

BIOLOGY OF THE SPOTTED SEATROUT



Edited by
STEPHEN A. BORTONE

Suitability

- Optimum
- High
- Moderate
- Low



CRC PRESS

**BIOLOGY
OF THE
SPOTTED SEATROUT**



Marine Science Series

The CRC Marine Science Series is dedicated to providing state-of-the-art coverage of important topics in marine biology, marine chemistry, marine geology, and physical oceanography. The series includes volumes that focus on the synthesis of recent advances in marine science.

CRC MARINE SCIENCE SERIES

SERIES EDITOR

Michael J. Kennish, Ph.D.

PUBLISHED TITLES

- Artificial Reef Evaluation with Application to Natural Marine Habitats*, William Seaman, Jr.
- Chemical Oceanography, Second Edition*, Frank J. Millero
- Coastal Ecosystem Processes*, Daniel M. Alongi
- Ecology of Estuaries: Anthropogenic Effects*, Michael J. Kennish
- Ecology of Marine Bivalves: An Ecosystem Approach*, Richard F. Dame
- Ecology of Marine Invertebrate Larvae*, Larry McEdward
- Ecology of Seashores*, George A. Knox
- Environmental Oceanography, Second Edition*, Tom Beer
- Estuary Restoration and Maintenance: The National Estuary Program*, Michael J. Kennish
- Eutrophication Processes in Coastal Systems: Origin and Succession of Plankton Blooms and Effects on Secondary Production in Gulf Coast Estuaries*, Robert J. Livingston
- Handbook of Marine Mineral Deposits*, David S. Cronan
- Handbook for Restoring Tidal Wetlands*, Joy B. Zedler
- Intertidal Deposits: River Mouths, Tidal Flats, and Coastal Lagoons*, Doeke Eisma
- Morphodynamics of Inner Continental Shelves*, L. Donelson Wright
- Ocean Pollution: Effects on Living Resources and Humans*, Carl J. Sindermann
- Physical Oceanographic Processes of the Great Barrier Reef*, Eric Wolanski
- The Physiology of Fishes, Second Edition*, David H. Evans
- Pollution Impacts on Marine Biotic Communities*, Michael J. Kennish
- Practical Handbook of Estuarine and Marine Pollution*, Michael J. Kennish
- Practical Handbook of Marine Science, Third Edition*, Michael J. Kennish
- Seagrasses: Monitoring, Ecology, Physiology, and Management*, Stephen A. Bortone

BIOLOGY OF THE SPOTTED SEATROUT

Edited by
STEPHEN A. BORTONE



CRC PRESS

Boca Raton London New York Washington, D.C.

Cover art courtesy of R. Grant Gilmore, Jr.

Library of Congress Cataloging-in-Publication Data

Biology of the spotted seatrout / Stephen A. Bortone, editor

p. cm. -- (Marine biology series)

Includes bibliographical references and index.

ISBN 0-8493-1129-2 (alk. paper)

1. Spotted seatrout. I. Bortone, Stephen A. II. Marine biology series (Boca Raton, Fla.)

QL638.S34 B56 2002

597.5'7—dc21

2002019437

This book contains information obtained from authentic and highly regarded sources. Reprinted material is quoted with permission, and sources are indicated. A wide variety of references are listed. Reasonable efforts have been made to publish reliable data and information, but the author and the publisher cannot assume responsibility for the validity of all materials or for the consequences of their use.

Neither this book nor any part may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, microfilming, and recording, or by any information storage or retrieval system, without prior permission in writing from the publisher.

All rights reserved. Authorization to photocopy items for internal or personal use, or the personal or internal use of specific clients, may be granted by CRC Press LLC, provided that \$1.50 per page photocopied is paid directly to Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923 USA. The fee code for users of the Transactional Reporting Service is ISBN 0-8493-1129-2/02/\$0.00+\$1.50. The fee is subject to change without notice. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

The consent of CRC Press LLC does not extend to copying for general distribution, for promotion, for creating new works, or for resale. Specific permission must be obtained in writing from CRC Press LLC for such copying.

