicated that 685,000 resident anglers made 4.8M saltwater fishing trips in Texas in 2011. When asked about targeted species, the majority of anglers reported three species; Red Drum (73.3%), seatrout (42%), and flounder (flatfish – 28%). The majority of Texas anglers were male (76%) and 'non-Hispanic' (83%). The percent of Hispanic respondents was higher in Texas than in all the other Gulf states combined at 17%. In addition, 75% of the respondents identified themselves as 'White' with other groups, including 'African American', either not being reported or in too low of numbers to report (USFWS 2014c). About 56% of the respondents were between the ages of 35 and 64 years of age but all ages were represented in the survey from 18-74 years of age. About 10% reported incomes of <$20K annually and the remaining respondents ranged from $50-$150K+ per year.

## Subsistence Fishing

### Early Fishery Participants

The indigenous people that occupied the Gulf region utilized the estuarine and marine waters as sources of food for thousands of years. The patterns of use and importance of various resources can be determined by processing mounds near historic camp sites known as middens, which are essentially the trash piles left by the inhabitants. Materials found in the layers of buried debris cast light on the timing of occupancy of a site (seasonal) and identification of resources consumed left as shell or bone remains. In addition, the relative size, and it some cases age of the remains provide still more information on the preferred or most abundant resources available. Hadden (2015) examined a total of twelve settlements along the northern Gulf from Big Bend, Florida to Mobile, Alabama and described the seasonality and reliance on the various resources by the indigenous people during the Late Archaic to Woodland periods (5000 B.C. to A.D. 1100; Figure 8.1).

Red Drum (*Sciaenops ocellatus*) were not as common in the diets of the coastal inhabitants but were present at a number of sites. The few skeletal remains and otoliths examined by Hadden (2015) indicate juvenile Red Drum were preferred when they did occur. Across all the sites, the reliance on 'fish' versus shellfish varied widely with fish contributing anywhere from 5-72% of the marine sourced resource to shellfish contributing between 13-84% of the biomass (Hadden 2015). The author points out that mullet and oysters were present at all sites along with Ladyfish (*Elops saurus*), Hardhead Catfish *(Arius felis*), various *Cynoscion*, and Atlantic Croaker (*Micropogonias undulatus*). It is suggested that these species were more vulnerable to capture using poisons, nets, traps, rakes, and scoops rather than individual hooks and harpoons and were the likely method of capture for a consistent food source of the indigenous people (Hadden 2015).

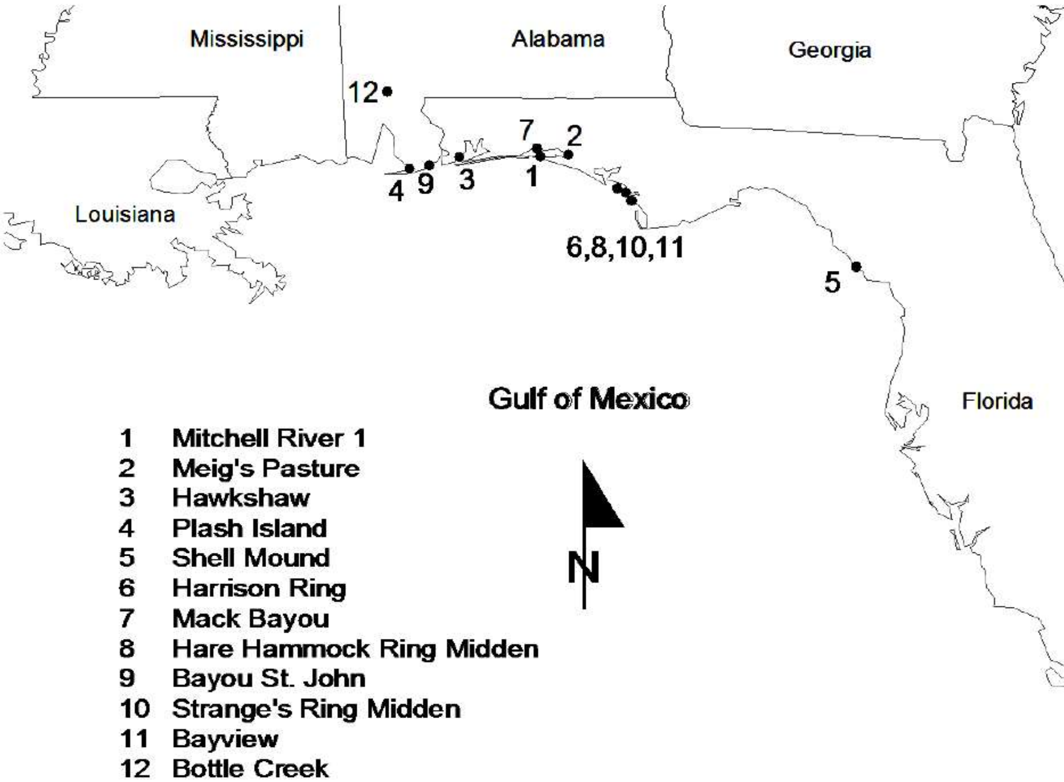



Figure 8.1 Twelve sites examined to describe coastal subsistence along the northern Gulf of Mexico occupied by early Americans from 5000 BC to 1100 AD (Figure 3.3 *from* Hadden 2015).

Jewell (1997) examined two prehistoric sites along the Mississippi coast dating from A.D. 200-400 (Godsey site) and A.D. 1200-1550 (Singing River site) located in Harrison and Jackson counties, respectively. Marine fish dominated both sites although many bones uncovered in the middens could not be identified to taxa. Those that could were sea catfishes, Sheepshead (*Archosargus probatocephalus*), and members of the drum family Sciaenidae (Red Drum, Black Drum, and Atlantic Croaker). Generally, marine fish bones examined from both sites indicate that most of the fish utilized by the indigenous people at both locations were less than 40 cm SL. All species in the study were nearshore, estuarine species and Jewell (1997) notes that there were no offshore pelagic fish in any of the samples taken and the species represented are year-round residents which made it difficult to pinpoint seasonality of site occupation. Fish were likely captured using nets of various types from gill nets to seines and tidal traps.

Examinations of indigenous people encampments along the central Texas coast dating from 2500 B.C. to A.D. 1250 provided a large number of otoliths from marine species common to the area. Over 2,000 individual otoliths were recovered from middens near the Corpus Christi and Upper Laguna Madre Bay systems (Colura and Vickers 1998) including Red Drum, Spotted Seatrout (*Cynoscion nebulosus*), Black Drum (*Pogonias cromis*), and Atlantic Croaker. Species are reasonably easy to identify using whole otolith morphology and broken ones that contained a core were sectioned using standard ageing techniques to evaluate population structure for each. The proportion of Red Drum present in the two locations were significantly different (229 from Corpus, 12 from Upper Laguna Madre). Overall, Red Drum were the least common of the four Sciaenids with Black Drum dominating. Virtually none of the fish specimens recovered were estimated to be larger than 300-450 mm TL suggesting a preference for smaller individuals or a size selection by the gear used to capture them. The authors suggest an early gill-type net was used by the coastal inhabitants (Colura and Vickers 1998).

## Modern Day Participants

As noted earlier, Red Drum are a highly accessible species to target inshore by all recreational anglers in all fishing modes; shore, private boat, or for-hire. In general, every saltwater angler could be included as a 'Red Drum angler'. However, there are a number of fishery participants that do not fish to recreate but rather fish to survive. In general, there is a dichotomy of recreational fishing between subsistence fishermen and sport anglers. For this document, 'subsistence' fishing is defined as fishing that uses simple fishing techniques to capture fish to feed family and relatives of the fishermen while 'sport fishing' is defined here as fishing that is for enjoyment and competition. Pitchon and Norman (2012) summarized that the lack of research and interest in subsistence fishing in the U.S, "may be in part because individuals engaged in subsistence fishing are often members of long-established poor, indigenous or diasporic communities." Fisheries managers haven't understood subsistence fishing and Ebbin (2017) found that even among people who were actively participating in subsistence fishing in Connecticut, virtually none understand the term or how it applied directly to them, they considered themselves just recreational anglers.

Despite little effort to document the social and economic motivations/context of the subsistence fisheries, there have been studies that suggest the idea of recreational fishing as a reasonable and affordable response to food insecurity for many underserved in our communities. Fedler and Ditton (1994) reviewed a number of published studies which attempted to describe the 'motivation' for recreational anglers in general. They reported that, among shore-based anglers for Black Drum in Texas, a fish that was under-utilized and long considered a trash fish (Leard et al. 1993), consumption was the highest motivation. Conversely, consumption was the lowest motivator in tournament billfish anglers. These motivations likely represent the two extremes of recreational fishing at every level (investment, time, skill, etc.) of the angler populations examined. Hunt et al. (2007) further described the differences of motivation and angler attitudes between African-American and Anglo-American anglers but did not inquire as to the 'need' aspect of catching fish to those surveyed as perhaps a primary source of protein in their family or community.

There are virtually no studies in the Gulf region that characterize who these subsistence anglers are and what ethnic, social, or economic groups they may represent. However, Boucquey and Fly (2021) described shore-based anglers who fished for a variety of species from piers, bridges, and other public areas around Tampa Bay, Florida. These 'urban fishing spaces' included both municipality-supported structures which boast a number of amenities (bait shops, restrooms, and cleaning stations) and smaller, unmaintained structures without amenities that are often less clean or safe but still provide fishing access (seawalls and rocky breakwaters). The study highlights the use of these lower quality locations by a number of anglers and characterizes the people fishing in these spaces.

The results for all areas surveyed (maintained and unmaintained) indicated that anglers spent considerable time fishing at these locations, regardless of location. On average, anglers spent over five hours for each trip and 25% of interviewees fished 10 times or more each month (Boucquey and Fly 2021). While 52% of those interviewed were ethnically white, the remaining 49% were mixed with anglers indicating 'Black' (15%), 'Asian' (11%), and 'Latinx' (22%), and 'Native Americans' and 'no response' reported equally at 3% each. Male anglers made up the majority of all anglers (87%) and among all respondents, 43 % of household incomes were under $50,000, 38% were between $50,000-100,000, and 18% were over $100,000.

The researchers also examined the motivations for participating, specifically food insecurity and fishing out of necessity. Seventeen percent of those interviewed indicated that they occasionally or often did not have enough money to buy food during the previous year and 10% had skipped a meal due to their financial situations; fishing was critical as a source of cheap or free protein. The authors reported that one respondent called the water “his grocery store”. Interestingly, among all the anglers, not just those noting food insecurity, 77% kept fish they caught and 97% of those consumed them. In addition, 11% indicated the fish they retained prevented themselves or a family member from going hungry (Boucquey and Fly 2021). While the Boucquey and Fly (2021) results are localized to Tampa Bay, there are numerous elements which are common with other marine and inland fishing communities in the U.S. and around the world (Hunt et al. 2007, Ebbin 2017, Funge-Smith and Bennett 2019, Quimby et al. 2020, Nyboer et al. 2022). Quimby et al. (2020) notes that in Southern California, ‘the accessibility and low-cost of fishing may make it an especially attractive option for poor, undocumented, and underprivileged members of urban communities.”

Subsistence fishing is also an environmental justice concern as marginalized groups depend on wild caught fish more often than the rest of society and are therefore disproportionately exposed to harmful contaminants that accumulate in the seafood that they harvest (Dietz and Yang 2020). A recent study in Louisiana surveyed recreational anglers statewide on their rate of sportfish consumption and awareness of fish advisory programs. About 88% of the 1,774 respondents reported that they eat sportfish, which is higher than the proportion of sportfish eaten by the general public (Sunderland 2007). The average consumption of anglers was about two meals per month, with 9% of sportfish consumers eating more than four meals per month. Male anglers and saltwater license holders were significantly more likely to consume sportfish than females and freshwater license holders, respectively. The most frequently consumed sportfish was Red Drum, followed by Spotted Seatrout and catfish. All three of these species have been shown to have elevated levels of methylmercury (Katner et. al 2010). Additionally, 88% of respondents had either seen, read, or heard about fish consumption warnings in Louisiana but women (53%) and African Americans (43%) were less likely to be aware of warnings (Katner et. al 2011).

However, only 30% of those that said they were aware of fish consumption advisories changed their fishing behavior (behaviors included no longer eating fish from water bodies where warnings had been issued, eating less fish from those water bodies, or buying more fish from a store instead). When asked why anglers did not change their behavior, respondents answered that they do not eat enough fish for advisories to apply to them (27%), “people have been fishing here forever and they’re not sick” (15%), the health benefits of eating fish exceeded the risks (>10%), and the advisories were inaccurate (<5%) (Katner et. al 2011).

## Attitudes Towards Aquaculture and Stock Enhancement of Red Drum

Red Drum are farmed in the Gulf of Mexico for both stock enhancement and seafood production. Most domestic Red Drum on the market today is farmed primarily from Texas, though some are also commercially cultured in Louisiana and Florida. The TPWD implemented a stock enhancement program of Red Drum and Spotted Seatrout since 1993 (Vega et al. 2011). After hatching fish larvae, the program released juveniles to help supplement wild populations. This strategy was shown to improve the catch rate of Red Drums along the Texas coast, as well as led to more recreational fishing licenses being sold (Vega et al. 2011). However, a Florida focused study argued that while stocking may be beneficial in the short term, enhancement leads to at least partial displacement of wild stock as well as increased fishing pressure (Camp et al. 2013). More research is needed into motivations/typologies and attitudes towards Red Drum stock enhancement of anglers in Florida.

Another study developed an integrated socio-ecological model to evaluate the potential for stock enhancement in the Red Drum fishery in the Tampa Bay Estuary (Camp et al. 2014). Results showed that regardless of the size of fish stocked, abundance of wild type Red Drum would decrease, thus decreasing the conservation objective. Stocking large fish will increase angler satisfaction and total fishing effort (socioeconomic objectives). Models show that stock enhancement has inherent costs but can be useful in certain situations and is not a panacea. Similarly, a bio-economic model was created to identify tradeoffs between conservation and socioeconomic benefits of Florida's Red Drum fishery as a result of stock enhancement (Camp et al. 2017). Results showed that maximizing socioeconomic objectives came at the detriment of conservation objectives when only abundance of wild-type fish were considered. However, when hatchery fish were considered the same as wild fish in terms of conservation value, these tradeoffs were eliminated. Perceived stakeholder attitudes towards stocking impacted frontier curves of the model. Assuming that satisfaction was inherently related to stocking resulted in a scenario of stocking low numbers of small fish, or "mock stocking" that would lead to stakeholder satisfaction but not lead to any meaningful biological effects.

## Broader Challenges Facing Gulf of Mexico Fishing Communities

The Gulf of Mexico is home to hundreds of fishing communities with their social identity and well-being inextricably linked with fisheries (Jacob et al. 2001, 2010, and 2013). However, many of these fishing communities have been strained by many fishery-related and other stressors, including regulatory changes, storms, and rising waterfront property prices (Gale 1991, Jepson 2007). On a vulnerability index, sixty-seven (67) fishing communities in the Gulf of Mexico were analyzed from 1980-2000 and twenty-two (22) were categorized as 'not vulnerable', thirty-two (32) as 'somewhat vulnerable', and thirteen (13) as 'very vulnerable' based on employment opportunities and community well-being. When compared to all other coastal communities, 174 highly engaged/reliant commercial fishing communities showed significant differences in social vulnerabilities - higher levels of poverty, personal disruption, labor force, and housing characteristics indices (Colburn et al. 2016).

# Chapter 9
# RESEARCH AND DATA NEEDS

## Goals and Objectives for the Fishery

As demonstrated throughout this profile, there is a need for directed research on this species throughout its range in the Gulf of Mexico to better inform management. The most recent assessment for Red Drum in the Gulf of Mexico was SEDAR 49 (SEDAR 2016) as a data-limited species. This is in part due to the fact that there were no data available on the offshore, adult spawning population. However, based on escapement rates, the states have exceeded the goals set by NOAA by the rebuilding plan, but a stock status has yet to be determined. Despite the success and total closure of the EEZ, the stock status requires significantly more data.

## Data Gaps and Considerations for Management

Management of Red Drum in the Gulf assumes that 30% of the inshore stocks must escape to federal waters to rebuild the offshore stocks depleted during the 1970s and 1980s. Based on information presented in this profile, management needs to consider to what extent Red Drum inhabit the offshore federal waters and the implications for current state management. The items below highlight current limitations in understanding Red Drum in the Gulf of Mexico. They are separated into 'critical needs,' which are those data needs considered necessary for management, and 'secondary needs,' which are items that would help our general understanding but may not be necessary for management.

## Critical Needs

### *Stock Status*

- Update abundance estimates of the adult population along with size and age structure. This information is crucial in understanding the dynamics of the adult stock and the implications to sub-adult populations in terms of recruitment and subsequent escapement.

- Explore the possibility of conducting aerial surveys of surface schools in state and federal waters to get adult population estimates.

- Prioritize placing Gulf of Mexico Red Drum back on the SEDAR stock assessment schedule.

### *Fishery-Independent Data*

- Establish routine fisheries-independent surveys for offshore waters to collect length-at-age, gonad, and gut samples from adult Red Drum.

- Expand the SEAMAP Bottom Longline Survey to include Florida waters between 3-10m to collect age, gonad, and gut samples from nearshore waters.

### *Distribution and Migration*

- *Acoustic/PSAT/Passive Tagging* - Better understanding of spatial structure, mixing and migration, movement of adult fish, sub-adult fish transitioning to maturity, ontogenetic movement, and regional philopatry.

### *Reproduction*

- *Reproduction* – In order to conduct a stock assessment, spawning frequency, batch fecundity, potential skip spawning and reproductive potential needs to be updated across potential regions (stocks) and Gulf-wide.

### *Habitat*

- *Habitat Change* - Quantify habitat change and the scale at which stressors may affect the Red Drum stocks and potential reductions in productivity (local versus regional). Examples of stressors include red tide, oil spill, seagrass loss, change in freshwater inflow.

## Secondary Needs

### *Predator-Prey*

- *Predation on Red Drum* – There is no documented predation on Red Drum.

### *Fishery-Related*

- *Release mortality* – Given the range of habitats, seasonality and gear used to catch Red Drum, release mortality could have significant differences that need to be quantified to aid in the assessment of the stock/stocks (Chapter 6).

### *Habitat*

- Comprehensive understanding of habitat uses across the Gulf to get idea of Red Drum plasticity (Implications – predict effect of climate change and how species may adapt to future environmental stressors).

### *Economics*

- Explore and quantify any 'value-added' and any associated mark ups of the Red Drum currently in the market as it moves through the channels to consumers.

- Contingent valuation analysis of consumer willingness to pay for Gulf wild caught Red Drum. Domestic demand is currently met by a combination of domestic and foreign aquacultured Red Drum. Evaluating consumer preferences regarding wild caught Gulf Red Drum could provide insights into the economic potential of a limited commercial fishery in the Gulf.

### *Sociology*

- *Demographics* - A better understanding of demographics of saltwater anglers in general and those targeting Red Drum is needed as little recent information is available. The U.S. Census Bureau conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR), but data are only collected every 5 years and state-level data are not released immediately (the most recent state-level participation rates are from the 2011 survey).