Direct all inquiries to CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation, without intent to infringe.

Visit the CRC Press Web site at www.crcpress.com

© 2003 by CRC Press LLC

No claim to original U.S. Government works

International Standard Book Number 0-8493-1129-2

Library of Congress Card Number 2002019437

Printed in the United States of America 1 2 3 4 5 6 7 8 9 0

Printed on acid-free paper

Preface

Many estuaries around the world are becoming environmentally stressed due to a trend toward increased human habitation along their shores. This stress can be manifested by changes in water quality or biotic measures of relative condition such as the abundance of seagrasses. Often it reflects the biotic integrity of the entire ecosystem or is manifested in modifications to the life history attributes of its living components. Thus, there is growing interest in being able to carefully assess the conditions and health of these coastal aquatic biotopes, with the hope of determining the specific factors that might be altered to correct a perceived overall downward trend in biotic conditions.

The spotted seatrout is often the target of commercial and recreational fishers throughout its range (i.e., throughout coastal estuaries of the temperate and warm-temperate Atlantic coast of North America). Although widely distributed among various biotopes in coastal areas, it is most often associated with grass beds. It is a noted sound-producing fish and an important trophic link within the estuary between filter feeders, such as fish and shrimp, and the higher-level predators, notably bottlenose dolphins. One of the most intriguing aspects of its life history, however, is that most of the individuals apparently remain within a single estuary their entire lives. Thus, the spotted seatrout is unlike many estuarine fishes that usually have some aspect of their life history met by waters outside the estuary proper. Depending upon the species, most other estuarine-associated fish species migrate offshore (like most other croakers or drums) or upstream (such as striped bass) to spawn or move between estuaries on feeding forays.

Because it is widely distributed and highly regarded as a food and sport fish, and especially because it has been well studied and found to be nearly restricted to its "home" estuary throughout its life, the spotted seatrout has the potential to serve as an important estuarine biological sentinel and monitor. This idea is based on the premise that the life history condition of this and other fishes is largely dependent upon the quality of the aquatic environment in which they live. Thus, it is likely that many biological attributes of aquatic species can reflect changes in aquatic conditions over time or between places. Special here is the totally estuarine dependent and restricted nature of the spotted seatrout.

This book represents compilation and summary chapters on the biological knowledge of spotted seatrout by noted authorities in their respective fields. The primary objective is to make the latest and most up-to-date life history information available on this species for the express purpose of beginning the task of assessing differences in estuarine-restricted subpopulations of spotted seatrout. A second objective is to indicate areas in which life history aspects of spotted seatrout can be used to show their potential as indicators of estuarine conditions. A third objective is to begin to integrate estuarine-specific life history features into the overall management of estuaries and of an estuarine-dependent fishery.

Above all, this publication demonstrates a directed effort toward a goal of improving our ability to monitor estuaries and fisheries simultaneously and gives purposeful direction to future research efforts regarding the biology of estuarine fishes. Clearly, this is an initial and untried effort for any species in any habitat, but, if the principles presented here hold true, the "spotted seatrout biology-estuarine condition" sentinel should serve as a guide to develop information sources in other estuaries, using a broad suite of life history characters from other estuarine-dependent species as indicators of environmental conditions.

Stephen A. Bortone, Ph.D.

Acknowledgment

Thanks to many individuals who helped with various stages of this volume's development. Discussions with laboratory personnel from the U.S. Environmental Protection Agency in Gulf Breeze, Florida, and especially Michael Lewis initiated the search for fish life history data that could be used to evaluate estuaries. On a grant funded by the Florida Department of Environmental Protection (now the Florida Fish and Wildlife Conservation Commission), co-investigators Chad Bedee, Doug DeVries, Churchill Grimes, and Chris Palmer helped gather some of the initial data that formed the basis of discussions on the need for such a book. Later, Ken Cummins, then of the South Florida Water Management District, developed the concept more fully and suggested spotted seatrout as a potential candidate for a fish species to evaluate estuaries. The quality of chapters was greatly enhanced by the expert editorial and referee advice selflessly offered by Robert Chapman, Richard Cody, John Couch, James Cowan, Douglas DeVries, R. Grant Gilmore, John Gold, and, especially, Charles Wenner. Thanks also to John Sulzycki, Pat Roberson, Judith Kamin, and the staff at CRC Press for their thoughtful guidance and patience in the production of this volume. Lastly, but most importantly, the authors are acknowledged for their professionalism and diligence in preparing their respective manuscripts for timely inclusion.

Stephen A. Bortone

Editor

Stephen A. Bortone is director of the Marine Biology Laboratory at the Sanibel-Captiva Conservation Foundation in Sanibel, Florida. He holds administrative appointment to the graduate faculty at the University of South Alabama, courtesy faculty appointment at the Florida Gulf Coast University, and is research professor at Florida Atlantic University and its Florida Center for Environmental Studies. Previously he was professor at the University of West Florida, where he also served as director for the Institute for Coastal and Estuarine Research. He also was the director of environmental science at the Conservancy of Southwest Florida. Dr. Bortone received a B.S. degree from Albright College in Reading, Pennsylvania, an M.S. degree from Florida State University, Tallahassee, and a Ph.D. from the University of North Carolina, Chapel Hill.

For the past 35 years, Dr. Bortone has conducted research on the life history of estuarine organisms, especially fishes and seagrasses, chiefly in the southeastern U.S. and the Gulf of Mexico. He has published more than 130 scientific articles on the broadest aspects of biology, including such diverse fields as anatomy, behavior, biogeography, ecology, endocrinology, evolution, histology, oceanography, physiology, reproductive biology, sociobiology, systematics, and taxonomy.

Conducting his research and teaching activities, Dr. Bortone has traveled widely. He has served as visiting scientist at The Johannes Gutenberg University (Mainz, Germany) and conducted extensive field surveys with colleagues from La Laguna University in the Canary Islands. He was Mary Ball Washington Scholar at University College, Dublin, Ireland. He has received several other teaching and research awards, including the title "Fellow" from the American Institute of Fishery Research Biologists.

Dr. Bortone has served as scientific editor and reviewer for numerous organizations, such as the National Science Foundation, the Environmental Protection Agency, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service, and several journals, including *Bulletin of Marine Science*, *Copeia*, *Estuaries*, and *Transactions of the American Fisheries Society*.

Contributors

Jerald S. Ault

University of Miami
Rosenstiel School of Marine and
Atmospheric Science
Miami, Florida

Donald M. Baltz

Oceanography and Coastal Sciences
Coastal Fisheries Institute
Louisiana State University
Baton Rouge, Louisiana

Chad D. Bedee

St. Martins Marsh Aquatic Preserve
Florida Department of Environmental
Protection
Crystal River, Florida

Reginald B. Blaylock

Gulf Coast Research Laboratory
College of Marine Sciences
The University of Southern Mississippi
Ocean Springs, Mississippi

Stephen A. Bortone

The Marine Biology Laboratory
Sanibel-Captiva
Conservation Foundation
Sanibel, Florida

Nancy J. Brown-Peterson

Department of Coastal Sciences
College of Marine Sciences
The University of Southern Mississippi
Ocean Springs, Mississippi

Ning Labbish Chao

Bio-Azoniana Conservation International
Baltimore, Maryland

Robert W. Chapman

South Carolina Department of Natural
Resources
Marine Resources Research Institute
Charleston, South Carolina