- *Participation* - Current participation rates of saltwater anglers in the Gulf of Mexico is highly limited. NOAA's Marine Recreational Fisheries Statistics Survey (MRFSS) collected participation rates in the past, but has since been replaced by the Marine Recreational Information Program (MRIP) which does not directly measure participation rates.

- *Motivations/Attitudes, Subsistence* - Qualitative and quantitative information is needed regarding the social and economic motivations, satisfaction, and attitudes of Red Drum fishery participants. Understanding angler preferences can help managers predict how well new regulations will be received before they are implemented.
  - *Subsistence* - Specific emphasis should be on characterizing subsistence users. Fishing for food in the Gulf of Mexico is of widespread importance, but there are few statistics available on this user group.

# Chapter 10
# REFERENCES


Adams, C., S. Jacob, and S. Smith. 2001. What happened after the net ban? Citeseer.

ADCNR/MRD (Alabama Department of Conservation and Natural Resources Marine Resources Division). 1988. Age Class Structure of Exploited Red Drum from The Inshore and Fishery Conservation zone, North Central Gulf of Mexico. MARFIN Annual Report NA87WC-H-06115. 25 pp.

ADCNR/MRD (Alabama Department of Conservation and Natural Resources Marine Resources Division). 1989. Age Class Structure of Exploited Red Drum from The Inshore and Fishery Conservation zone, North Central Gulf of Mexico. MARFIN Annual Report NA88WC-H-MF190. 11 pp.

ADCNR/MRD (Alabama Department of Conservation and Natural Resources Marine Resources Division). Unpublished Data. Sport fish Restoration Program. Alabama Marine Resources Division. Dauphin Island, Alabama.

Addis, D. 2020. The 2020 stock assessment of Red Drum, *Sciaenops ocellatus*, in Florida. Florida Fish and Wildlife Conservation Commission. Florida Fish and Wildlife Research Institute. St. Petersburg, Florida. IHR 2020-002. 129 pp.

Adkins, G., J. Tarver, P. Bowman, and B. Savoie. 1979. A study of the coastal finfish in coastal Louisiana. Louisiana Department of Wildlife and Fisheries. Technical Bulletin No. 29, 87 pp.

Adkins, G., V. Guillory, and M. Bourgeois. 1990. A creel survey of Louisiana recreational saltwater anglers. Louisiana Department of Wildlife and Fisheries, Technical Bulletin 41, Baton Rouge, Louisiana. 58 pp.

Adriance, J. Personal Communication. Louisiana Department of Wildlife and Fisheries. New Orleans, Louisiana.

Aguilar, R. 2003. Short-term Hooking Mortality and Movement of Adult Red Drum (*Sciaenops ocellatus*) in the Neuse River, North Carolina. MS Thesis. North Carolina State University. Raleigh, North Carolina. 138 pp.

Allen, K.O., and J.W. Hardy. 1980. Impacts of navigational dredging on fish and wildlife a literature review. U.S. Fish and Wildlife Service, FWS/OBS-80/07. 81 pp.

Alpine, A.E., and J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 27:946-955.

Anderson, D.H., and R.B. Ditton. 2004. Demographics, participation, attitudes, and management preferences of Texas Anglers. Texas A&M University, Human Dimensions of Fisheries Research Laboratory Technical Document HD-630, College Station, Texas.

Anson, K., and J. Mareska. 2021. Multifaceted Fisheries and Ecosystem Monitoring in Alabama's Marine Waters and the Gulf of Mexico: 2015-2019 Completion Report. Alabama Marine Resources Division. Dauphin Island, Alabama. National Fish and Wild Foundation Report. 151 pp.

Arnold, C.R., T.D. Bailey, T.D. Williams, A. Johnson, and J.L. Lasswell. 1977. Laboratory spawning and larval rearing of red drum and southern flounder. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 31:497-440.

ASMFC (Atlantic States Marine Fisheries Commission). 2004. NRC report outlines the impact of oil on marine fish habitat. Habitat Hotline Atlantic 11(3):1-5.

ATSDR (Agency for Toxic Substances and Disease Registry). 1995. Toxicological profile from polycyclic aromatic hydrocarbons (PAHs). U.S. Department of Health and Human Services, Atlanta, Georgia.

Auil-Marshalleck, S., R.P. Campbell, and L. Butler. 2002. Trends in Texas commercial fishery landings, 1972-2000. Texas Parks and Wildlife, Coastal Fisheries Division. Austin, Texas.

Baker, J.M. 1999. Ecological effectiveness of oil spill countermeasures: how clean is clean? Pure and Applied Chemistry 71(1):135-151.

Baltz, D.M., J.W. Fleeger, C.F. Rakocinski, and J.N. McCall. 1998. Food, density, and microhabitat factors affecting growth and recruitment potential of juvenile saltmarsh fish. Environmental Biology of Fishes 53:89-103.

Banks, P. Personal Communication. Louisiana Department of Wildlife and Fisheries. Baton Rouge, Louisiana.

Barr, B.W. 1987. The dredging handbook: a primer for dredging in the coastal zone of Massachusetts. Massachusetts Coastal Zone Management, 870-181-500-6-87-CR, Boston, Massachusetts.

Barret, B.B., J.L. Merrell, T.P. Morrison, M.C. Gillespie, E.J. Ralph, and J.F. Burdon. 1978. A study of Louisiana's major estuaries and adjacent offshore waters. Louisiana Department of Wildlife and Fisheries. Technical Bulletin. No. 27. 197 pp.

Barrett, B.B., J.W. Tarver, W.R. Latapie, J.F. Pallard, W.R. Mock, G.B. Adkins, W.J. Guidry, and C.J. White. 1971. Cooperative Gulf of Mexico estuarine inventory and study, Louisiana, Phase III, sedimentology. Louisiana Department of Wildlife and Fisheries Commission, New Orleans, Louisiana. 131-191.

Bartram, B. Personal Communication. Texas Parks and Wildlife Department. Corpus Christi, Texas.

Bass, R.J., and J.W.J. Avault. 1975. Food habits, length-weight relationship, condition factor, and growth of juvenile Red Drum, *Sciaenops ocellata*, in Louisiana. Transactions of the American Fisheries Society 104(1):35-45.

Battelle. 2000. An initial survey of aquatic invasive species issues in the Gulf of Mexico region. EPA/OCPD Contract No. 68-C-00-121. 227 pp.

Beaumariage, D.S., and A.C Wittich. 1966. Returns from the 1964 Schlitz Tagging Program. Board of Conservation Division of Salt Water Fisheries. Technical Series No. 47. 50 pp.

Beckman, D.W. 1989. Age and growth of Red Drum, *Sciaenops ocellatus*, and black drum, *Pogonias cromis*, in the northern Gulf of Mexico. Department of Marine Science. Louisiana State University. Doctor of Philosophy: 159 pp.

Beckman, D.W., C.A. Wilson, and A.L. Stanley. 1989. Age and growth of Red Drum, *Sciaenops ocellatus*, from offshore waters of the northern Gulf of Mexico. Fishery Bulletin 87:17-28.

Behringer, D. 2019. Using acoustic telemetry, stable isotope mixing models, and diet analysis to determine the relationship between resource contribution and habitat use of juvenile Red Drum in a Louisiana estuary. MS Thesis. University of Louisiana, Lafayette. 74 pp.

Bennetts, C. 2018. Life-history characteristics and fishery dynamics of Red Drum (*Sciaenops ocellatus*), in the north-central Gulf of Mexico. MS Thesis. University of Southern Mississippi. 348 pp.

Bennetts, C.F., R.T. Leaf, and N.J. Brown-Peterson. 2019. Sex-specific growth and reproductive dynamics of Red Drum in the northern Gulf of Mexico. Marine and Coastal Fisheries 11(2):213–230.

Bergen, A., C. Alderson, R. Bergfors, C. Aquila, and M.A. Matsil. 2000. Restoration of a *Spartina alterniflora* salt marsh following a fuel oil spill, New York City, New York. Wetland Ecology and Management 8:185-195.

Berthelot, E. Jr. Personal Photo. Golden Meadow, Louisiana.

Blake, E.S., E.N. Rappaport, and C.W. Landsea. 2007. The deadliest, costliest and most intense United States tropical cyclones from 1851 to 2006 (and other frequently requested hurricane facts). National Weather Service, NOAA Technical Memorandum NWS TPC-5, Miami, Florida. 43 pp.

Blaylock, R.B., and D.S. Whelan. 2004. Fish health management for offshore aquaculture in the Gulf of Mexico. Pages 129-161. *In*: Bridger, C. (ed). Efforts to Develop a Responsible Offshore Aquaculture Industry in the Gulf of Mexico: A Compendium of Offshore Aquaculture Consortium Research. Bridger, C.J. MASGP-040029. 33 pp.

Bohnsack, B.L., and R.B. Ditton. 1999. Demographics, participation, attitudes, and management preferences of Texas anglers. Texas A&M University, Human Dimensions of Fisheries Research Laboratory Technical Document HD-611, College Station, Texas

Bonin, P. 2015. Potential No. 1 redfish caught, released in Venice. Louisiana Sportsman Online – Inland Fishing. May 19, 2015. https://www.louisianasportsman.com/fishing/inshore-fishing/potential-no-1-redfish-caught-released-in-venice/

Bonin, P. 2017. Houma angler lands 'mutant' redfish. Photos Courtesy Brent Dupre. Louisiana Sportsman Online – Inland Fishing. January 5, 2017. https://www.louisianasportsman.com/fishing/inshore-fishing/houma-angler-lands-mutant-redfish/

Boothby, R.N., and J.W.J. Avault. 1971. Food habits, length-weight relationships, and condition factor of the Red Drum (*Sciaenops ocellata*) in southeastern Louisiana. Transactions of the American Fisheries Society 100(2):290-295.

Boucquey, N., and J. Fly. 2021. Contested Commoning: Urban Fishing Spaces and Community Wellbeing. International Journal of the Commons 15(1):305–319.

Bowling, B.G. 1996. A summary of fish tagging on the Texas Coast, November 1975- December 1993. Management Data Series 2 Number 126. Texas Parks and Wildlife, Coastal Fisheries Division. Austin, Texas. 31 pp.

Bowling, B.G, and A.L Sunley. 2003. A summary of fish tagging on the Texas coast: November 1975–December 1999. Texas Parks Wildlife Dept., Coastal Fisheries Division. Management Data Series 219:36.

Bowling, B.G., and S.R. Marwitz. 1991. A summary of fish tagging in Texas bays: 1975-1989. Texas Parks and Wildlife Department - Coastal Fisheries Division, Austin Texas. Management Data Series No. 63. 60 pp.

Bradford, C. 1908. The Angler's Guide: A handbook of the haunts and habits of the popular game fishes, inland and marine. The Nassau Press. 155 pp.

Breuer, J.P. 1957. An ecological survey of Baffin and Alazan Bays, Texas. Publication of the Institute of Marine Science, University of Texas 4:134–155

Britton, J.C., and B. Morton. 1989. Shore Ecology of the Gulf of Mexico. University of Texas Press, Austin, Texas. 396 pp.

Broom, B. 2017. Redfish action heats up with fall weather; Go shallow for best redfish bite of the year. Mississippi Clarion Ledger On-line. October 28, 2017. https://www.clarionledger.com/story/sports/2017/10/28/redfish-action-heats-up-fall-weather/806555001/

Browder, J.A. 1991. Watershed management and the importance of freshwater flow to estuaries. pages 7-22 *In:* Treat, S.F. and P.A. Clark (eds). Proceedings, Tampa Bay Area Scientific Information Symposium 2. Vol 2. Tampa, Florida.

Browder, J.A., and D. Moore. 1981. A new approach to determining the quantitative relationship between fishery production and the flow of fresh water to estuaries. pages 403-430 *In:* Cross, R. and D. Williams (eds). Proceedings, National Symposium on Freshwater Inflow to Estuaries, Vol 1. U.S. Fish and Wildlife Service, Washington, D.C.

Brown, C.A., G.A. Jackson, and D.A. Brooks. 2000. Particle transport through a narrow tidal inlet due to tidal forcing and implications for larval transport. Journal of Geophysical Research 105(C10):24,141-24,156.

Browning, Z.S., A.A. Wilkes, E.J. Moore, T.W. Lancon, and F.J. Clubb. 2012. The effect of otolith malformation on behavior and cortisol levels in juvenile Red Drum fish (*Sciaenops ocellatus*). Comparative Medicine 62(4):251-256.

Bryant, H.E., M.R. Dewey, N.A. Funicelli, G.M. Ludwig, D.A. Meineke and L.J. Mengal. 1989. Movement of five selected sports species of fish in Everglades National Park. Bulletin of Marine Science 44(1):515.

Buff, V., and S. Turner. 1987. The Gulf initiative. Magoon, Orville T. Coastal Zone '87: Proceedings of the Fifth Symposium on Coastal and Ocean Management, the Westin Hotel, Seattle, Washington, May 26-29, 1987. New York, N.Y.: American Society of Civil Engineers, 1987.

Bullard, S.A., and R.M. Overstreet. 2004. Two new species of *Cardicola* (Digenea:Sanguinicolidae) in Drums (Sciaenidae) from Mississippi and Louisiana. Journal of Parasitology 90(1):128-136.

Buller, N.B. 2004. Aquatic animal species and organism relationship. Pages 1-74. *In*: Bacteria from fish and other aquatic animals: a practical identification manual. CABI 352 pp.

Burdick, D.M., I.A. Mendelssohn, and K.L. McKee. 1989. Live standing crop and metabolism of the marsh grass *Spartina patens* as related to edaphic factors in a brackish, mixed marsh community in Louisiana. Estuaries 12(3):195-204.

Burfeind, D.D., and G.W. Stunz. 2007. The effects of boat propeller scarring on nekton growth in subtropical seagrass meadows. Transactions of the American Fisheries Society 136:1546-1551.

Burnsed, S.W., S. Lowerre-Barbieri, J. Bickford, and E.H. 2020. Recruitment and movement ecology of Red Drum *Sciaenops ocellatus* differs by natal estuary. Marine Ecology Progress Series 633:181-196.

Buskey, E.J., H.B. Liu, C. Collumb, and J.G.F. Bersano. 2001. The decline and recovery of a persistent Texas brown tide algal bloom in the Laguna Madre (Texas, USA). Estuaries 24(3):337-346.

Cahoon, D.R., and R.E. Turner. 1989. Accretion and canal impacts in a rapidly subsiding wetland II. Feldspar marker horizon technique. Estuaries 12(4):260-268.

Camp, E.V., K. Lorenzen, R.N.M. Ahrens, and M.S. Allen. 2014. Stock enhancement to address multiple recreational fisheries objectives: an integrated model applied to Red Drum *Sciaenops ocellatus* in Florida. Journal of Fish Biology 85(6):1868–1889.

Camp, E.V., S.L. Larkin, R.N.M. Ahrens, and K. Lorenzen. 2017. Trade-offs between socioeconomic and conservation management objectives in stock enhancement of marine recreational fisheries. Fisheries Research 186:446–459.

Camp, E.V., K. Lorenzen, R.N.M. Ahrens, L. Barbieri, and K.M. Leber. 2013. Potentials and limitations of stock enhancement in marine recreational fisheries systems: an integrative review of Florida's Red Drum enhancement. Reviews in Fisheries Science 21(3-4):388–402.

Camp, E.V., R.N. Ahrens, C. Crandall, and K. Lorenzen. 2018. Angler travel distances: Implications for spatial approaches to marine recreational fisheries governance. Marine Policy 87:263-274.

Camp, E.V., R.N. Ahrens, T.C. MacDonald, K.A. Thompson, and K. Lorenzen. 2019. Identifying forage populations of concern: A new perspective based on predator recruitment considerations. Fisheries Research 219, p.105319.

Caraco, N.F., J.J. Cole, P.A. Raymond, D.L. Strayer, M.L. Pace, S.E.G. Findlay, and D.T. Fischer. 1997. Zebra mussel invasion in a large, turbid river: phytoplankton response to increased grazing. Ecology 78(2):588-602.

Carlton, J.T. 2001. Introduced species in U.S. coastal waters: environmental impacts and management priorities. Pew Oceans Commission. 28 pp.

Carson, E.W., S. Karlsson, E. Saillant and J.R. Gold. 2009. Genetic studies of hatchery-supplemented populations of Red Drum in four Texas bays. North American Journal of Fisheries Management 29:1502-1510.

Carson, E.W., B.W. Bumguardner, M. Fisher, E. Saillant and J.R. Gold. 2014. Spatial and temporal variation in recovery of hatchery-released Red Drum (*Sciaenops ocellatus*) in stock-enhancement of Texas bays and estuaries. Fisheries Research 151:191-198.

Castro-Aguirre, J.L. 1978. Catalogo sistematico de los peces marinos que penetran a las aguas continentales de Mexico con aspectos zoogeograficos y ecologicos. Departamento de Pesca, Mexico City, Mexico, Instituto Nacional de Pesca. 296 pp.

Caudill, M.C. 2005. Nekton utilization on black mangrove (*Avicennia germinans*) and smooth cordgrass (*Spartina alterniflora*) sites in southwestern Caminada Bay, Louisiana. MS Thesis. Louisiana State University, Baton Rouge, Louisiana.

Causey, D. 1953. Parasitic copepoda of Texas coastal fishes. Publications of the Institute of Marine Science 3(1):6-16.

Chakalall, B. 1993. Species cultured in insular Caribbean countries, Belize, French Guiana, Guyana and Suriname. Caribbean Technical Co-operation Network in Artisanal Fisheries an Aquaculture. FAO Regional Office for Latin America and the Caribbean. RLAC/93/28-PES-24. Santiago, Chile. 32 p.

Chandler, A.C. 1935. Parasites of fishes in Galveston Bay. Proceedings of the United States National Museum 83:123-157 + plates 6-12.

Chao, L.N. 1976. Aspects of systematics, morphology, life history and feeding of western Atlantic Sciaenidae (Pisces: Perciformes). PhD Dissertation. College of William and Mary, Williamsburg, Virginia. 419 pp.

Chen, Y. 2017. Chapter 9. Fish resources of the Gulf of Mexico. Pages 869-1038 *In*: Ward, C.H. (ed). Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill - Vol 2. Springer Open.

Cho, H.J., and M.A. Poirrier. 2002. Recent resurgence of submersed aquatic vegetation. Lake Pontchartrain Basin Foundation, New Orleans, Louisiana. 127 pp.

Cho, H.J., and M.A. Poirrier. 2005. Response of submersed aquatic vegetation (SAV) in Lake Pontchartrain, Louisiana to the 1997-2001 El Nino southern oscillation shifts. Estuaries 28(2):215-225.

Christmas, J.Y. 1973. Cooperative Gulf of Mexico estuarine inventory and study, Mississippi. Gulf Coast Research Laboratory, Ocean Springs, Mississippi. 512 pp.

Cochrane, J.E. 1965. The Yucatan Current. Texas A&M University, Progress Report for A&M Project 286, College Station. p 20-27.