Edward J. Chesney

Louisiana Universities Marine Consortium
Chauvin, Louisiana

John D. Christensen

NOAA/NOS/NCCOS/CCMA Biogeography
Program
Silver Spring, Maryland

Randall D. Clark

NOAA/NOS/NCCOS/CCMA Biogeography
Program
Silver Spring, Maryland

Michael S. Coyne

NOAA/NOS/NCCOS/CCMA Biogeography
Program
Silver Spring, Maryland

Douglas A. DeVries

National Marine Fisheries Service
Southeast Fisheries Science Center
Panama City, Florida

R. Grant Gilmore, Jr.

Dynamac Corporation
Kennedy Space Center, Florida

John R. Gold

Center for Biosystematics and Biodiversity
Department of Wildlife and Fisheries
Sciences
Texas A&M University
College Station, Texas

G. Joan Holt

Marine Science Institute
University of Texas at Austin
Port Aransas, Texas

Scott A. Holt

Marine Science Institute
University of Texas at Austin
Port Aransas, Texas

Jiangang Luo

University of Miami
Rosenstiel School of Marine and
Atmospheric Science
Miami, Florida

Robert H. McMichael, Jr.

Florida Fish and Wildlife Conservation
Commission
Florida Marine Research Institute
St. Petersburg, Florida

Mark E. Monaco

NOAA/NOS/NCCOS/CCMA Biogeography
Program
Silver Spring, Maryland

Wendy Morrison

NOAA/NOS/NCCOS/CCMA Biogeography
Program
Silver Spring, Maryland

Robert G. Muller

Florida Fish and Wildlife Conservation
Commission
Florida Marine Research Institute
St. Petersburg, Florida

Michael D. Murphy

Florida Fish and Wildlife Conservation
Commission
Florida Marine Research Institute
St. Petersburg, Florida

Robin M. Overstreet

Gulf Coast Research Laboratory
College of Marine Sciences
The University of Southern Mississippi
Ocean Springs, Mississippi

Christopher L. Palmer

National Marine Fisheries Service
Southeast Fisheries Science Center
Panama City, Florida

Leah B. Stewart

Center for Biosystematics and Biodiversity
Department of Wildlife and Fisheries
Sciences
Texas A&M University
College Station, Texas

R. Glenn Thomas

Marine Fisheries Division
Louisiana Department of Wildlife and
Fisheries
Baton Rouge, Louisiana

Steven J. VanderKooy

Gulf States Marine Fisheries Commission
Ocean Springs, Mississippi

John D. Wang

University of Miami
Rosenstiel School of Marine and
Atmospheric Science
Miami, Florida

Rocky Ward

Perry R. Bass Marine Fisheries Research
Station
Texas Parks and Wildlife Department
Palacios, Texas

Bradley A. Wiley

National Marine Fisheries Service
Protected Resources
Arcata, California

Table of Contents

Chapter 1

Introduction	1
<i>Stephen A. Bortone</i>	

Chapter 2

Taxonomy of the Seatrout, Genus <i>Cynoscion</i> (Pisces, Sciaenidae), with Artificial Keys to the Species	5
<i>Ning Labbish Chao</i>	

Chapter 3

Population Structure of Spotted Seatrout (<i>Cynoscion nebulosus</i>) along the Texas Gulf Coast, as Revealed by Genetic Analysis	17
<i>John R. Gold, Leah B. Stewart, and Rocky Ward</i>	

Chapter 4

Population Structure of Spotted Seatrout, <i>Cynoscion nebulosus</i> , along the Atlantic Coast of the U. S.	31
<i>Bradley A. Wiley and Robert W. Chapman</i>	

Chapter 5

Age Determination and Growth of Spotted Seatrout, <i>Cynoscion nebulosus</i> (Pisces: Sciaenidae)	41
<i>Michael D. Murphy and Robert H. McMichael, Jr.</i>	

Chapter 6

Estuary-Specific Age and Growth of Spotted Seatrout in the Northern Gulf of Mexico	57
<i>Chad D. Bedee, Douglas A. DeVries, Stephen A. Bortone, and Christopher L. Palmer</i>	