Colburn, L.L., M. Jepson, C. Weng, T. Seara, J. Weiss, and J.A. Hare. 2016. Indicators of climate change and social vulnerability in fishing dependent communities along the Eastern and Gulf Coasts of the United States. Marine Policy 74:323–333.

Colorni, A., and A. Diamant. 1995. Splenic and cardiac lymphocystis in the Red Drum, *Sciaenops ocellatus* (L.). Journal of Fish Diseases 18:467-471.

Colorni, A., and A. Diamant. 2014. Chapter 5: Infectious diseases of warmwater fish in marine and brackish waters. Pages 155-192 *In*: Woo, P.T.K., and D.W. Bruno (eds). Diseases and Disorders of Finfish in Cage Culture, 2nd Edition.

Colura, R.L., and R. Vickers. 1998. Comparison of age structure, growth and mortality of prehistoric Texas marine fishes with contemporary populations. Texas Parks and Wildlife Department, Final Report, Federal Aid in Sport Fish Restoration Act, Austin, Texas. 22 pp.

Colura, R.L., B.T. Hysmith, and R.E. Stevens. 1976. Fingerling Production of Striped Bass (*Morone saxatilis*), Spotted Seatrout (*Cynoscion nebulosus*), and Red Drum (*Sciaenops ocellatus*), in Saltwater Ponds 1. *In*: Proceedings of the annual meeting-World Mariculture Society 7(1-4):79-92.

Comeaux, R.S., M.A. Allison, and T.S. Bianchi. 2012. Mangrove expansion in the Gulf of Mexico with climate change: implications for wetland health and resistance to rising sea levels. Estuarine, Coastal and Shelf Science 96(0):81-95.

Comyns, B.H., J. Lyczcowski-Shultz, D.L. Nieland, and C.A. Wilson. 1991. Reproduction of Red Drum, *Sciaenops ocellatus*, in the northcentral Gulf of Mexico: seasonality and spawner biomass. Pages 17-26 *In:* Hoyt, R.D. (ed). Larval Fish Recruitment and Research in the Americas. NOAA Technical Report NMFS 95.

CONAPESCA (Comisión Nacional de Acuacultura y Pesca). 2013. Anuario Estadístico de Acuacultura y Pesca 2013. Mazatlán, Sinaloa México. 299 pp.

Condrey, R.E. 1994. Bycatch in the U.S. Gulf of Mexico menhaden fishery: results of onboard sampling conducted in the 1992 fishing season. Louisiana State University, Coastal Fisheries Institute, Baton Rouge, Louisiana. 42 pp.

Connell, C.H., and J.B. Cross. 1950. Mass mortality of fish associated with the protozoan *Gonyaulax* in the Gulf of Mexico. Science 112:359.

Costanza, R., O. Perez-Maqueo, M.L. Martinez, P. Sutton, S.J. Anderson, and K. Mulder. 2008. The value of coastal wetlands for hurricane protection. Ambio 37(4):241-248.

Couvillion, B.R., J.A. Barras, G.D. Steyer, W. Sleavin, M. Fisher, H. Beck, N. Trahan, B. Griffin, and D. Heckman. 2011. Land area change in coastal Louisiana from 1932 to 2010. U.S. Geological Survey Scientific Investigations Map 3164. 12 pp.

Craig, N.J., R.E. Turner, and J.W.J. Day. 1979. Land loss in coastal Louisiana (USA). Environmental Management 3(2):133-144.

Craig, S.R., D.S. MacKenzie, G. Jones, D.M. Gatlin. 2000. Seasonal changes in the reproductive condition and body composition of free-ranging Red Drum, *Sciaenops ocellatus*. Aquaculture 190(1-2):89–102.

Crance, J.H. 1971. Description of Alabama estuarine area -- Cooperative Gulf of Mexico inventory. Alabama Marine Resources Bulletin 6:85.

Crocker, P.A., C.R. Arnold, J.A. DeBoer, and J.D. Holt. 1981. Preliminary evaluation of survival and growth of juvenile Red Drum (*Sciaenops ocellata*) in fresh and salt water. Journal of the World Mariculture Society 12(1):122-134.

Daily Picayune. 1892. Gulf Fisheries. Interesting Results of the Investigation by the United States Fish Commission. Vol LVI, No. 132. Page 7. New Orleans, Louisiana

Dance, M.A., and J.R. Rooker. 2015. Habitat- and bay-scale connectivity of sympatric fishes in an estuarine nursery. Estuarine, Coastal and Shelf Science 167:447-457.

Dance, M.A., and J.R. Rooker. 2016. Stage-specific variability in habitat associations of juvenile Red Drum across a latitudinal gradient. Marine Ecology Progress Series 557:221-235.

Darnell, R.M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publications of the Institute of Marine Science, University of Texas 5:353-416.

Day, J., N. Psuty, and B. Perez. 2000. The role of pulsing events in the functioning of coastal barriers and wetlands: implications for human impact, management and the response to sea level rise. Pages 633–659 *In*: Weinstein, M., and D. Kreeger (eds). Concepts and Controversies in Tidal Marsh Ecology. Kluwer Academic Publishers, Dordrecht.

de Silva, J.A., and R.E. Condrey. 1998. Discerning patterns in patchy data: a categorical approach using Gulf menhaden, *Brevoortia patronus*, bycatch. Fishery Bulletin 96:193-209.

de Sylva, D.P. 1969. Trends in Marine Sport Fisheries Research, Transactions of the American Fisheries Society 98(1):151-169.

Deardorff, T.L., and R.M. Overstreet. 1981. Larval *Hysterothylacium* (=*Thynnascaris*) (Nematod: Anisakidae) from fishes and Invertebrates in the Gulf of Mexico. Proceedings of the Helminthological Society of Washington 48(2):113-126.

Deegan, F. 1990. Mississippi: saltwater angler attitude and opinion survey. Mississippi Department of Wildlife, Fisheries, and Parks, Bureau of Marine Resources. Biloxi, Mississippi. Internal Report. 45 pp.

Deegan, L.A., and R.N. Buchsbaum. 2005. The effect of habitat loss and degradation on fisheries. Pages 67-96 *In*: Buchsbaum, R., J. Pederson, and W.E. Robinson (eds). The Decline of Fisheries Resources in New England: Evaluating the Impacts of Overfishing, Contamination, and Habitat Degredation. MIT Sea Grant, Cambridge, Massachusetts.

del Rio-Rodriguez R.E., J.G. Ramirez-Paredes, S.A. Soto-Rodriguez, Y. Shapira, M. del Jesus Huchin-Cortes, J. Ruiz-Hernandez, M.I. Gomez-Solano, and D.J. Haydon. 2021. First evidence of fish nocardiosis in Mexico caused by *Nocardia seriolae* in farmed Red Drum (*Sciaenops ocellatus*, Linnaeus). Journal of Fish Diseases 2021;00:1-14.

DeLorenzo, M.E., G.I. Scott, and P.E. Ross. 2001. Toxicity of pesticides to aquatic microorganisms: a review. Environmental Toxicology and Chemistry 20(1):84-89.

Diamant, A., A.B. Ucko, A. Colorni, W. Knibb, and H. Kvitt. 2000. Mycobacteriosis in wild Rabbitfish, *Siganus rivulatus*, associated with cage farming in the Gulf of Eilat, Red Sea. Diseases of Aquatic Organisms 39:211-219.

Diener, R.A. 1975. Cooperative Gulf of Mexico estuarine inventory and study -- Texas: area description, NOAA Technical Report NMFS CIRC-393. 127 pp.

Dietz, M., and S. Yang. 2020. Effectively Communicating with Subsistence Fish Consumers to Reduce Exposure to Contaminants. MS Thesis. Duke University, Nicholas School of the Environment. Durham, North Carolina. 98 pp.

Ditton, R.B., and K.M. Hunt. 1996. Demographics, participation, attitudes, management preferences, and trip expenditures of Texas anglers. Technical Document #HD-605. Department of Fisheries and Wildlife Sciences, Texas A&M University, College Station, Texas. 58 pp.

Doerzbacher, J.F., A.W. Green, and G.C. Matlock. 1988. A temperature compensated von Bertalanffy growth model and tagged Red Drum and Black Drum in Texas bays. Fisheries Research 6:135-152.

Drake, L.A., P.T. Jenkins, and F.C. Dobbs. 2005. Domestic and international arrivals of NOBOB (no ballast on board) vessels to lower Chesapeake Bay. Marine Pollution Bulletin 50(5):560-565.

Dresser, B. K. 2003. Habitat use and movement of subadult Red Drum, *Sciaenops ocellatus*, within a salt-marsh-estuarine system. MS Thesis. University of Georgia. 154 pp.

Drummond, K.H., and G.B. Austin. 1958. Some aspects of the physical oceanography of the Gulf of Mexico. U.S. Fish and Wildlife Service, Gulf of Mexico physical and chemical data from Alaska cruises: U.S. Fish and Wildlife Service Special Scientific Report - Fisheries 249:5-19.

Dzwonkowski, B. Personal Communication. University of South Alabama, Dauphin Island Sea Lab. Dauphin Island, Alabama.

Eardley, C. 2016. Monterey Bay Aquarium Seafood Watch: Red Drum *Sciaenops ocellatus*. Monterey Bay Aquarium, Monterey, CA, 67p.

Ebbin, S.A., 2017. Fishing for food: piloting an exploration of the invisible subsistence harvest of coastal resources in Connecticut. Agriculture & Food Security 6(1):1-10.

Eldar, A., S. Perl, P.F. Frelier, and H. Bercovier. 1999. Red Drum *Sciaenops ocellatus* mortalities associated with *Stretococcus iniae* infection. Diseases of Aquatic Organisms 36: 121-127.

Eleuterius, C.K. 1976a. Mississippi Sound: salinity distributions and indicated flow patterns. Mississippi-Alabama Sea Grant Consortium, MASGP-76-023, Ocean Springs, Mississippi. 128 pp.

Eleuterius, C.K. 1976b. Mississippi Sound: temporal and spatial distribution of nutrients. Mississippi-Alabama Sea Grant Consortium, MASGP-76-024, Ocean Springs, Mississippi. 58 pp.

Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436:686-688.

Ern, R., and A.J. Esbaugh. 2018. Effects of salinity and hypoxia-induced hyperventilation on oxygen consumption and cost of osmoregulation in the estuarine Red Drum (*Sciaenops ocellatus*). Comparative Biochemistry and Physiology 222(Part A):52–59.

Facendola, J.J., and F.S. Scharf. 2012. Seasonal and ontogenetic variation in the diet and daily ration of estuarine Red Drum as derived from field-based estimates of gastric evacuation and consumption. Marine and Coastal Fisheries 4:546–559.

FAO Website (Food and Agriculture Organization). https://www.fao.org/fishery/culturedspecies/Sciaenops_ocellatus/en

FAO (Food and Agriculture Organization). Unpublished Data. FishStatJ Version 4.02.04, March 2022. Rome, Italy.

FAO (Food and Agriculture Organization). 2022. *Sciaenops ocellatus*. Cultured Aquatic Species Information Programme. Text by Cynthia K. and A. Faulk. Fisheries and Aquaculture Division [online]. Rome. Updated 2006-11-06 [Cited Thursday, May 12th 2022]. https://www.fao.org/fishery/en/culturedspecies/Sciaenops_ocellatus/en

FAO (Food and Agriculture Organization). Unpublished Data. World Aquaculture Production. FAO. Rome, Italy.

Fedler, A.J., and R.B. Ditton. 1994. Understanding angler motivations in fisheries management. Fisheries 19(4):6-13.

Felsher, J.N. 2019. Big Reds Rising. MDWFP News. October 10. Mississippi Department of Wildlife, Fisheries, and Parks. https://www.mdwfp.com/media/news/fishing-boating/big-reds-rising/

Ferguson, M.O. 1986. Characteristics of Red Drum and Spotted Seatrout commercial fishermen in Texas. North American Journal of Fisheries Management 6(3):344–358.

Field, I.A. 1907. Unutilized Fishes and Their Relation to the Fishing Industries. Bureau of Fisheries Document No. 622. Department of Commerce and Labor, Government Printing Office, Washington. 53 pp.

Fish, M.P., and W.H. Mowbray. 1970. Sounds of Western North Atlantic fishes. Johns Hopkins Press, Baltimore, Maryland. 205 pp.

Flaherty, K.E., B.L. Winner, J.L. Vecchio, and T.S. Switzer. 2013. Spatial and Size Distribution of Red Drum Caught and Released in Tampa Bay, Florida, and Factors Associated with Post-Release Hooking Mortality. Gulf and Caribbean Research 25 (1):29-41.

Floyd, M.F., L. Nicholas, I. Lee, J.H. Lee, and D. Scott. 2006. Social stratification in recreational fishing participation: research and policy implications. Leisure Sciences 28(4):351-368.

Fodrie, F.J., K.L. Heck, S.P. Powers, W.M. Graham, and K.L. Robinson. 2010. Climate-related, decadal-scale assemblage changes of seagrass-associated fishes in the northern Gulf of Mexico. Global Change Biology 16(1):48-59.

Fonseca, M., G.A. Piniak, and N. Cosentino-Manning. 2017. Susceptibility of seagrass to oil spills: A case study with eelgrass, *Zostera marina* in San Francisco Bay, USA. Marine Pollution Bulletin 115(1-2):29-38.

Fontenot, B.J., and H.E. Rogillio. 1970. A study of estuarine sportfishes in the Biloxi marsh complex, Louisiana. Baton Rouge, Louisiana, Louisiana Wildlife and Fisheries Commission: 172 p.

Fowler, H.W. 1940. A collection of fishes obtained on the west coast of Florida by Mr. and Mrs. C.G. Chaplin. Proceedings of the Academy of Natural Sciences of Philadelphia 92:1-22

Fowler, H.W. 1952. A list of the fishes of New Jersey, with off-shore species. Proceedings of the Academy of Natural Sciences of Philadelphia, 104:89-151.

Francis-Floyd, R., and M.R. Floyd. 2011. *Amyloodinium ocellatum*, an important parasite of cultured marine fish. Southern Regional Aquaculture Center Pub No. 4705. 12 pp.

Froese, R., and D. Pauly (eds). 2022. FishBase. World Wide Web electronic publication. www.fishbase.org, version (05/2022).

Fulton, M.H., G.I. Scott, A. Fortner, T.F. Bidleman, and B. Ngabe. 1993. The effects of urbanization on small high salinity estuaries of the southeastern United States. Archives of Environmental Contamination and Toxicology 25(4):476-484.

Funge-Smith, S., and A. Bennett. 2019. A fresh look at inland fisheries and their role in food security and livelihoods. Fish and Fisheries, 20(6):1176-1195.

FWC (Florida Fish and Wildlife Conservation Commission). Website. Marine Stock Enhancement in Florida. Marine Stock Enhancement in Florida | FWC. https://myfwc.com/research/saltwater/stock-enhancement/general-information/marine/

FWC (Florida Fish and Wildlife Conservation Commission). Unpublished Data. Florida Fish and Wildlife Conservation Commission. Tallahassee, Florida.

FWC/FWRI (Florida Fish and Wildlife Conservation Commission/Fish and Wildlife Research Institute). Unpublished Data. FWC. St Petersburg, Florida.

Gain, I. 2009. Oyster reefs as nekton habitat in estuarine ecosystems. MS Thesis. Texas A&M University Corpus Christi. 84 pp.

Gale, R.P. 1991. Gentrification of America's coasts: impacts of the growth machine on commercial fishermen. Society & Natural Resources 4(2):103–121.

Galil, B.S. 2007. Seeing Red: Alien species along the Mediterranean coast of Israel. Aquatic Invasions 2(4):281-312.

Gallaway, B.J., J.G. Cole, L.R. Martin, J.M. Nance, and M. Longnecker. 2003. An evaluation of an electronic logbook as a more accurate method of estimating spatial patterns of trawling effort and bycatch in the Gulf of Mexico shrimp fishery. North American Journal of Fisheries Management 23:787–809

Galtsoff, P. (ed). 1954. Gulf of Mexico, its origin, waters, and marine life. Fishery Bulletin 55(89):1-604.

Garcia, H.E., R.A. Locarnini, T.P. Boyer, J.I. Antonov, O.K. Baranova, M.M. Zweng, and D.R. Johnson. 2010. World Ocean Atlas 2010, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation. Levitus, S. (ed), NOAA Atlas NESDIS 70. U.S. Government Printing Office, Washington, D.C., 344 pp.

Gates, J.A., and W.B. Wilson. 1960. The toxicity of *Gonyaulax monilata* Howell to *Mugil cephalus*. Limnology and Oceanography 5:171-174.

GCRL (University of Southern Mississippi's Gulf Coast Research Laboratory). Unpublished Data. Ocean Springs, Mississippi.

Gearhart, J., 2002. JOB 3: Hooking Mortality of Spotted Seatrout (*Cynoscion nebulosus*), Weakfish (*Cynoscion regalis*), Red Drum (*Sciaenops ocellata*), and Southern Flounder (*Paralichthys lethostigma*) in North Carolina. *In*: Interstate Fisheries Management Program Implementation for North Carolina. Study II Documentation and Reduction of Bycatch in North Carolina Fisheries. Completion Report for Cooperative Agreement No. NA 87FG0367/2. 30 pp.

GMFMC (Gulf of Mexico Fishery Management Council). Unpublished Data. Gulf of Mexico Fishery Management Council. Tampa, Florida.

GMFMC (Gulf of Mexico Fishery Management Council). 1986. Proposed Secretarial Fishery Management Plan, Regulatory Impact Review, Initial Regulatory Flexibility Analysis, and Draft Environmental Impact Statement for the Red Drum Fishery of the Gulf of Mexico. Gulf of Mexico Fishery Management Council. Tampa, Florida. 204 pp.

GMFMC (Gulf of Mexico Fishery Management Council). 1987. Amendment Number 1 and Environmental Assessment and Supplemental Regulatory Impact Review and Initial Regulatory Flexibility Analysis to the Secretarial Fishery Management Plan for the Red Drum Fishery of the Gulf of Mexico. Gulf of Mexico Fishery Management Council. Tampa, Florida. 43 pp.

GMFMC (Gulf of Mexico Fishery Management Council). 1988. Amendment Number 2 and Environmental Assessment and Supplemental Regulatory Impact Review and Initial Regulatory Flexibility Analysis to the Secretarial Fishery Management Plan for the Red Drum Fishery of the Gulf of Mexico. Gulf of Mexico Fishery Management Council. Tampa, Florida. 43 pp.

GMFMC (Gulf of Mexico Fishery Management Council). 1992. Amendment Number 3 to the Fishery Management Plan for the Red Drum Fishery of the Gulf of Mexico (Includes Environmental Impacts and Regulatory Impact Review). Gulf of Mexico Fishery Management Council. Tampa, Florida. 19 pp.

GMFMC (Gulf of Mexico Fishery Management Council). 1998. Generic amendment for addressing essential fish habitat requirements. Gulf of Mexico Fisheries Management Council, Tampa, Florida. 507 pp.

GMFMC (Gulf of Mexico Fishery Management Council). 2016. Final Report Review of Essential Fish Habitat Requirements. National Oceanic and Atmospheric Administration Award No. NA15NMF4410011

GMFMC (Gulf of Mexico Fishery Management Council). 2021. Status Determination Criteria and Optimum Yield for Reef Fish and Red Drum: Amendment 48 to the Fishery Management Plan for Reef Fish Resources of the Gulf of Mexico and Amendment 5 to the Fishery Management Plan for the Red Drum Fishery of the Gulf of Mexico including Environmental Assessment and Fishery Impact Statement. Gulf of Mexico Fisheries Management Council, Tampa, Florida. 169 pp.

GMFMC/GSMFC (Gulf of Mexico Fishery Management Council/Gulf States Marine Fisheries Commission). 1984. Fishery Profile of Red Drum. Gulf of Mexico Fishery Management Council, Gulf States Marine Fisheries Commission. Tampa, Florida. 176 pp.

Golani, D., and D. Mires. 2000. Introduction of fishes to the freshwater system of Israel. The Israeli Journal of Aquaculture Bamidgeh 52:47-60.

Golani, D., O. Sonin, and G. Rubinstein. 2015. Records of *Paralichthys lethostigma* and *Sciaenops ocellatus* in the Mediterranean and *Channa micropeltes* in Lake Kinneret (Sea of Galilee), Israel. Marine Biodiversity Records 8. 4 pp.

Gold, J.R., and L.R. Richardson. 1994. Mitochondrial DNA variation among ‘red’ fishes from the Gulf of Mexico. Fisheries Research 20:137-150.

Gold, J.R., and T.F. Turner. 2002. Population Structure of Red Drum (*Sciaenops ocellatus*) in the Northern Gulf of Mexico, as inferred from variation in nuclear-encoded microsatellites. Marine Biology 140:249-265.

Gold, J.R., L.R. Richardson, and T.F. Turner. 1999. Temporal stability and spatial divergence of mitochondrial DNA haplotype frequencies in Red Drum (*Sciaenops ocellatus*) from coastal regions of the western Atlantic Ocean and Gulf of Mexico. Marine Biology 133:593-602.

Gold, J.R., C.P. Burridge, and T.F. Turner. 2001. A modified stepping-stone model of population structure in Red Drum, *Sciaenops ocellatus* (Sciaenidae), from the northern Gulf of Mexico. Genetica 111:305-317.

Gold, J.R., L.R. Richardson, C. Furman, and T.L. King. 1993. Mitochondrial DNA differentiation and population structure in Red Drum (*Sciaenops ocellatus*) from the Gulf of Mexico and Atlantic Ocean. Marine Biology 116:175-185.

Goldsborough, W.J. 1997. Human impacts on SAV- a Chesapeake Bay case study. Pages 38-70 *In*: Stephan, C.D. and T.E. Bigford (eds), Atlantic Coastal Submerged Aquatic Vegetation: A Review of its Ecological Role, Anthropogenic Impacts, State Regulation, and Value to Atlantic Coastal Fisheries. ASMFC Habitat Management Series #1, 68 p + appendices, Washington, DC.

Goode, G.B. 1884. The fisheries and fisheries industries of the United States: Section I - natural history of useful aquatic animals with an atlas of two hundred and seventy-seven plates. Government Printing Office, Washington, D.C. pages 381-386.

Goodell, W. 1988. State/Federal Conflicts in Gulf of Mexico Redfish Resource Management. Tulane Environmental Law Journal 1:40-49.

Goodyear, C.P. 1987. Status of the Red Drum stocks of the Gulf of Mexico. Miami, Florida, Southeast Fishery Center: 119 pp.

Goodyear, C.P. 1991. Status of the Red Drum stocks of the Gulf of Mexico. NMFS Southeast Fisheries Center Costal Resource Division Contribution MIA-90/91-87. Miami, Florida.

Goodyear, C.P. 1996. Status of the Red Drum stocks of the Gulf of Mexico. NOAA, NMFS, Southeast Fisheries Science Center, Miami Laboratory Contribution MIA-95/96-47, Miami, Florida. 57 pp.

Gould, E., P.E. Clark, and F.P. Thurberg. 1994. Pollutant effects on dermersal fishes. Pages 30-41 *In*: Langton, R.W., J.B. Pearce, and J.A. Gibson (eds). Selected Living Resources, Habitat Conditions, and Human Perturbations of the Gulf of Maine: Environmental and Ecological Considerations for Fishery Management. NOAA Technical Memorandum, NMFS-NE-106, Woods Hole, Massachusetts.

Grammer, P.O., J.L. Green, C.M. Lapniewski, J.S. Franks, and J.M. Hendon. 2019. Movement patterns and fidelity of juvenile Red Drum and Bull Shark. Final Report - Mississippi Tidelands Trust Fund Program Projects FY15-M400-37 and FY16-M648-42. 85 pp.

Green, A.W., H.R. Osburn, G.C. Matlock, and H.E. Hegen. 1985. Estimated survival rates for immature Red Drum in northwest Gulf of Mexico bays. Fisheries Research 3:263-277.

Green, J., and M. Hill. 2021. Assessment of Red Drum in Mississippi coastal waters. Mississippi Department of Marine Resources Final Report to Sport Fish Restoration Program. 20 pp.

Green, L.M., and R.P. Campbell. 2010. Trends in Finfish Landings of Sport-Boat Anglers in Texas Marine Waters, May 1974 – May 2008. Texas Parks and Wildlife Department – Coastal Fisheries Division. Management Data Series No. 257.

Grubich, J.R. 2000. Crushing motor patterns in drum (Teleostei: Sciaenidae): Functional novelties associated with molluscivory. The Journal of Experimental Biology 203:3161–3176.

Guest, W.C., and J.L. Lasswell. 1978. A note on courtship behavior and sound production of Red Drum. Copeia 1978, 337-338.

Guillory, V., and G. Hutton. 1982. A survey of bycatch in the Louisiana Gulf menhaden fishery. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 36:213-223.

Guillory, V., and G. Hutton. 1990. Survey of the marine recreational fishery of lower Barataria Bay, Louisiana, 1975-1977, Technical Bulletin 41, Louisiana Dept. Wildlife and Fisheries. p. 59-73.

Guillory, V., and P. Prejean. 2001. Red Drum predation on blue crabs (*Callinectes sapidus*). Proceedings of the Blue Crab Mortality Symposium, Ocean Springs, Mississippi, Gulf States Marine Fisheries Commission. GSMFC Number 90:93-104.

Gunter, G. 1945. Studies of marine fishes of Texas. Publications of the Institute of Marine Science, University of Texas 1(1):1-190.

Haab, T., R. Hicks, K. Schneir, and J.C. Whitehead. 2012. Angler heterogeneity and the species-specific demand for marine recreational fishing. Marine Resource Economics 27(3):229-251.

Hadden, C.J.S. 2015. Coastal subsistence and settlement systems on the northern Gulf of Mexico, USA. PhD Dissertation. University of Georgia, Athens. 388 pp.

Hall, Q.A., J.M. Curtis, J. Williams, and G.W. Stunz. 2019. The importance of newly-opened tidal inlets as spawning corridors for adult Red Drum (*Sciaenops ocellatus*). Fisheries Research 212:48-55.

Hallock, C. 1876. Camp Life in Florida; A handbook for sportsmen and settlers. Forest and Stream Publishing Company, New York. 364 pp.

Handley, L., and C. Lockwood. 2020. Introduction. Pages 1-11 *In*: Handley, L. and C. Lockwood (eds). Seagrass Status and Trends Update for the Northern Gulf of Mexico: 2002-2017. Final Report to the Gulf of Mexico Alliance for Contract No.: 121701-00. Ocean Springs, Mississippi.

Handley, L., D. Altsman, and R. DeMay. 2007. Seagrass status and trends in the northern Gulf of Mexico: 1940-2002. U.S. Geological Survey Scientific Investigations Report 2006-5287 and U.S. Environmental Protection Agency 855-R-04-003, 267 pp.

Handley, L., K. Spear, A. Leggett, and C. Thatcher. 2013b. Chapter H: Statewide summary for Mississippi. *In:* Handley, L, K. Spear, C. Thatcher and S. Wilson (eds). Emergent Wetlands Status and Trends in the Northern Gulf of Mexico: 1950–2010. USGS. 9 pp.

Handley, L., K. Spear, A. Leggett, and C. Thatcher. 2013c. Chapter I: Mississippi Sound. *In:* Handley, L, K. Spear, C. Thatcher and S. Wilson (eds). Emergent Wetlands Status and Trends in the Northern Gulf of Mexico: 1950–2010. USGS. 16 pp.

Handley, L., K. Spear, S. Jones, and C. Thatcher. 2013a. Chapter J: Statewide summary for Alabama. *In:* Handley, L, K. Spear, C. Thatcher and S. Wilson (eds). Emergent Wetlands Status and Trends in the Northern Gulf of Mexico: 1950–2010. USGS. 18 pp.

Hanson, J., M. Helvey, and R. Strach. 2003. Non-fishing impacts to essential fish habitat and recommended conservation measures. National Marine Fisheries Service (NOAA Fisheries), Southwest Region, Version 1, Long Beach, California, 75 pp.

Harrison, W.C. 1995. Gill Net Restrictions in the Gulf of Mexico. Water Log, A Legal Reporter of the Mississippi-Alabama Sea Grant Consortium. 15(4).

Havel, L.N., L.A. Fuiman, and A.F. Ojanguren. 2015. Benthic habitat properties can delay settlement in an estuarine fish (*Sciaenops ocellatus*). Aquatic Biology 24:81-90.

Hayes, M.O., R. Hoff, J. Michel, D. Scholz, and G. Shigenaka. 1992. An introduction to coastal habitats and biological resources for oil spill response. Report No. HNRAD 92-4, Hazardous Materials Response and Assessment Division, National Oceanic and Atmospheric Administration. 401 pp.

Heath, S.R., W.J. Eckmayer, C.W. Wade, J.P. Hawke, and R.V. Minton. 1981. Research and Management of Alabama Coastal Fisheries. Completion Report PL 88-309, Project 2-330-R-3. 212 pp.

Heffernan, T.L., and R.J. Kemp. 1980. Management of the Red Drum Resources in Texas. Pages 71–80 *In*: Williams, R.O., J.E. Weaver, and F.A. Kalber (eds). Proceedings of the Colloquium on the Biology and Management of Red Drum and Seatrout. Gulf States Marine Fisheries Commission. Pub No 5

Heilner, V. 1940. Salt water fishing, 6th edition. Penn Publishing, Philadelphia. 330 pp.

Henley, M.W., and D.H. Lewis. 1976. Anaerobic bacteria associated with epizootics in grey mullet (*Mugil cephalus*) and redfish (*Sciaenops ocellata*) along the Texas Gulf Coast. Journal of Wildlife Diseases 12(3):448–453.

Henshall, J.A. 1884. Camping and cruising in Florida. Cincinnati, R. Clarke & Company. 233 pp. + Appendix.

Hernandez, F.J., Jr. 2001. The across-shelf distribution of larval, postlarval and juvenile fishes collected at oil and gas platforms and coastal jetty off Louisiana west of the Mississippi River delta. Ph.D. Dissertation. 223 pp.

Hernandez, F.J., Jr., W.M. Graham, and K. Bayha. 2013. Spatial distribution and abundance of Red Snapper (*Lutjanus campechanus*), Vermilion Snapper (*Rhomboplites aurorubens*), and Red Drum (*Sciaenops ocellatus*) eggs across the northern Gulf of Mexico based on SEAMAP continuous underway fish egg sampler (CUFES) surveys, 52 p. Final Report NOAA/ MARFIN Award Number NA09NMF4330153.

Hickey, Jr., C.R. 1972. Common abnormalities in fishes, their causes and effects. Technical Reports of the New York Ocean Sciences Laboratory 0013, 20 pp.

Hightower, C.L. 2013. Evaluating the current status of Red Drum (*Sciaenops ocellatus*) in offshore waters of the north central Gulf of Mexico: age and growth, abundance, and mercury concentrations. MS Thesis. University of South Alabama. 108 pp.

Hightower, C.L., J.M. Drymon, A.E. Jefferson, M.B. Jarkowsky, E.A. Seubert, S.Dedman, J.F. Mareska, and S.P. Powers. 2021. Population dynamics, relative abundance, and habitat suitability of adult Red Drum (*Sciaenops ocellatus*) indicate vulnerability to harvest in nearshore waters of the north central Gulf of Mexico. Fishery Bulletin 120:162–175

Hildebrand, S.F., and W.C. Schroeder. 1928. Fishes of the Chesapeake Bay. Reprinted 1972, TFH Publ., Neptune City, NJ, 388 pp.

Hingston, J.A., C.D. Collins, R.J. Murphy, and J.N. Lester. 2001. Leaching of chromate copper aresenate wood preservatives: a review. Environmental Pollution 111:53-66.

Hoagland, K.D., J.P. Carder, and R.L. Spawn. 1996. Effects of organic toxic substances. Pages 469-496 *In*: Stevenson, R.J., M.L. Bothwell, and R.L. Lowe (eds). Algal Ecology: Freshwater Benthic Ecosystems. New York, New York. Academic Press.

Hoff, R. 1995. Responding to oil spills in coastal marshes: the fine line between help and hindrance. HAZMAT Report 96-1, National Oceanic and Atmospheric Administration, Hazardous Materials Response and Assessment Division. 16 pp.

Hoff, R., P. Hensel, E.C. Proffitt, P. Delgado, G. Shigenaka, R. Yender, and A.J. Mearns. 2002. Oil spills in mangroves, planning and response considerations. NOAA, Office of Response and Restoration. 96 pp.

Holland, A.F., D.M. Sanger, C.P. Gawle, S.B. Lerberg, M.S. Santiago, G.H.M. Riekerk, L.E. Zimmerman, and G.I. Scott. 2004. Linkages between tidal creek ecosystems and the landscape and demographic attributes of their watersheds. Journal of Experimental Marine Biology and Ecology 298(2):151-178.

Holland, G.J., and P.J. Webster. 2007. Heightened tropical cyclone activity in the North Atlantic: natural variability or climate trend? Philosophical Transactions of the Royal Society. Series A: Mathematical, Physical, and Engineering Sciences 365:2695-2716.

Hollenbeck, C.M., D.S. Portnoy, and J.R. Gold. 2019. Evolution of Population Structure in an Estuarine-Dependent Marine Fish. Ecology and Evolution 9:3141-3152.

Holt, S.A. 2008. Distribution of Red Drum spawning sites identified by a towed hydrophone array. Transactions of the American Fisheries Society 137:551-561.

Holt, G.J., R. Godbout, and C.R. Arnold. 1981b. Effects of temperature and salinity on egg hatching and larval survival of Red Drum. Fishery Bulletin 79(3):569-573.

Holt, G.J., S.A. Holt, and C.R. Arnold. 1985. Diel periodicity of spawning in sciaenids. Marine Ecology Progress Series 27:1-7.

Holt, G.J., A.G. Johnson, C.R. Arnold, W.A. Fable, Jr., and T.D. Williams. 1981a. Description of eggs and larvae of laboratory reared Red Drum, *Sciaenops ocellata*. Copeia 4:751-756

Holt, S.A., C.L. Kitting, and C.R. Arnold. 1983. Distribution of young Red Drums among different sea-grass meadows. Transactions of the American Fisheries Society 112:267-271.

Horst, M.N., and A.N. Walker. 1999. Effects of the pesticide methoprene on morphogenesis and shell formation in the blue crab *Callinectes sapidus*. Journal of Crustacean Biology 19(4):699-707.

Hunt, K.M., M.F. Floyd, and R.B. Ditton. 2007. African-American and Anglo anglers' attitudes toward the catch-related aspects of fishing. Human Dimensions of Wildlife 12(4):227-239.

Hutton, R.F. 1964. A second list of parasites from marine and coastal animals of Florida. Transactions of the American Microscopical Society 83(4):439-448.

ICES (International Council for the Exploration of the Sea). 1992. Report of the ICES working group on the effects of extraction of marine sediments on fisheries. ICES Cooperative Research Report #182. ICES: Burnaby, BC, Canada. 84 pp.

IGFA (International Game Fish Association). 2018. World recreational fishing records. Dania Beach, Florida.

Ingle, R.M., R.F. Hutton, and R.W. Topp. 1962. Result of the tagging of salt water fishes in Florida. Florida State Board of Conservation, Division of Salt Water Fisheries, Technical Series Number 38, St. Petersburg, Florida. 57 pp.

Inglis, A. 1959. Predation on shrimp. US. Fish and Wildlife Service Circular. 62:50-53.

Iverson, E.S., and B. Yokel. 1963. A Myxosporidian (Sporozoan) parasite in the Red Drum, *Sciaenops ocellatus*. Bulletin of Marine Science of the Gulf and Caribbean 13(3):449-453.

Jacob, S., F.L. Farmer, M. Jepson, and C. Adams. 2001. Landing a definition of fishing dependent communities: potential social science contributions to meeting National Standard 8. Fisheries 26(10):16–22. Taylor & Francis.

Jacob, S., P. Weeks, B.G. Blount, and M. Jepson. 2010. Exploring fishing dependence in gulf coast communities. Marine Policy 34(6):1307–1314.

Jacob, S., P. Weeks, B. Blount, and M. Jepson. 2013. Development and evaluation of social indicators of vulnerability and resiliency for fishing communities in the Gulf of Mexico. Marine Policy 37:86–95.

Jannke, T.E. 1971. Abundance of young sciaenid fishes in Everglades National Park, Florida in relation to season and other variables. University of Miami Sea Grant Program Sea Grant Technical Bulletin 11. 128 pp.

Jensen, J.R., K. Rutchey, M.S. Koch, and S. Naurmalani. 1995. Inland wetland change detection in the Everglades Water Conservation Area 2A using a time series of normalized remotely sensed data. Photographic Engineering and Remote Sensing 61(2):199-209.

Jepson, M. 2007. Social Indicators and Measurements of Vulnerability for Gulf Coast Fishing Communities. NAPA Bulletin 28(1):57–68.

Jewell, J.D. 1997. Prehistoric adaptation on the Mississippi Gulf Coast: faunal exploitation at the Godsey site (22HR591), Harrison County, and at the Singing River site (22JA520), Jackson County, Mississippi. The University of Southern Mississippi, Hattiesburg, Mississippi. 174 pp.

Johns, W.E., T.L. Townsend, D.M. Fratantoni, and W.D. Wilson. 2002. On the Atlantic inflow to the Caribbean Sea. Deep Sea Research 49:211–243.

Johnson, G.D. 1978. Development of fishes of the Mid Atlantic Bight - An atlas of egg, larval and juvenile stages. Volume IV. Carangidae through Ephippidae. Washington, D.C., United States Fish and Wildlife Service: Red Drum pages 242-246.

Johnson, M.R., C. Boelke, L.A. Chiarella, P.D. Colosi, K. Greene, K. Lellis-Dibble, H. Ludemann, M. Ludwig, S. McDermott, J. Ortiz, D. Rusanowsky. M. Scott, and J. Smith. 2008. Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States. NOAA Technical Memorandum NMFS-NE-209. 339 pp.

Johnson, S.K. 1990. Recognition and control of diseases common to grow-out aquaculture of Red Drum. Pages 113-130 *In*: Chamberlain, G.W., R.J. Miget, and M.G. Haby (eds). Red Drum Aquaculture, Texas A&M University Sea Grant College Program, College Station, Texas.