Chapter 7

The Demographics and Reproductive Biology of Spotted Seatrout, <i>Cynoscion nebulosus</i> , in Six Northwest Florida Estuaries	79
<i>Douglas A. DeVries, Chad D. Bedee, Christopher L. Palmer, and Stephen A. Bortone</i>	

Chapter 8

The Reproductive Biology of Spotted Seatrout	99
<i>Nancy J. Brown-Peterson</i>	

Chapter 9

Effects of Variable Salinity on Reproduction and Early Life Stages of Spotted Seatrout	135
<i>G. Joan Holt and Scott A. Holt</i>	

Chapter 10	
Spotted Seatrout Habitat Affinities in Louisiana	147
<i>Donald M. Baltz, R. Glenn Thomas, and Edward J. Chesney</i>	
Chapter 11	
Sound Production and Communication in the Spotted Seatrout	177
<i>R. Grant Gilmore, Jr.</i>	
Chapter 12	
Diseases and Parasites of the Spotted Seatrout	197
<i>Reginald B. Blaylock and Robin M. Overstreet</i>	
Chapter 13	
Management of Spotted Seatrout and Fishery Participants in the U.S.	227
<i>Steven J. VanderKooy and Robert G. Muller</i>	
Chapter 14	
Modeling the Distribution and Abundance of Spotted Seatrout: Integration of Ecology and GIS Technology to Support Management Needs	247
<i>Randall D. Clark, Wendy Morrison, John D. Christensen, Mark E. Monaco, and Michael S. Coyne</i>	
Chapter 15	
A Spatial Ecosystem Model to Assess Spotted Seatrout Population Risks from Exploitation and Environmental Changes	267
<i>Jerald S. Ault, Jiangan Luo, and John D. Wang</i>	
Chapter 16	
Spotted Seatrout as a Potential Indicator of Estuarine Conditions	297
<i>Stephen A. Bortone</i>	
Index	301

1 Introduction

Stephen A. Bortone

The spotted seatrout, *Cynoscion nebulosus*, is a fish species of the croaker and drum family (i.e., Sciaenidae) that has special interest among a wide audience of individuals. Broadly distributed in coastal areas along the eastern Atlantic and Gulf of Mexico coasts of the U.S., it is known officially as the spotted seatrout (Robins et al., 1990) but colloquially and locally as speck, seatrout, gray trout, trout, spotted weakfish, spotted seateague, winter trout, and speckled trout (Johnson and Seaman, 1986). In the southern portion of its range along the Gulf Coast of Mexico it is known as trucha del mar, corvina, and corvina pinta. In both countries it is the target of recreational and commercial fishers as well as of the seafood-eating public because of its size and taste.

Scientists have their own interests in the species. Biologically, it is a sound-producing species that serves as an important trophic link in estuaries, between invertebrates and small fishes and the larger, fish-eating predators such as groupers, snappers, sharks, and bottle-nosed dolphins. Ecologically, it is found nearly exclusively within estuaries where it seems to have a strong habitat affinity for seagrasses. Interest in this species can also be found among those who help manage and protect natural coastal resources as the influx of coastal dwellers increases in virtually every part of the world.

Estuarine coasts have become prime settlement areas for new inhabitants. Increasing human settlement results in stress to the coastal waters through increases in storm-water runoff that reduce water quality, destruction of natural shoreline habitat, and elimination of submerged aquatic vegetation (Kennish, 1992). Unfortunately, estuaries often reflect the negative effects of coastal development; this reality means that environmental managers should be vigilant in making sure that declining conditions of coastal waters are kept to a minimum. Subsequent to the immediate problem of reducing the amount of deterioration of water quality is the objective of restoring estuaries and coastal habitats to a state that emulates a minimally disturbed ecosystem, thus assuring the sustainability of our near-shore natural resources.