Johnson, W.B., and J.G. Gosselink. 1982. Wetland loss directly associated with canal dredging in the Louisiana coastal zone. Pages 60-72 *In*: Boesch, D.F. (ed), Proceedings of the Conference on Coastal Erosion and Wetland Modification in Louisiana. U.S. Fish and Wildlife Service, FWS/OBS-82-59.

Jones, J.I., R.E. Ring, M.O. Rinkel, and R.E. Smith (eds). 1973. A summary of knowledge of the eastern Gulf of Mexico. State University System of Florida, Institute of Oceanography, St. Petersburg, Florida. 7 pp.

Jordan, D., and B. Evermann. 1896-1900: The fishes of North and Middle America. Part. I (1896), II (1898), III (1898) & IV (1900). Bulletin of the United States Natural History Museum 47:1-3313.

Jordan, S. 2018. Tips for Inshore Fishing in the Winter. Great Days Outdoors On-line. January 15. https://greatdaysoutdoors.com/2018/01/tips-for-inshore-fishing-in-the-winter/

Justic, D., N.N. Rabalais, R.E. Turner, and W.J. Wiseman, Jr. 1993. Seasonal coupling between riverborne nutrients, net productivity, and hypoxia. Marine Pollution Bulletin 26(4):184-189.

Karlsson, S., E. Saillant, B.W. Bumguardner, R.R. Vega, and J.R. Gold. 2008. Genetic identification of hatchery-released Red Drum in Texas bays and estuaries. North American Journal of Fisheries Management 28:1294-1304.

Katner, A., M.H. Sun, and M. Suffet. 2010. An evaluation of mercury levels in Louisiana fish: Trends and public health issues. Science of the Total Environment 408:5707–5714.

Katner, A., E. Ogunyinka, M.H. Sun, S. Soileau, D. Lavergne, D. Dugas, and M. Suffet. 2011. Fishing, fish consumption and advisory awareness among Louisiana's recreational fishers. Environmental Research 111(8):1037-1045.

Kell, J.M. 1900. Recollections of a Naval Life: Including the Cruises of the Confederate States Steamers "Sumter" and "Alabama". The Neale Company. Washington. 320 pp.

Kelso, W.E., B.D. Rogers, D.A. Rutherford, and D.R. Rodgers. 1991. Survey of Louisiana sport fishermen - 1990. Louisiana Agricultural Experiment Station Mimeo Report 57. Baton Rouge, Louisiana. 65 pp.

Kelso, W.E., 1992. Survey of Louisiana recreational anglers, 1991. Louisiana Agricultural Experiment Station mimeo report (USA). 89 pp.

Kelso, W.E., B.D. Rogers, T.A. Bahel, D.A. Rutherford, and D.R. Rogers. 1994. A 1993 survey of Louisiana saltwater anglers. Louisiana State University Agricultural Center, Louisiana Agricultural Experiment Station. 93 pp.

Kemp, R.J. 1949. Report on stomach analysis from June 1, 1949 through August 31, 1949. Austin, Texas: p 100-127.

Kennedy, V.S. 1990. Anticipated effects of climate change on estuarine and coastal fisheries. Fisheries 15:16-25.

Kennish, M.J. 1998. Pollution Impacts on Marine Biotic Communities. CRC Press. Boca Raton Florida, 310 pp.

Kesaulya, I., and R. Vega. 2019. Effects of hypersaline conditions on the growth and survival of larval Red Drum (*Sciaenops ocellatus*). Jordan Journal of Biological Sciences 12(1):119-122.

Khursigara, A.J., P. Perrichon, N.M. Bautista, W.W. Burggren, and A.J. Esbaugh. 2017. Cardiac function and survival are affected by crude oil in larval Red Drum, *Sciaenops ocellatus*. Science of the Total Environment 579:797-804.

King, T.L., R. Ward, I.R. Blandon, R. Colura and J.R. Gold. 1995. Using genetics in the design of Red Drum and Spotted Seatrout stocking programs in Texas: a review. American Fisheries Society Symposium 15:499-502.

Knapp, F.T. 1950. Menhaden utilization in relation to the conservation of food and game fishes of the Texas coast. Transactions of the American Fisheries Society 79:137-144.

Kohler, C.C., and W.R. Courtenay. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries 11(2):39-42.

Kowalchyk, C. Personal Communication. North Carolina Division of Marine Fisheries. North Carolina Department of Environmental Quality. Greenville, North Carolina.

Krebs, J.M, and R.G. Turingan. 2003. Intraspecific variation in gape–prey size relationships and feeding success during early ontogeny in Red Drum, *Sciaenops ocellatus.* Environmental Biology of Fishes 66:75–84.

Kroetz, A.M., J.M. Drymon, and S.P. Powers. 2017. Comparative dietary diversity and trophic ecology of two estuarine mesopredators. Estuaries and Coasts 40: 1171–1182.

Kvenvolden, K.A., and C.K. Cooper. 2003. Natural seepage of crude oil into the marine environment. Geo-Marine Letters 23:140-146.

Kyle, G.T., M.A. Schuett, K. Lee, J.I. Yoon, C. Ding, and K. Wallen. 2013. Demographics, participation, attitudes, and management preferences of Texas anglers. College Station, Texas, Texas A&M University. 71 pp.

Lacepède, B.G.E. 1802. Histoire Naturelle des Poissons, vol. 4, xlvi+ 728 pp. Chez Plassan, Paris.

Landon, A.C., J. Jun, G.T. Kyle, J.I. Yoon, and M.A. Schuett. 2012. Demographics, participation, attitudes, and management preferences of Texas anglers. College Station, Texas: Human Dimensions of Natural Resources Laboratory, Texas A&M University. Report to the Texas Parks and Wildlife Department. 68 pp.

Landsberg, J.H. 1993a. Two new species of coccidian parasites (Apicomplexa, Eimeriorina) from Red Drum *Sciaenops ocellatus*. Diseases of Aquatic Organisms 16:83-90.

Landsberg, J.H. 1993b. Kidney myxosporean parasites in Red Drum *Sciaenops ocellatus* (Sciaenidae) from Florida, USA, with a description of *Parvicapsula renalis* n. sp. Diseases of Aquatic Organisms 17:9-16.

Landsberg, J.H., G.K. Vermeer, S.A. Richards, and N. Perry. 1991. Control of the parasitic copepod *Caligus elongatus* on pond-reared Red Drum. Journal of Aquatic Animal Health 3:206-209.

Landsberg, J.H., L.J. Flewelling, and J. Naar. 2009. *Karenia brevis* red tides, brevetoxins in the food web, and impacts on natural resources: decadal advancements. Harmful Algae 8:598-607.

Landsea, C.W. 2007. Counting Atlantic tropical cyclones back to 1900. Eos, Transactions American Geophysical Union 88(18):197-202.

Latour, R.J., K.H. Pollock, C.A. Wenner, and J.M. Hoenig. 2001. Estimates of fishing and natural mortality for subadult Red Drum in South Carolina waters. North American Journal of Fisheries Management 21:733–744.

Law, R.J., and J. Hellou. 1999. Contamination of fish and shellfish following oil spill incidents. Environmental Geoscience 6:90-98.

Lawler, A.R. 1980. Studies on *Amyloodinium ocellatum* (Dinoflagella) in Mississippi Sound: natural and experimental hosts. Gulf Research Reports 6 (4):403-413.

LDWF (Louisiana Department of Wildlife and Fisheries). Unpublished Data. Louisiana Department of Wildlife and Fisheries, Marine Fisheries Division. Baton Rouge, Louisiana

LDWF (Louisiana Department of Wildlife and Fisheries). 1997. 1997 report on the status of spotted seatrout. Louisiana Department of Wildlife and Fisheries, Marine Fisheries Division, Socioeconomic Research and Development Section, and Enforcement Division. Baton Rouge, Louisiana. 30 pp.

Leard, R.R., R. Matheson, K. Meador, W. Keithly, C. Luquet, M. VanHoose, C. Dyer, S. Gordon, J. Robertson, D. Horn, and R. Scheffler. 1993. The Black Drum fishery of the Gulf of Mexico, United States: A regional management plan. Gulf States Marine Fisheries Commission, Publication Number 28, Ocean Springs, Mississippi.

Lee, R., and Y. Oshima. 1998. Effects of selected pesticides, metals and organometallics on development of blue crab (*Callinectes sapidus*) embryos. Marine Environmental Research 46(1-5):479-482.

Lee, W.Y., G.J. Holt, and C.R. Arnold. 1984. Growth of Red Drum larvae in the laboratory. Transactions of the American Fisheries Society 113:243-246.

Lehrter, J. Personal Communication. Dauphin Island Sea Lab, Dauphin Island, Alabama.

Lemus, J. Personal Communication. Florida Fish and Wildlife Conservation Commission. Palmetto, Florida.

Leon, S. 2002. Chasing Redfish in the Heart of Dixie. WLOX On-line. June 27. https://www.wlox.com/story/836246/chasing-redfish-in-the-heart-of-dixie/

Letourneur, Y., P. Chabanet, P. DurviLLe, M. Taquet, E. Teissier, M. Parmentier, J.C. Quero, and K. Pothin. 2004. An updated checklist of the marine fish fauna of Reunion Island, south-western Indian Ocean. Cybium 28(3):199-216.

Lin, Q., and I.A. Mendelssohn. 1996. A comparative investigation of the effects of south Louisiana crude oil on the vegetation of fresh, brackish and salt marshes. Marine Pollution Bulletin 32(2):202-209.

Linnaeus, C. 1766. Systema Natura, Pt. 1. Reprinted by British Museum (Natural History), London. 491 pp.

Linton, E. 1901. Parasites of fishes of the Woods Hole region. Bulletin of the United States Fish Commission:405-492.

Linton, E. 1905. Parasites of Fishes of Beaufort, North Carolina. Bulletin of the Bureau of Fisheries:321-428 + 34 plates.

Liu, G., G.S. Janowitz, and D. Kamykowski. 2001. Influence of environmental nutrient conditions on *Gymnodinium breve* (Dinophyceae) population dynamics: a numerical study. Marine Ecology Progress Series 213:13-37.

Liu, P.C., W, Chuang, and K. Lee. 2003. Infectious gastroenteritis caused by *Vibrio harveyi* (*V. carchariae*) in cultured Red Drum, *Sciaenops ocellatus*. Journal of Applied Ichthyology 19:59-61.

Llansó, R.J., S.S. Bell, and F.E. Vose. 1998. Food habits of Red Drum and Spotted Seatrout in a restored mangrove impoundment. Estuaries 21:294–306.

Lohoefener, R., C. Roden, W. Hoggard, and K. Mullin. 1987. Distribution and relative abundance of near-surface schools of large Red Drum, *Sciaenops ocellatus*, in Northern Gulf of Mexico and selected inland waters. NMFS, Mississippi Laboratories. 95 pp.

Loomis, D.K., and R.B. Ditton. 1993. Distributive justice in fisheries management. Fisheries 18(2):14–18.

Lovell, S., J. Hilger, E. Rollins, N.A. Olsen, and S. Steinback. 2020. The economic contribution of marine angler expenditures on fishing trips in the United States, 2017. NOAA Tech Memo. NMFS-F/SPO-201, 80p.

Lowerre-Barbieri, S.K., L.R. Barbieri, J.R. Flanders, A.G. Woodard, C.F. Cotton and M.K. Knowlton. 2008. Use of passive acoustics to determine Red Drum spawning in Georgia waters. Transactions of the American Fisheries Society 137(2):562-575.

Lowerre-Barbieri, S.K., M. Tringali, J. Bickford, S. Burnsed, and M. Murphy. 2016a. The Red Drum (*Sciaenops ocellatus*) spawning population in the eastern Gulf of Mexico: composition, site fidelity, and size. SEDAR49-DW-07. SEDAR, North Charleston, South Carolina. 23 pp.

Lowerre-Barbieri, S.K., M.D. Tringali, C.P. Shea, S. Walters Burnsed, J. Bickford, M. Murphy, and C. Porch. 2019. Assessing Red Drum spawning aggregations and abundance in the eastern Gulf of Mexico: a multidisciplinary approach. ICES Journal of Marine Science 76(2):516-529.

Lowerre-Barbieri, S.K., S.L. Walters Burnsed, and J.W. Bickford. 2016b. Assessing reproductive behavior important to fisheries management: a case study with Red Drum, *Sciaenops ocellatus*. Ecological Applications 26(4):979-995.

Luczkovich J.J., S.E. Johnson, and M.W. Sprague. 1998. Using sound to map fish spawning: determining the seasonality and location of spawning by fishes in the family Sciaenidae (seatrouts, drums, and croakers) within Pamlico Sound, NC. The Journal of the Acoustical Society of America 103(3000):2173-2174.

Lyczkowski-Shultz, J., and J.P. Steen, Jr. 1991. Diel vertical distribution of Red Drum *Sciaenops ocellatus* larvae in the northcentral Gulf of Mexico. Fishery Bulletin 89:631-641.

Lyczcowski-Shultz, J., J.P. Steen, Jr., and B.H. Comyns. 1988. Early life history of Red Drum (*Sciaenops ocellatus*) in the northcentral Gulf of Mexico. Final Report. Mississippi-Alabama Sea Grant Consortium. Project No. R/LR-12. MASGP-88-013. 163 pp.

MacDonald, I.R. 1998. Natural oil spills. Scientific American 279:56-61.

MacDonald, I.R. 2011. Remote sensing and sea-truth measurements of methane flux to the atmosphere (HYFLUX project), final report DE-NT0005638, Natl. Energy Technol. Lab., Dep. of Energy, Morgantown, USA. 85 pp.

MacDonald, I.R., N.L. Guinasso Jr., S.G. Ackleson, J.F. Amos, R. Duckworth, R. Sassen, and J.M. Brooks. 1993. Natural oil slicks in the Gulf of Mexico visible from space. Journal of Geophysical Research 98(C9):16,351-16,364.

MacDonald, I.R., J.F. Reilly Jr., W.E. Best, R. Venkataramaiah, R. Sassen, N.S. Guinasso Jr., and J. Amos. 1996. Remote sensing inventory of active oil seeps and chemosynthetic communities in the northern Gulf of Mexico. Hydrocarbon Migration and its Near-surface Expression. D. Schumacher and M.A. Abrams [eds.]. American Association of Petroleum Geologists Memoir 66:27-37.

MacKenzie, C.L. 2007. Causes underlying the historical decline in eastern oyster (*Crassostrea virginica* Gmelin, 1791) landings. Journal of Shellfish Research 26(4):927-938.

Magana, H.A., C. Contreras, and T.A. Villareal. 2003. A historical assessment of *Karenia brevis* in the western Gulf of Mexico. Harmful Algae 2:163-171.

Magnuson, J.T., A.J. Khursigara, E.B. Allmon, A.J. Esbaugh, and A.P. Roberts. 2018. Effects of Deepwater Horizon crude oil on ocular development in two estuarine fish species, Red Drum (*Sciaenops ocellatus*) and Sheepshead Minnow (*Cyprinodon variegatus*). Ecotoxicology and Environmental Safety 166:186-191.

Malinowski, C., J. Cavin, J. Chanton, L. Chasar, F. Coleman, and C. Koenig. 2019. Trophic relationships and niche partitioning of Red Drum *Sciaenops ocellatus* and Common Snook *Centropomus undecimalis* in coastal estuaries of South Florida. Estuaries and Coasts 42(3):842-856.

Mann, M.E., K.A. Emanuel, G.J. Holland, and P.J. Webster. 2007. Atlantic tropical cyclones revisited. Eos, Transactions American Geophysical Union 88(36):349-350.

Martin, J.H., L.W. McEachron, J.F. Doerzbacher, K.W. Rice, and J.M. Mambretti. 1987. Comparison of trotline catches on four bait types in the Laguna Madre during June-August 1985. Management Data Series. Austin, Texas, Texas Parks and Wildlife Department. 124 pp.

Marwitz, S.R. 1989. A summary of fish tagging in Texas Bays: 1975-1988. Texas Parks and Wildlife Department, Fisheries Division, Management Data Series No. 1, Austin, Texas. 52 pp.

Mashburn, E. 2017. Fishing for Redfish in Lower Mobile Bay Bayous. November 2. Great Days Outdoors On-line. https://greatdaysoutdoors.com/2017/11/fishing-for-redfish-in-lower-mobile-bay-bayous/

Mashburn, E. 2018. Bull Redfish Off the Beach. Great Days Outdoors On-line. February 26. https://greatdaysoutdoors.com/2018/02/bull-redfish-off-beach/

Matlock, G.C. 1980. History and management of the Red Drum fishery. Pages 37-53 *In*: Williams, R.O., J.E. Weaver, and F.A. Kalber (eds). Proceedings of the Colloquium on the Biology and Management of Red Drum and Seatrout. Gulf States Marine Fisheries Commission. Pub No 5.

Matlock, G.C. 1984. A summary of 7 years of stocking Texas bays with Red Drum. Texas Parks and Wildlife Department, Coastal Fisheries Branch, Management Data Series Number 60, Austin, Texas. 20 pp.

Matlock, G.C. 1986. A summary of 10 years of stocking fishes into Texas bays. Austin, Texas, Texas Parks and Wildlife Department, Coastal Fisheries Branch: 19 pp.

Matlock, G.C. 1987. The life history of Red Drum. Pages 1-17 *In:* Chamberlain, G.W., R.J. Miget, and M.G. Haby. Manual of Red Drum Aquaculture. Texas Agricultural Extension Service and Sea Grant College Program, Texas A&M University, College Station, Texas.

Matlock, G.C., L.W. McEachron, J.A. Dailey, P.A. Unger, and P. Chai. 1993. Short-term hooking mortalities of Red Drums and spotted seatrout caught on single-barb and treble hooks. North American Journal of Fisheries Management 13(1):186-189.

Matlock, G.C., and J.E. Weaver. 1979. Fish tagging in Texas bays during November 1975-September 1976. Texas Parks and Wildlife Department, Coastal Fisheries Branch, Management Data Series Number 1, Austin, Texas. 136 pp.

McDonald, D., B. Bumguardner, and P. Cason. 2015. Effect of salinity on the upper lethal temperature tolerance of early-juvenile Red Drum. Journal of Thermal Biology 53:33-37.

McEachron, L.W., J.F. Doerzbacher, G.C. Matlock, A.W. Green, and G.E. Saul. 1988. Reducing the bycatch in a commercial trotline fishery. Fishery Bulletin 86(1):109-117.

McEachron, L., D. Pridgen, and R. Hensley. 1998. Texas red tide fish kill estimates. Workshop Meeting, Red Tide in Texas: from Science to Action, April 17-18, 1998. University of Texas Marine Science Institute, Port Aransas, Texas. (Abstract).

McGill, K. 1988. Man behind the redfish craze has other fish to fry. January 7, 1988. AP News. Available: https://apnews.com/article/ee73a10d2c5e9977cc12239448e8104c. (August 2021).

McKee, K.L., and I.A. Mendelssohn. 1989. Response of a freshwater marsh plant community to increased salinity and increased water level. Aquatic Botany 34:301–316.

McMillan, C., and C.L. Sherrod. 1986. The chilling tolerance of black mangrove, *Avicennia germinans*, from the Gulf of Mexico coast of Texas, Louisiana and Florida. Contributions in Marine Science 29:9-16.

McNulty, J.K., W.N. Lindall, Jr. and J.E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I, area description. U. S. Department of Commerce, NOAA Technical Report, NMFS CIRC-368, 126 pp.

McPherson, B.F., and K.M. Hammett. 1991. Tidal rivers of Florida. Pages 31–41 *In*: Livingston, R.L. (ed). The Rivers of Florida. Springer-Verlag. New York, 289 pp.

MDMR (Mississippi Department of Marine Resources). Unpublished Data. Marine Fisheries, Mississippi Department of Marine Resources. Biloxi, Mississippi.

Meade, R.H., and J.A. Moody. 2010. Causes for the decline of suspended sediment discharge in the Mississippi River system, 1940-2007. Hydrological Processes 24:35-49.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao. 2007. Chapter Global climate projections. Pages 747-845 *In*: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA.

Meeuwig, J.J., J.B. Rasmussen, and R.H. Peters. 1998. Turbid waters and clarifying mussels: their moderation of empirical chl:nutrient relations in estuaries in Prince Edward Island, Canada. Marine Ecology Progress Series 171:139-150.

Meise, J.A. 1930. Gifts of nature yield millions; Forest products, oil, gas, minerals, game, fish add to wealth. New Orleans States Newspaper. January 3. page 9.

Mendelssohn, I.A., and K.L. McKee. 1988. *Spartina alterniflora* die-back in Louisiana: time course investigation of soil waterlogging effects. The Journal of Ecology 76:509–521.

Mendelssohn, I.A., M.W. Hester, and J.M. Hill. 1993. Effects of oil spills on coastal wetlands and their recovery. U.S. Department of the Interior, Minerals Management Service, OCS Study MMS 93-0045, New Orleans, Louisiana.

Messieh, S.N., T.W. Rowell, D.L. Peer and P.J. Cranford. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf seabed. Continental Shelf Research 11(8-10):1237-1263.

Meyers, T.R., and J.D. Hendricks. 1982. A summary of tissue lesions in aquatic animals induced by controlled exposures to environmental contaminants, chemotherapeutic agents, and potential carcinogens. Marine Fisheries Review 44(12):1-17.

Miles, D.W. 1950. The life histories of the sea-trout, *Cynoscion nebulosus*, and the redfish, *Sciaenops ocellatus.* Texas Game and Fish Commission: p 66-103.

Miles, D.W. 1951. The life histories of the sea-trout, *Cynoscion nebulosus*, and the redfish, *Sciaenops ocellatus*: sexual development. Rockport, Texas, Texas Game and Fish Commission: 11 p.

Miles, D.W., and E.G. Simmons. 1950. The menhaden fishery. Texas Game, Fish, and Oyster Commission, Marine Lab Series II, Austin, Texas. 28 pp.

Miller, G.L., and S.C. Jorgensen. 1973. Meristic characters of some marine fishes of the western Atlantic Ocean. Fishery Bulletin of the U.S. 71:301-317.

Mills, K.E., and M.S. Fonseca. 2003. Mortality and productivity of eelgrass *Zostera marina* under conditions of experimental burial with two sediment types. Marine Ecology Progress Series 255:127-134.

Milon, J. W. 2001. Current and future participation in marine recreational fishing in the southeast U.S. region, NOAA Technical Memorandum NMFS-F/SPO-44. 33 pp.

Minton, R.V., and M. Van Hoose. 1989. Age class structure of exploited Red Drum from the inshore and fishery conservation zone, North Central Gulf of Mexico. MARFIN NA88WC-H-MF190. 11 pp.

Miranda, L.E., and A.J. Sonski. 1985. Survival of Red Drum fingerlings in fresh water: dissolved solids and thermal minima. Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies 39:228-237.

Mitchell, K.M., and T. Henwood. 1999. Red Drum (*Sciaenops ocellatus*) Tag/Recapture Experiment (1997-1998). NMFS-MS Laboratories. 15 pp.

Mitsch, W.J., and J.G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold. New York, New York, 722 pp.

MMS (Minerals Management Service). 1997. Gulf of Mexico OCS lease sales 169, 172, 175, 178, and 182, Central Planning Area, Final Environmental Impact Statement. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, Louisiana.

MMS (Minerals Management Service). 2007a. Programmatic environmental impact statement for alternative energy development and production and alternate use of facilities on the outer continental shelf, Final Environmental Impact Statement. U.S. Department of the Interior, Minerals Management Service, New Orleans, Louisiana.

MMS (Minerals Management Service). 2007b. Gulf of Mexico OCS oil and gas lease sales: 2007-2012. Final Environmental Impact Statement. OCS EIS/EA MMS 2007-018, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana.

MMS (Minerals Management Service). 2008. Gulf of Mexico OCS oil and gas lease sales: 2009-2012, central planning area sales 208, 213, 216, and 222, western planning area sales 210, 215, and 218. Final Supplemental Environmental Impact Statement. OCS EIS/EA, MMS 2008-41, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, Louisiana.

Molina, E.M., D.M. Gatlin III, and J.R. Tomasso Jr. 2016. Survival and physiological responses of juvenile Red Drum exposed to hypersalinity and elevated temperatures. North American Journal of Aquaculture 78:174–177.

Moore, A., and C.P. Waring. 2001. The effects of a synthetic pyrethroid pesticide on some aspects of reproduction in Atlantic salmon (*Salmo salar* L.). Aquatic Toxicology 52:1-12.

Morning Advocate. 1950. Pompano-Redfish. Page 8-B. Baton Rouge, Louisiana. Sunday Morning, November 12.

Moulton, D.L., M.A. Dance, J.A. Williams, M.Z. Sluis, G.W. Stunz, and J.R. Rooker. 2017. Habitat partitioning and seasonal movement of Red Drum and Spotted Seatrout. Estuaries and Coasts 40:905-916.

Moulton, D.W., T.E. Dahl, and D.M. Dahl. 1997. Texas coastal wetlands; status and trends, mid-1950s to early 1990s. U.S. Department of the Interior, Fish and Wildlife Service, Albuqerque, New Mexico, 32 pp.

Mugetti, D., K. Varello, A. Gustinelli, P. Pastorino, V. Menconi, D. Florio, M. L. Fioravanti, E. Bozzetta, S. Zoppi, A. Dondo and M. Prearo. 2020. *Mycbacterium pseudoshottsii* in Mediterranean Fish Farms: New Trouble for European Aquaculture? Pathogens 9, 610. 11 pp.

Mullin, K., T. Henwood, W. Hoggard, C. Rogers, C. Rode, and S. O'Sullivan. 1996. Distribution and Relative Abundance of Large Near-Surface Red Drum, *Sciaenops ocellatus*, in the Northern Gulf of Mexico. NMFS, Mississippi Laboratories. 26 pp.

Murphy, M. Personal Communication. The Nature Conservancy. Vancleave, Mississippi

Murphy, M.D., and R.G. Taylor. 1990. Reproduction, growth, and mortality of Red Drum *Sciaenops ocellatus* in Florida waters. Fishery Bulletin 88:531-542.

Murphy-Grimshaw, H. 1897. Tarpon-Fishing. The Badminton magazine of sports and pastimes; London. 4(20):313-328.

Music, J.L., and J.M. Pafford. 1984. Population Dynamics and Life History Aspects of Major Marine Sportfishes in Georgia's Coastal Waters. Georgia Department of Natural Resources. Contribution Series Number 38. 382 pp.

Nahhas F.M., and R.B. Short. 1965. Digenetic trematodes of marine fishes from Apalachee Bay, Gulf of Mexico. Tulane Studies in Zoology 12(2):39-50.

Najjar, R.G., H.A. Walker, P.J. Anderson, E.J. Barro, R.J. Bord, J.R. Gibso, V.S. Kennedy, C.G. Knight, J.P. Megonigal, R.E. O'Conner, C.D. Polsky, N.P. Psuty, B.A. Richards, L.G. Sorenson, E.M. Steele, and R.S. Swanson. 2000. The potential impacts of climate change on the mid-Atlantic coastal region. Climate Research 14:219-233.

Nakayama, S., K. Rose, and L. Fuiman. 2011. Batch spawning decreases competition among early life stages in coastal fishes: a simulation study using Red Drum *Sciaenops ocellatus*. Marine Ecology Progress Series. 441:213–223.

Nance, J.M., W. Keithly, Jr., C. Caillouet, Jr., J. Cole, W. Gaidry, B. Gallaway, W. Griffin, R. Hart, and M. Travis. 2008. Estimation of effort, maximum sustainable yield, and maximum economic yield in the shrimp fishery of the Gulf of Mexico. USDOC, NOAA Tech. Memo. NMFS-SEFSC-570, 73 pp.

NAS (National Academy of Sciences). 2000. El Niño and La Niña: Tracing the dance of ocean and atmosphere. National Academy of Sciences, Office on Public Understanding of Science, Washington, D.C.

Nelson, T.R. 2019. Intrapopulation Diversity in Salinity use of Red Drum (*Sciaenops ocellatus*). PhD. Dissertation. University of South Alabama. 287 pp.

Nelson, T.R., and S. Powers. 2020. Estimates of Red Drum Mortality via Acoustic Telemetry. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 12:78-97.

Newell, R.C., L.J. Seiderer, and D.R. Hitchcock. 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanography and Marine Biology: an Annual Review 36:127-178.

Nichols, S. 1988. An estimate of the Red Drum spawning stock using mark/recapture. National Marine Fisheries Service. Pascagoula, Mississippi. 27 pp.

NMFS (National Marine Fisheries Service). 2011. Impacts to essential fish habitat from non-fishing activities in Alaska. National Marine Fisheries Service, Alaska Region. 123 pp.

NMFS (National Marine Fisheries Service). 2022. Fisheries Economics of the United States, 2019. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/SPO-229, 236 pp.

NOAA (National Oceanic and Atmospheric Administration). Personal Communication. Fisheries Statistics and Economics Division, Silver Spring, Maryland.

NOAA (National Oceanic and Atmospheric Administration). Unpublished Data. Fisheries Statistics and Economics Division, Silver Spring, Maryland.

NOAA (National Oceanic and Atmospheric Administration). 1985. Gulf of Mexico coastal and ocean zones strategic assessment: data atlas. U.S. Department of Commerce, NOAA, NOS. Metadata File (tar.gz)

NOAA (National Oceanic and Atmospheric Administration). 2010. Characteristic coastal habitats: choosing spill response alternatives. National Oceanic and Atmospheric Administration, National Ocean Service, Office of Response and Restoration, Emergency Response Division. Seattle, Washington. 86 pp.

NOAA (National Oceanic and Atmospheric Administration). 2013. Storm surge overview. National Weather Service, National Hurricane Center. Available at http://www.nhc.noaa.gov/ssurge/ssurge_overview.shtml.

NOAA (National Oceanic and Atmospheric Administration). 2021. NOAA Fisheries Commercial Landings Query Page. Available: https://www.fisheries.noaa.gov/national/sustainable-fisheries/commercial-fisheries-landings. (August 2021).

NOAA/NMFS (National Oceanic and Atmospheric Administration/National Marine Fisheries Service). 2017. Improving International Fisheries Management 2017. Report to Congress. US Department of Commerce. Washington, D.C. 93 pp.

NOAA/NMFS (National Oceanic and Atmospheric Administration/National Marine Fisheries Service). 2019. Improving International Fisheries Management 2019 Report to Congress. US Department of Commerce. Washington, D.C. 92 pp.

Norris, T. 1865. The American angler's book. Porter and Coates, Philadelphia. 733 pp.

Nowlin W.D. Jr, A.E. Jochens, R.O. Reid, and S.F. DiMarco. 1998. Texas–Louisiana shelf circulation and transport processes study synthesis report, volume 1: technical report. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, OCS Study MMS 98-0035, New Orleans, Louisiana. 502 pp.

NRC (National Research Council). 2000. Clean coastal waters: understanding and reducing the effects of nutrient pollution. National Academy Press, Washington, D.C. 421 pp.

NRC (National Research Council). 2003. Oil in the sea III: inputs, fates and effects. National Academy Press. Washington DC. 280 pp.

Nyboer, E.A., H.S. Embke, A.M. Robertson, R. Arlinghaus, S. Bower, C. Baigun, D. Beard, S.J. Cooke, I.G. Cowx, J.D. Koehn, R. Lyach, M. Milardi, W. Potts, and A.J. Lynch. 2022. Overturning stereotypes: The fuzzy boundary between recreational and subsistence inland fisheries. Fish and Fisheries. Fish and Fisheries 00:1-17.

O'Reilly, J.E. 1994. Nutrient loading and eutrophication. Pages 25-30 *In*: Langton, R.W., J.B. Pearce, and J.A. Gibson (eds). Selected living resources, habitat conditions, and human perturbations of the Gulf of Maine: environmental and ecological considerations for fishery management. Woods Hole (MA): NOAA Technical Memorandum. NMFS-NE-106.

Ochoa, J., H. Sheinbaum, A. Badan, J. Candela, and D. Wilson. 2001. Geostrophy via potential vorticity inversion in the Yucatan Channel. Journal of Marine Research 59:725-747.

Odum, W.E. 1971. Pathways of energy flow in a south Florida estuary. Doctoral Dissertation. University of Miami, Miami, Florida. 162 pp.

Odum, W.E., C.C. McIvor, and T.J. Smith. 1982. The ecology of the mangroves of south Florida: a community profile. FWS/OBS-81/24, USFWS Office of Biological Services, Washington, D.C., 144 pp.

Onuf, C.P. 1994. Seagrasses, dredging and light in Laguna Madre, Texas, U.S.A. Estuarine, Coastal and Shelf Science 39:75-91.

Onuf, C.P. 1996. Seagrass responses to long-term light reduction by brown tide in upper Laguna Madre, Texas: distribution and biomass patterns. Marine Ecology Progress Series 138:219–231.

Oouchi, K., J. Yoshimura, H. Yoshimura, R. Mizuta, S. Kusunoki, and A. Noda. 2006. Tropical cyclone climatology in a global-warming climate as simulated in a 20 km-mesh global atmospheric model: frequency and wind intensity analysis. Journal of the Meteorological Society of Japan 84(2):259-276.

Orth, R.J., T.J.B. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourqurean, K.L. Heck, A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, S. Olyarnik, F.T. Short, M. Waycott, and S.L. William. 2006. A global crisis for seagrass ecosystems. Bioscience 56(12):987-996.

Osburn, H.R., G.C. Matlock, and A.W. Green. 1982. Red Drum (*Sciaenops ocellatus*) Movements in Texas Bays. Contributions in Marine Sciences 25:85-97.

Overstreet, R.M. 1983. Aspects of the biology of the Red Drum, *Sciaenops ocellatus*, in Mississippi. Gulf Research Reports Supplement 1:45-68.

Overstreet, R.M., and R.W. Heard. 1978. Food of the Red Drum, *Sciaenops ocellata*, from Mississippi Sound. Gulf Research Reports 6(2):131-135.

Overstreet, R.M., and W.E. Hawkins. 2017. Diseases and Mortalities of Fishes and Other Animals in The Gulf of Mexico. pages 1589-1738 *In:* C.B. Ward, editor. Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill, Volume 1: Water Quality, Sediments, Sediment Contaminants, Oil and Gas Seeps, Coastal Habitats, Offshore Plankton and Benthos, and Shellfish. Springer, New York, New York.

Page, L.M., H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, N.E. Mandrak, R.L. Mayden, and J.S. Nelson. 2013. Common and Scientific Names of Fishes from the United States, Canada, and Mexico, 7th edition. American Fisheries Society Special Publication 34. 243 pp.

Parmentier, E., J. Tock, J.C. Falguière, and M. Beauchaud. 2014. Sound production in *Sciaenops ocellatus*: preliminary study for the development of acoustic cues in aquaculture. Aquaculture 432:204-211.

Parr, A.E. 1935. Report on hydrographic observations in the Gulf of Mexico and the adjacent straits made during the Yale Oceanographic Expedition on the MABEL TAYLOR in 1932. Bulletin of the Bingham Oceanographic Collections 5(1):1-93.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries Volume II: species life history summaries. Silver Spring, Maryland, NOAA/NOS Strategic Environmental Assessments Division: 337 pp.

Peacock, T. 2014. A synthesis of Red Drum feeding ecology and diets from North Carolina and South Carolina. MS Thesis. Department of Biology. East Carolina University. 96 pp.

Pearce, H.H., Jr. Personal Communication. Harlon's La Fish. Kenner, Louisiana

Pearson, J.C. 1929. Natural history and conservation of redfish and other commercial Sciaenids on the Texas coast. Bulletin of the U.S. Bureau of Fisheries 44:129-214.

Penland, S., A. Beall, and J. Kindinger. 2002. Environmental Atlas of the Lake Pontchartrain Basin - USGS Open File Report 02-206. www.usgs.gov/of/2002/of02-206/index.html.

Perez-Castaneda, R., Z. Blanco-Martinez, J.G. Sanchez-Martinez, J.L. Rabago-Castro, G. Aguirre-Guzman, and M. Vazquez-Sauceda. 2010. Distribution of *Farfantepenaeus aztecus* and *F. duorarum* on submerged aquatic vegetation habitats along a subtropical coastal lagoon (Laguna Madre, Mexico). Journal of the Marine Biological Association of the United Kingdom 90(3):445-452.

Perez-Dominguez, R., and J.G. Holt. 2002. Effects of nursery environmental cycles on larval Red Drum (*Sciaenops ocellatus*) growth and survival. Fisheries Science 68(sup1):186-189.

Perez-Dominguez, R.P., S.A. Holt, and G.J. Holt. 2006. Environmental variabilities in seagrass meadows effects of nursery environment cycles on growth and survival in larval Red Drum *Sciaenops ocellatus*. Marine Ecology Progress Series 321:41-53.

Perret, W.S., B.B. Barrett, W.R. Latapie, J.F. Pollard, W.R. Mock, G.B. Adkins, W.J. Gaidry, and C.J. White (eds). 1971. Phase I, Area description. Cooperative Gulf of Mexico Estuarine Inventory and Study, Louisiana. Louisiana Department of Wildlife and Fisheries, New Orleans, Louisiana. Pages 1-27.

Perret, W.S., J.E. Weaver, R.O. Williams, P.L. Johansen, T.D. McIlwain, R.C. Raulerson, and W.M. Tatum. 1980. Fishery profiles of Red Drum and Spotted Seatrout. Gulf States Marine Fisheries Commission, Publication No. 6, Ocean Springs, Mississippi. 60 pp.

Perry, C.L., and I.A. Mendelssohn. 2009. Ecosystem effects of expanding populations of *Avicennia germinans* in a Louisiana salt marsh. Wetlands 29(1):396-406.

Perry, H.M, K.C. Stuck, and H.D. Howse. 1979. First record of a bloom of *Gonyaulax monilata* in coastal waters of Mississippi. Gulf Research Reports 6(3):313-316.

Peters, K.M., and R.H. McMichael, Jr. 1987. Early life history of the Red Drum, *Sciaenops ocellatus* (Pisces Sciaenidae), in Tampa Bay, Florida. Estuaries 10(2):92-107.

Peterson, D., D. Cayan, J. Dileo, M. Noble, and M. Dettinger. 1995. The role of climate in estuarine variability. American Scientist 83:58-67.

Peterson, G.W. 1986. Distribution, habitat preferences, and relative abundance of juvenile Spotted Seatrout and Red Drum in the Caminada Bay estuary, Louisiana. MS Thesis. Louisiana State University. 96 pp.

Pezeshki, S.R., R.D. DeLaune, and W.H. Patrick, Jr. 1987. Response of *Spartina patens* to increasing levels of salinity in rapidly subsiding marshes of the Mississippi River deltaic plain. Estuarine, Coastal and Shelf Science 24:389–399.

Pitchon, A., and K. Norman. 2012. Fishing off the Dock and Under the Radar in Los Angeles County: Demographics and Risks. Bulletin of the Southern California Academy of Science 111(2):141–152.

Plumb J.A., J.H. Schachte, and J.L. Gaines. 1974. *Streptococcus* sp. from marine fishes along the Alabama and northwest Florida coast of the Gulf of Mexico. Transactions of the American Fisheries Society 2:358-361.

Plumb, J.A. 1991. Major diseases of Striped Bass and Redfish. Veterinary and Human Toxicology 33(Suppl 1):34-39.

Poirrier, M.A., and L.R. Handley. 2007. Chandeleur Islands. Pages 62-71 *In*: Handley, L., D. Altsman, and R. DeMay (eds). Seagrass Status and Trends in the Northern Gulf of Mexico—1940–2002. U.S. Geological Survey, Scientific Investigations Report 2006–5287.

Porch, C.E. 2000. Status of the Red Drum stocks of the Gulf of Mexico. Sustainable Fisheries Division Contribution, Southeast Fisheries Science Center: SFD-99/00-85. Miami, Florida, USA. 70 pp.

Porch, C., C. Wilson, and D. Nieland. 2002. A new growth model for Red Drum (*Sciaenops ocellatus*) that accomodates seasonal and ontogenetic changes in growth rate. Fishery Bulletin 100(1):149-152.

Powers, S., and C.L. Hightower. 2018. Assessing the Current Status of Red Drum (*Sciaenops ocellatus*) in the Northern Gulf of Mexico: A Multistate Cooperative Effort. SK Grant Number:NA14NMF4270046. 24 pp.

Powers, S., C.L. Hightower, J.M. Drymon, and M. Johnson. 2012. Age composition and distribution of Red Drum (*Sciaenops ocellatus*) in offshore waters of the north central Gulf of Mexico: an evaluation of a stock under a federal harvest moratorium. Fishery Bulletin 110(3):283-292.

Preston, B.L. 2002. Indirect effects in aquatic ecotoxicology: implications for ecological risk assessment. Environmental Management 29(3):311-323.

Proffitt, C.E. 1998. Effects and management of oil spills in marsh ecosystems: a review produced from a workshop convened July 1996 at McNeese State University. U.S. Department of Energy, Minerals Management Service, Gulf of Mexico OCS Region, OCS Study MMS 98-0018, New Orleans, Louisiana. 52 pp.

Pulich, W.M., Jr. 1999. Introduction to Texas seagrass conservation plan. Pages 14-25 *In*: Texas Parks and Wildlife Department, Resource Protection Division, Austin, Texas. 84 pp.

Pulich, W.M., Jr., C. Blair, and W.A. White. 1997. Current status and historical trends in seagrass in the Corpus Christi Bay National Estuary Program Study area. Corpus Christi Bay National Estuary Program Office, TAMU-CC, Report CCBNEP-20, Corpus Christi, Texas, 131 pp.

Pulich, W.M., Jr., and C. Onuf. 2007. Statewide summary for Texas. Pages 7-16 *In*: Handley, L., D. Altsman, and R. DeMay (eds). Seagrass Status and Trends in the Northern Gulf of Mexico: 1940-2002. U.S. Geological Survey, Scientific Investigations Report 2006-5287 and U.S. Environmental Protection Agency 855-R-04-003.

Quang, H.T., T.L. Lan, T.T.H. Hai, P.T.H. Yen, T.Q.K. Van, H.T.Tung, M.N. Binh, N.K.H. Son, N.Q. Linh, and N.D.Q. Tram. 2020. Genetic Diversity and toxic genes analysis of vibrio spp. Isolated from white leg shrimp and marine fishes cultured in Tam Giang lagoon in Thua Thien Hue province, Vietnam. Indian Journal of Science and Technology 13(13):1412-1422.

Quimby, B., S.E.S Crook, K.M. Miller, J. Ruiz, and D. Lopez-Carr. 2020. Identifying, defining and exploring angling as urban subsistence: Pier fishing in Santa Barbara, California. Marine Policy 121. https://doi.org/10.1016/j.marpol.2020.104197

Rabalais, N.N., and R.E. Turner. 2001. Hypoxia in the northern Gulf of Mexico: description, causes, and change. Pages 1-36 *In:* Rabalais, N.N., and R.E. Turner (eds.). Coastal hypoxia: consequences for living resources and ecosystems. Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.

Rabalais, N.N., R.E. Turner, and W.J. Wiseman, Jr. 1997. Hypoxia in the northern Gulf of Mexico: past, present, and future. Proceedings of the first Gulf of Mexico hypoxia management conference. Gulf of Mexico Program Office, EPA-55-R-001.

Rabalais, N.N., R.E. Turner, D. Justic, Q. Dortch, and W.J. Wiseman. 1999. Characterization of hypoxia, Topic 1 report for the integrated assessment of hypoxia in the Gulf of Mexico. NOAA, National Ocean Service, Coastal Ocean Program, Decision Analysis Series No. 15. 185 pp.

Rabalais, N.N., R.E. Turner, B.K. Sen Gupta, D.F. Boesch, P. Chapman, and M.C. Murrell. 2007. Hypoxia in the northern Gulf of Mexico: does the science support the plan to reduce, mitigate, and control hypoxia? Estuaries and Coasts 30(5):753-772.

Railey, J. 1933, 1935, and 1936. Local Fishing Reports. Tampa Tribune. Tampa Florida.

Ramsey, P.R., and J.M. Wakeman. 1987. Population structure of *Sciaenops ocellatus* and *Cynoscion nebulosus* (Pisces: Sciaenidae): Biochemical Variation, Genetic Subdivision and Dispersal. Copeia 1987(3):682-695.

Reid, G.K., Jr. 1955. A summer study of the biology and ecology of East Bay, Texas. Part II. The fish fauna of East Bay, the Gulf Beach, and summary. Texas Journal of Science 7:430-453.

Reid, G.K., Jr., A. Inglis, and H.D. Hoese. 1956. Summer foods of some fish species in East Bay, Texas. The Southwestern Naturalist 1(3):100-104.

Rester, J.K., and R.E. Condrey. 1999. Characterization and evaluation of bycatch reduction devices in the Gulf Menhaden fishery. North American Journal of Fisheries Management 19:42-50.

Rice, S.D., J.W. Short, R.A. Heintz, M.G. Carls, and A. Moles. 2000. Life-history consequences of oil pollution in fish natal habitat. Pages 1210-1215 *In*: P. Catania (ed). Energy 2000: The Beginning of a New Millennium. Technomic Publishers, Lancaster, Pennsylvania.

Rideout, R.M., and J. Tomkiewicz. 2011. Skipped spawning in fishes: more common than you might think. Marine and Coastal Fisheries 3(1):176–189.

Riggin, G.T., Jr., and A.K. Sparks. 1962. A new gasterostome, *Bucephaloides megacirrus*, from the redfish, *Sciaenops ocellata*. Proceedings of the Helminthological Society of Washington 29(1):27-29.

Robins, C.R., G.C. Ray, and J. Douglass. 1986. A field guide to Atlantic Coast fishes of North America. The Peterson Guide Series, Volume 32. Houghton Mifflin Company, Boston, Massachusetts. 354p.

Roessler, M. 1967. Observations on the seasonal occurrence and life histories of fishes in Buttonwood Canal, Everglades National Park, Florida. University of Miami, Coral Gables, Florida. 155p.

Rohr, B.A. 1980. Use of hard parts to age Gulf of Mexico Red Drum. Page 15 *In:* Williams, R.O., J.E. Weaver, and F.A. Kalber (eds). Proceedings of the Colloquium on the Biology and Management of Red Drum and Seatrout. Gulf States Marine Fisheries Commission. Pub No 5.

Rooker, J.R., and S.A. Holt. 1997. Utilization of subtropical sea-grass meadows by newly settle Red Drum patterns of distribution and growth. Marine Ecology Progress Series 158:139-149.

Rooker, J.R., G.J. Holt, and S.A. Holt. 1998b. Vulnerability of newly settled Red Drum (*Sciaenops ocellatus*) to predatory fish is early life survival enhanced by seagrass meadows? Marine Biology 131:145-151.

Rooker, J.R., S.A. Holt, G.J. Holt, and L.A. Fuiman. 1999. Spatial and temporal variability in growth, mortality, and recruitment potential of postsettlement Red Drum, *Sciaenops ocellatus*, in a subtropical estuary. Fishery Bulletin 97:581-590.

Rooker, J., S. Holt, J. Holt, and L. Fuiman. 1997. Spatial and temporal variability in growth, mortality, and recruitment potential of postsettlement Red Drum, *Sciaenops ocellatus*, in a subtropical estuary. Fishery Bulletin 97(3):581–590.

Rooker, J.R., S.A. Holt, M.A. Soto, and G.J. Holt. 1998a. Postsettlement patterns of habitat use by sciaenid fishes in subtropical seagrass meadows. Estuaries 21(2):318-327.

Rooker, J.R., G.W. Stunz, S.A. Holt, and T.J. Minello. 2010. Population connectivity of Red Drum in the northern Gulf of Mexico. Marine Ecology Progress Series 407:187-196.

Ross, J.L., T.M. Stevens, and D.S. Vaughan. 1995. Age, growth, mortality, and reproductive biology of Red Drums in North Carolina waters. Transactions of the American Fisheries Society 124(1):37-54.

Rozas, L.P., T.J. Minello, and C.B. Henry. 2000. An assessment of potential oil spill damage to salt marsh habitats and fishery resources in Galveston Bay, Texas. Marine Pollution Bulletin 40(12):11488-1160.

Runcie, J., C. Macinnis-Ng, and P. Ralph. 2005. The toxic effects of petrochemicals on seagrasses. Institute for Water and Environmental Resource Management/University of Technology, Sydney, Australia. 21pp.

Rydene, D.A., and R.E.J. Matheson. 2003. Diurnal fish density in relation to seagrass and drift algae cover in Tampa Bay, Florida. Gulf of Mexico Science 1:35-58.

Ryman, N., and L. Laikre. 1991. Effects of Supportive Breeding on the Genetically Effective Population Size. Conservation Biology 5(3):325-329.

Sagarese, S.R., M.A. Nuttall, J.E. Serafy, and E. Scott-Denton. 2016. Review of bycatch in the Gulf Menhaden fishery with implications for the stock assessment of Red Drum. SEDAR49-DW-04. SEDAR, North Charleston, South Carolina. 30 pp.

Saha, K., X. Zhao, H. Zhang, K.S. Casey, D. Zhang, S. Baker-Yeboah, K.A. Kilpatrick, R.H. Evans, T. Ryan, and J.M. Relph. 2018. AVHRR Pathfinder version 5.3 level 3 collated (L3C) global 4km sea surface temperature for 1981-Present. NOAA National Centers for Environmental Information.

Sasaki, K. 2000. Sciaenidae. Croakers and drums. Page 621. *In*: J.E. Randall and K.K.P. Lim (eds.) A checklist of the fishes of the South China Sea. Raffles Bulletin of Zoology 8:569-667.

Sawyer, R.T., A.R. Lawler, R.M. Overstreet. 1975. Marine leeches of the eastern United States and the Gulf of Mexico with a key to the species. Journal of Natural History 9:633-667.

Scaife, W.W., R.E. Turner, and R. Costanza. 1983. Coastal Louisiana recent land loss and canal impacts. Environmental Management 7:433–442.

Scharf, F.S., and K.K. Schlight. 2000. Feeding habits of Red Drum (*Sciaenops ocellatus*) in Galveston Bay, Texas: seasonal diet variation and predator-prey size relationships. Estuaries 23:128–139.

Schwartz, F.J., and J.F. Francesconi. 1998. A deformed, multi-spotted Red Drum, *Sciaenops ocellatus* (Sciaenidae), from North Carolina. The Journal of the Elisha Mitchell Scientific Society 114(4):219-224.

Scott-Denton, E., P.F. Cryer, B.V. Duffin, M.R. Duffy, J.P. Gocke, M.R. Harrelson, A.J. Whatley, and J.A. Williams. 2020. Characterization of the U.S. Gulf of Mexico and South Atlantic penaeidae and Rock Shrimp (Sicyoniidae) fisheries through mandatory observer coverage, from 2011 to 2016. Marine Fisheries Review 82(1-2):17-46.

Scott-Denton, E., P.F. Cryer, M.R. Duffy, J.P. Gocke, M.R. Harrelson, D.L. Kinsella, J.M. Nance, J.R. Pulver, R.C. Smith, and J.A. Williams. 2012. Characterization of the U.S. Gulf of Mexico and South Atlantic penaeid and rock shrimp fisheries based on observer data. Marine Fisheries Review 74(4):1–26.

SEAMAP (Southeast Area Monitoring and Assessment Program). Unpublished Data. Gulf States Marine Fisheries Commission. Ocean Springs, Mississippi.

SEAMAP Subcommittee Red Drum Work Group. 1990. Subcommittee Minutes from January 1990 Meeting. Gulf States Marine Fisheries Commission. Ocean Springs, Mississippi.

Secor, D.H. 2007. Do some Atlantic Bluefin Tuna skip spawning? Collective Volume of Scientific Papers ICCAT 60:1141-1153.

SEDAR (Southeast Data, Assessment, and Review). 2016. SEDAR 49 Stock Assessment Report - Gulf of Mexico Data-limited Species: Red Drum, Lane Snapper, Wenchman, Yellowmouth Grouper, Speckled Hind, Snowy Grouper, Almaco Jack, Lesser Amberjack. North Charleston, South Carolina. 618pp.

Seyoum, S., M.D. Tringali, T.M. Bert, D. McElroy, and R. Stokes. 2000. An analysis of genetic population structure in Red Drum, *Sciaenops ocellatus*, based on mtDNA control region sequences. Fishery Bulletin 98:127-138.

Sheinbaum, J., J. Candela, A. Badan, and J. Ochoa. 2002. Flow structure and transport in the Yucatan Channel. Geophysical Research Letters 29(3):10-1 – 10-4.

Sheridan, P. 2004. Recovery of floral and faunal communities after placement of dredged material on seagrasses in Laguna Madre, Texas. Estuarine, Coastal and Shelf Science 59:441-458.

Shivlani, M., D. Letson, and C.R. Sawczyn. 1998. Socioeconomic effects of the Florida Net Ban in Monroe county. The Florida Geographer 29:12-29.

Simmons, E.G. 1957. An ecological survey of the Upper Laguna Madre of Texas. Publications of the Institute of Marine Science, University of Texas. 4(2):156-200.

Simmons, E.G. 1969. Big Red. Texas Parks and Wildlife Magazine. 27(1):25-31

Simmons, E.G., and J.P. Breuer. 1962. A study of redfish (*Sciaenops ocellata*) Linnaeus and black drum (Pogonias cromis) Linnaeus. Publications of the Institute of Marine Science, University of Texas 8:184-211.

Simmons, E.G., and J.P. Breuer. 1976. Fish tagging on the Texas coast. Texas Parks and Wildlife Department, Coastal Fisheries Project Report, Austin, Texas. pages 66-107.

Sinclair, N.R., F.G. Smith, and J.J. Sullivan. 1972. The *Stomachicola rubea*: *Tubulovesicula pinguis* enigma. The Helminthological Society of Washington 39(2):253-258.

Sklar, F.H., R. Costanza, and J.W. Day, Jr. 1985. Dynamic spatial simulation modeling of coastal wetland habitat succession. Ecological Modeling 29:261–281.

Smith, D.R., S.R. Midway, R.H. Caffey, and J.M. Penn. 2022. Economic values of potential regulation changes for the Southern Flounder fishery in Louisiana. Marine and Coastal Fisheries 14(2).

Smith, M.E. and L.A. Fuiman. 2003. Causes of growth depensation in red drum, *Sciaenops ocellatus*, larvae. Environmental Biology of Fishes 66:49-60.

Smith, S., S. Jacob, M. Jepson, and G. Israel. 2003. After the Florida net ban: the impacts on commercial fishing families. Society and Natural Resources 16(1):39–59.

Snedaker, S.C. 1995. Mangroves and climate change in the Florida and Caribbean region: scenarios and hypotheses. Hydrobiologia 295:43–49.

Snyder, C.M., L.C. Feher, M.J. Osland, C.J. Miller, A.R. Hughes, and K.L. Cummins. 2021. The distribution and structure of mangroves (*Avicennia germinans* and *Rhizophora mangle*) near a rapidly changing range limit in the Northeastern Gulf of Mexico. Estuaries and Coasts 45:181-195.

Solis, R.S., and G.L. Powell. 1999. Hydrography, mixing characteristics, and residence times of Gulf of Mexico estuaries. Pages 29-62 *In*: Bianchi, T.S., J.R. Pennock and R.R. Twilley (eds). Biogeochemistry of Gulf of Mexico Estuaries. John Wiley & Sons, Inc., New York.

Soto, M.A., G.J. Holt, S.A. Holt, and J. Rooker. 1998. Food habits and dietary overlap of newly settled Red Drum (*Sciaenops ocellatus*) and Atlantic croaker (*Micropogonias undulatus*) from Texas seagrass meadows. Gulf and Caribbean Research 10(1):41-55.

Sparks, A.K. 1958. Some Digenetic Trematodes of Fishes of Grand Isle, Louisiana. Louisiana Academy of Science 20:71-82.

Springer, V.G., and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Florida State Board of Conservation Marine Laboratory, St. Petersburg, Florida. 104 pp.

Stewart, C.B. and F.S. Scharf. 2008. Estuarine recruitment, growth, and first-year survival of juvenile Red Drum in North Carolina. Transactions of the American Fisheries Society 137:1089-1103.

Stewart, P.L., and S.H. Arnold. 1994. Environmental requirements of Atlantic herring (*Clupea harengus harengus*) in eastern Canada and its response to human impacts. Canadian Technical Report of Fisheries and Aquatic Sciences 2003, ix + 37pp.

Strayer, D.L., K.A. Hattala, and A.W. Kahnle. 2004. Effects of an invasive bivalve (*Dreissena polymorpha*) on fish in the Hudson River estuary. Canadian Journal of Fisheries and Aquatic Sciences 61(6):924-941.

Stunz, G.W., T.J. Minello, and P.S. Levin. 2002a. A comparison of early juvenile Red Drum densities among various habitat types in Galveston Bay, Texas. Estuaries 25(1):76-85.

Stunz, G.W., T.J. Minello, and P.S. Levin. 2002b. Growth of newly settled Red Drum *Sciaenops ocellatus* in different estuarine habitat types. Marine Ecology Progress Series 238:227-236.

Suchanek, T.H. 1993. Oil impact on marine invertebrate populations and communities. American Zoologist 33:510-523.

Sunderland, E.M. 2007. Mercury exposure from domestic and imported estuarine and marine fish in the US seafood market. Environmental Health Perspectives 115(2):235-242.

Tao, Z., A.M. Larsen, S.A. Bullard, A.C. Wright, and C.R. Arias. 2012. Prevalence and population structure of *Vibrio vulnificus* on fishes from the northern Gulf of Mexico. Applied and Environmental Microbiology 78(21):7611-7618.

Teague, W., E. Jarosz, D. Wang, and D. Mitchell. 2007. Observed oceanic response over the upper continental slope and outer shelf during Hurricane Ivan. Journal of Physical Oceanography 37(9):2181–2206.

Teal, J., and M. Teal. 1969. Life and death of the salt marsh. Audubon/Ballentine Books, New York, New York, 278 pp.

Tester, P.A., and K.A. Steidinger. 1997. *Gymnodinium breve* red tide blooms: initiation, transport, and consequences of surface circulation. Limnology and Oceanography 42(5, part 2):1039-1051.

TGLO (Texas General Land Office). 1996. Texas coastal wetlands, a handbook for local governments. Austin, Texas, 142 pp.

Thayer, W.G., M.S. Fonseca, and J.W. Kenworthy. 1997. Ecological value of seagrasses: a brief summary for the ASMFC habitat committee's SAV subcommittee. Pages 7-11 *In*: Stephan, C.D., and T.E. Bigford (eds). Atlantic Coastal Submerged Aquatic Vegetation: a Review of its Ecological Role, Anthropogenic Impacts, State Regulation, and Value to Atlantic Coastal Fisheries. Washington (DC): ASMFC Habitat Management Series #1, 68 pp + appendices.

Thomas, R.G. 1991. Environmental factors and production characteristics affecting the culture of Red Drum, *Sciaenops ocellatus*. PhD Dissertation. Louisiana State University. 59pp.

Thomas, R.G. 1995. Hook-release mortality of Red Drum (*Sciaenops ocellatus*) and Spotted Seatrout (*Cynoscion nebulosus*) caught with four hook/bait combinations. LDWF Memo. 3p.

Thompson, M. 2010. Bama Redfish in June. September 28, 2010. Game & Fish Magazine. https://www.gameandfishmag.com/editorial/fishing_saltwater-fishing_al_0609_02/245160

Topp, R.W., and C.F. Cole. 1968. An osteological study of the sciaenid genus, *Sciaenops* Gill (Teleostei, Sciaenidae). Bulletin of Marine Science 18(4):902-945.

TPWD (Texas Parks and Wildlife Department). Unpublished Data. Texas Parks and Wildlife Department. Austin, Texas.

Treece, G.D. 2017. The Texas Aquaculture Industry – 2017. Available: http://www.texasaquaculture.org/PDF/2017%20PDF%20Documents/Tex.%20aquaculture%20industry%202017.pdf. (August 2021).

Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden, and P. Zhai. 2007. Observations: surface and atmospheric climate change. Pages 237-336 *In*: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds), Climate change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA.

Trimble, W.C. 1980. Yield trials for Red Drum in brackish-water ponds, 1976-1979. Proceedings of Annual Conference Southeastern Association Fish and Wildlife Agencies 33:432-441.

Tringali, M.D., K.M. Leber, W.G. Halstead, R. Mcmichael, J. O'hop, B. Winner, R. Cody, C. Young, C. Neidig, H. Wolfe, A. Forstchen, and L. Barbieri. 2008. Marine Stock Enhancement in Florida: A Multi-Disciplinary, Stakeholder-Supported, Accountability-Based Approach. Reviews in Fisheries Science 16(1):51-57.

Tseng, Y.P., N.A. Wolber, and R.B. Ditton. 2006. Demographics, participation, attitudes, management preferences, and trip expenditures of Texas anglers. Texas A&M University, Human Dimensions of Fisheries Research Laboratory Technical Document HD-605, College Station, Texas.

Turner, R.E. 1999. Inputs and outputs of the Gulf of Mexico. Pages 64-74 *In*: H. Kumpf, K. Steidinger, and K. Sherman, editors. The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management. Blackwell Science, Malden, Massachusetts.

Turner, R.E., J.M. Lee, and C. Neill. 1994. Backfilling canals to restore wetlands: empirical results in coastal Louisiana. Wetland Ecology and Management 3(1):63-78.

Turner-Turner, J. 1902. The Giant Fish of Florida. C. Arthur Pearson Limited, London. 206 pp.

Uhrin, A.V., and J.G. Holmquist. 2003. Effects of propeller scarring on macrofaunal use of the seagrass *Thalassia testudinum*. Marine Ecology Progress Series 250:61-70.

USCG (United States Coast Guard). 2018. Mexican Lancha Threat Overview. Powerpoint Presentation to the GMFMC. October 2018. 8pp.

USDA (United States Department of Agriculture). 2019. 2017 Census of Agriculture – 2018 Census of Aquaculture, Volume 3, Part 2. U.S. Dept. of Agriculture, Report AC-17-SS-2. 96p.

USDOC (U.S. Department of Commerce). 2018. Positive Certification Determination for Mexico's 2015 IUU Fishing Identification. Addendum to the 2017 Biennial Report to Congress. 2pp.

USDOC (United States Department of Commerce). 2010. Characteristic coastal habitats; choosing spill response alternatives. National Oceanic and Atmospheric Administration, National Ocean Service, Office of Response and Restoration-Emergency Response.

USEPA (United States Environmental Protection Agency). 1994. Habitat degradation action agenda for the Gulf of Mexico. EPA 800-B-94-00. 152pp.

USEPA (United States Environmental Protection Agency). 1995. National water quality inventory: 1994 report to Congress. EPA-841-R-95-005. 220pp.

USEPA (United States Environmental Protection Agency). 2005. National management measures to control nonpoint source pollution from urban areas. EPA-841-B-05-004, 518 pp.

USEPA (United States Environmental Protection Agency). 2009. National water quality inventory: 2004 Report to Congress. Washington (DC): US EPA Office of Water. EPA-841-R-08-001. 42pp.

USEPA (United States Environmental Protection Agency). 2021. Northern Gulf of Mexico Hypoxic Zone. USEPA Mississippi River/Gulf of Mexico Hypoxia Task Force. Available from: https://www.epa.gov/ms-htf/northern-gulf-mexico-hypoxic-zone. Website

USFDA (Food and Drug Administration). 2021. Advice about eating fish. 2 pp.
https://www.fda.gov/media/102331/download

USFWS (United States Fish and Wildlife Service). 1996. National survey of fishing, hunting, and wildlife-associated recreation. U.S. Government Printing Office, Washington, D.C. 115 pp.

USFWS (United States Fish and Wildlife Service). 2013a. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation - Mississippi. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. FHW/11-LA (Revised 2013). 94 pp.

USFWS (United States Fish and Wildlife Service). 2013b. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation - Louisiana. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. FHW/11-LA (Revised 2013). 94 pp.

USFWS (United States Fish and Wildlife Service). 2014a. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation - Alabama. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. FHW/11-LA (Revised 2014). 94 pp.

USFWS (United States Fish and Wildlife Service). 2014b. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation - Florida. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. FHW/11-LA (Revised 2014). 94 pp.

USFWS (United States Fish and Wildlife Service). 2014c. 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation - Texas. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. FHW/11-LA (Revised 2014). 94 pp.

USFWS (United States Fish and Wildlife Service). 2018. 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. FHW/16-NAT (Revised 2018). 144 pp.

USGS (United States Geological Survey). 1997. Louisiana coastal wetland loss continues. U.S. Department of the Interior, U.S. Geological Survey, News release June 30, 1997, Lafayette, Louisiana.

Valiela, I, D. Rutecki, and S. Fox. 2004. Salt marshes: biological controls of food webs in a diminishing environment. Journal of Experimental Marine Biology and Ecology 300(1-2):131-159.

Van Hoose, M. 1987. Biology of Spotted Seatrout, *Cynoscion nebulosus*, and Red Drum, *Sciaenops ocellatus*, in Alabama estuarine waters. Pages 26-37 *In*: Lowery, T.A. (ed). Symposium on the Natural Resources of the Mobile Bay Estuary. Alabama Sea Grant Extension Service MASGP-87-007.

VanderKooy, S.J. Personal Observation. Gulf States Marine Fisheries Commission. Ocean Springs, Mississippi.

VanderKooy, S.J. 2015. Management profile for the gulf and Southern Flounder fishery in the Gulf of Mexico. Gulf States Marine Fisheries Commission, Ocean Springs, Mississippi. Publication No. 247. 200 pp.

Vandermeulen, J.H., and Mossman, D. 1996. Sources of variability in seasonal hepatic microsomal oxygenase activity in Winter Flounder (*Pleuronectes americanus*) from a coal tar contaminated estuary. Canadian Journal of Fisheries and Aquatic Sciences 53:1741-1753.

Vecchi, G.A., and B.J. Soden. 2007. Increased tropical Atlantic wind shear in model projections of global warming. Geophysical Research Letters 34:L08702.

Vecchio, J.L., and C.A. Wenner. 2007. Catch-and-release mortality in subadult and adult Red Drum captured with popular fishing hook types. North American Journal of Fisheries Management 27(3):891-899.

Vega, R.R., W.H. Neill, J.R. Gold, and M.S. Ray. 2011. Enhancement of Texas sciaenids (Red Drum and Spotted Seatrout). Pages 85-92 *In*: R. R. Stickney, R. N. Iwamoto, and M. Rust (eds). Interactions of fisheries and fishing communities related to aquaculture: proceedings of the Thirty-eighth US-Japan Aquaculture Panel Symposium: Texas A & M University, Harte Research Institute, Corpus Christi, Texas, October 26-27, 2009.

Vetter, R.D., R.E. Hodson, and C.R. Arnold. 1983. Energy metabolism in a rapidly developing marine fish egg, the Red Drum (*Sciaenops ocellata*). Canadian Journal of Fisheries and Aquatic Sciences 40:627-634.

Vittor and Associates. 2009. Submerged aquatic vegetation mapping in Mobile Bay and adjacent waters of coastal Alabama in 2008 and 2009. Mobile Bay National Estuary Program, Mobile, Alabama, 16 pp.

Wake, H. 2005. Oil refineries: a review of their ecological impacts on the aquatic environment. Estuarine, Coastal and Shelf Science 62:131-140.

Wakefield, C.A., and R.L. Colura. 1983. Age and growth of Red Drum in three Texas bay systems. Annual Proceedings–American Fisheries Society, Texas Chapter. Austin, Texas, USA. 1983:77-87.

Wallace, R.A., and K. Selman. 1981. Cellular and dynamic aspects of oocyte growth in teleosts. American Zoologist 21:325-343.

Walters Burnsed, S., S. Lowerre-Barbieri, J. Bickford, and E.H. Leone. 2020. Recruitment and movement ecology of Red Drum, *Sciaenops ocellatus*, differs by natal estuary. Marine Ecology Progressive Series 633:181-196.

Ward, G.H., Jr., and N.E. Armstrong. 1980. Matagorda Bay, Texas: its hydrography, ecology and fishery resources. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-81/52. 230pp.

Ward, L.A., P.A. Montagna, R.D. Kalke, and E.J. Buskey. 2000. Sublethal effects of Texas brown tide on *Streblospio benedicti* (Polychaeta) larvae. Journal of Experimental Marine Biology and Ecology 248:121-129.

Wardle, W.J., S.M. Ray, and A.S. Aldrich. 1975. Mortality of marine organisms associated with offshore summer blooms of the toxic dinoflagellate *Gonyalax monilata* Howell at Galveston, Texas. Pages 257-263 *In*: LoCicero, V.R. (ed). Proceedings of the First International Conference on Toxic Dinoflagellate Blooms. The Massachusetts Science and Technology Foundation, Wakefield, Massachusetts.

Webster, P.J., G.J. Holland, J.A. Curry, and H.R. Chang. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309:1844-1846.

Weekly Houston Telegraph. 1837. August 8, 1837. Geography of Texas – Harrisburg County. Vol II, Issue 31:2

Weis, J.S., and P. Weis. 2002. Contamination of saltmarsh sediments and biota by CCA treated wood walkways. Marine Pollution Bulletin 44:504-510.

Weis, P., J.S. Weis, and L.M. Coohill. 1991. Toxicity to estuarine organisms of leachates from chromated copper arsenate treated wood. Archives of Environmental Contamination and Toxicology 20:118-124.

Weixelman, M.G. 1982. The fall Red Drum Gulf of Mexico pier fishery off Galveston Bay, Texas. Texas Parks and Wildlife Department, Coastal Fisheries Branch. TPWD Management Data Series No. 042. 28 pp.

Welsh, W.W., and C.M. Jr. Breder. 1923. Contributions to the life histories of Sciaenidae of the eastern United States coast. Bulletin of the Bureau of Fisheries 39:141-201.

Wenner, C.A. 1992. Red Drum: natural history and fishing techniques in South Carolina. South Carolina State Documents Depository. South Carolina Department of Natural Resources. Educational Report No. 17. Charleston, South Carolina. 45 pp.

Whaley, S.D., M.C. Christman, and J.J. Burd Jr. 2016. Spatial distribution–abundance relationships in juvenile (Age 0) Red Drum (*Sciaenops ocellatus*) and Spotted Seatrout (*Cynoscion nebulosus*). I: Influence of freshwater inflow. Estuaries and Coasts 39:742-751.

White, C.J., and W.S. Perret. 1974. Short term effects of the Toledo Bend project on Sabine Lake, Louisiana. Pages 710–721 *In*: A. L. Mitchell (editor), Proceedings of the 27th Annual Conference, of the Southeast Association of Game and Fish Committees, Hot Springs, Arkansas, 1973.

Wilber, D.H., and D.G. Clarke. 2001. Biological effects of suspended sediments: a review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management 21(4):855-875.

Wilber, D.H., W. Brostoff, D.G. Clarke, and G. Ray. 2005. Sedimentation: potential biological effects of dredging operations in estuarine and marine environments. DOER Technical Notes Collection, US Army Engineer Research and Development Center, ERDC TN-DOER-E20, Vicksburg Mississippi. 14 pp.

Williams, J., and R.M. Ingle. 1972. Ecological notes on *Gonyaulax monilata* (Dinophyceae) blooms along the West Coast of Florida. *In:* Florida Department of Natural Resources Leaflet Series: Phytoplankton, Part 1 (Dinoflagellates), No. 5.

Wilson, C.A., and D.L. Nieland. 1994. Reproductive biology of Red Drum, *Sciaenops ocellatus*, from the neritic waters of the northern Gulf of Mexico. Fishery Bulletin 92:841-850.

Winner, B.L., K.E. Flaherty-Walia, T.S. Switzer, and J.L. Vecchio. 2014. Multidecadal evidence of recovery of nearshore Red Drum Stocks off west-central Florida and connectivity with inshore nurseries. North American Journal of Fisheries Management 34(4):780–794.

Wiseman, W.J. Jr., and J. Sturges. 1999. Physical oceanography of the Gulf of Mexico: processes that regulate its biology. Pages 77-92 *In*: Kumpf, H., K. Steidinger, and K. Sherman (eds). The Gulf of Mexico Large Marine Ecosystem: Assessment, Sustainability, and Management. Blackwell Science, Malden, Massachusetts.

WNTF (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force). 2008. Gulf Hypoxia action plan for reducing, mitigating, and controlling hypoxia in the northern Gulf of Mexico and improving water quality in the Mississippi River basin. Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, Washington, D.C. 39 pp.

Wolfe, M.F., G.J.B. Schwartz, S. Singaram, E.E. Mielbrecht, R.S. Tjeerdema, and S.L. Sowby. 2001. Influence of dispersants on the bioavailability of trophic transfer of petroleum hydrocarbons to larval Topsmelt (*Atherinops affinis*). Aquatic Toxicology 52:49-60.

Wu, Y., F.H. Sklar, and K. Rutchey. 1995. Analysis and simulation of fragmentation patterns in the Everglades. Ecological Applications 7(1):268–276.

Xu, E.G., A.J. Khursigara, J. Magnuson, E.S. Hazard, G. Hardiman, A.J. Esbaugh, A.P. Roberts, and D. Schlenk. 2017. Larval Red Drum (*Sciaenops ocellatus*) sublethal exposure to weathered Deepwater Horizon crude oil developmental and transcriptomic consequences. Environmental Science and Technology 51(17):10162-10172.

Yamada, M., H. Takada, K. Toyoda, A. Yoshida, A. Shibata, H. Nomura, M. Wada, M. Nishimura, K. Okamoto, and K. Ohwada. 2003. Study on the fate of petroleum-derived polycyclic aromatic hydrocarbons (PAHs) and the effect of chemical dispersant using an enclosed ecosystem, mesocosm. Marine Pollution Bulletin 47:105-113.

Yanong, R.P.E. 2019. Viral Nervous Necrosis (Betanodavirus) Infections in Fish. IFAS Extension publication #FA180 6 pp.

Yen, P.T.H., N.Q. Linh, and N.D.Q. Tram. 2021. The identification and determination of toxic genes of *Vibrio* strains causing hemorrhagic disease on Red Drum (*Sciaenops ocellatus*) using PCR. AMB Express 11:4 8 pp.

Yokel, B.J. 1966. A contribution to the biology and distribution of the Red Drum, *Sciaenops ocellata*. MS Thesis. University of Miami, Coral Gables, Florida. 160 pp.

Yokel, B.J. 1980. A contribution to the biology and distribution of the Red Drum, *Sciaenops ocellata*. Pages 5-6 *In*: Williams, R.O., J.E. Weaver, and F.A. Kalber (eds). Proceedings of the Colloquium on the Biology and Management of Red Drum and Seatrout. Gulf States Marine Fisheries Commission. Pub No 5.

Zieman, J.C., S.A. Macko, and A.L. Mills. 1984. Role of seagrasses and mangroves in estuarine food webs: temporal and spatial changes in stable isotope composition and amino acid content during decomposition. Bulletin of Marine Science 35(3):380-392.

Zieman, J.C., and R.T. Zieman. 1989. The ecology of the seagrass meadows of the west coast of Florida: a community profile. U.S. Fish and Wildlife Service, Biological Report 85(7.25). 155 pp.

## About the Artist

### *Craig Brumfield*

Craig Brumfield, a native and lifelong resident of Ocean Springs, Mississippi, is an accomplished and well-respected artist on the Gulf Coast. While working in various mediums, his recent interests include Swordfish bill scrimshaw, oil painting, gyotaku printing of regional fish (bream to billfish), as well as illustration work.

Most of Craig's artistic influences have been a result of a lifetime of fishing the Gulf Coast waters. He is inspired by the natural beauty of our Coast and states that spending time in our Gulf Coast outdoor environment feeds his imagination and creativity.