The task at hand, then, is to monitor the condition of estuarine waters to assure minimal deterioration of environmental conditions and then to objectively evaluate efforts to restore and maintain the ecosystem to a level supporting an acceptable level of biotic integrity. Recently, several colleagues and I produced a book (Bortone, 2000) aimed at establishing a source of biological information and assessment methodology on seagrasses that could be used to assess estuarine conditions. While meeting the overall objective is becoming a reality, more than one biotic component of estuaries should be established as a biological sentinel. Since seagrasses are primary producers and are able to reflect biological impacts of long-term environmental conditions at a point (because they are rooted), a measure of more general biotic conditions within an estuarine ecosystem could be monitored by examining a motile species that is broadly distributed but restricted to a particular estuary.

After considerable discussion with colleagues with the broadest range of biological expertise, it became apparent that few animal candidates had the potential to provide a platform to study biological impacts on estuarine conditions. For example, oysters, mussels, and clams, while sedentary and long-lived, have larvae that are widely dispersed and have no specific estuarine affinity. Most estuarine fishes (including other croakers and drums) and crustaceans (such as shrimps and crabs) tend to migrate offshore to spawn; they have eggs or larvae that are discharged to the ocean and,

thus, also have no affinity to a “home” estuary. Some estuarine fishes such as striped bass move upstream to spawn and are subjected to non-estuarine conditions for a considerable amount of their lives. Nearly every species considered had characteristics that readily disqualified them for the purpose of estuarine monitoring.

The life history of the spotted seatrout, however, had fewer features to merit disqualification. It is broadly distributed along coasts that encompass a considerable number of estuaries. It is long-lived and thus able to be subjected to estuarine conditions for a period of time sufficient to serve as a time-series monitor. A species that serves as a trophic link between low-level secondary producers and top-level predators, it is common to abundant within the estuaries it inhabits. Importantly, it is entirely estuarine dependent, only rarely moving out of its home estuary. Lastly, because the species has attracted considerable attention from recreational and commercial fisheries, a reasonably detailed historical and current database on its life history and biology exists (e.g., Johnson and Seaman, 1986; Bortone et al., 1997).

There is, of course, a rather large number of potential candidates for a species whose life history attributes could serve as a biological monitor for estuarine conditions. However, when considered in total, the attributes of the spotted seatrout demand further examination into its utility to serve as an indicator of estuarine condition.

Our purpose here is to present summaries as well as new information on the current state of knowledge of spotted seatrout biology. The book begins with an introduction to the current taxonomic understanding of the species in the genus *Cynoscion* in order to establish its phylogenetic associates and to set the stage for future comparative biological studies with other species in the genus (see Roff, 1992; Stearns, 1992). An examination of the importance of genetic structure and population limits of the spotted seatrout follows, with interpretations of genetic data on its population structure from the Gulf of Mexico and southeastern Atlantic Ocean.

Long-term effects of environmental conditions have been most often inferred from data on age and growth attributes of populations. The potential importance of these life history attributes is evident and included as two separate but complementary examinations of the age and growth aspects of spotted seatrout. Numerous researchers have conducted reproductive studies for extended periods; the comprehensive summary presented here examines those studies from the broadest geographic perspective and fully explores this life history feature. Once fertilization takes place within its home estuary, the spotted seatrout is subjected to the vagaries of the environment as a fully independent organism. Early life history features are summarized, with special reference to the relationship larvae and juveniles have with a predominant environmental variable — salinity. Habitat affinities dominate many of the constraints of the species’ life history attributes and are examined, with special reference to habitat features associated with inshore estuarine areas in the northern Gulf of Mexico.

Sound is a peculiar and significant aspect of the life history of the spotted seatrout. Sound production and its relationship to habitat are given special treatment as a life history attribute. Concomitantly, diseases and parasites play a role in constraining the life history response of any species to the environment. Since the spotted seatrout is a prime target of both recreational and commercial fishers, it is important to have a clear understanding of the depth of the fisheries’ impact on the populations. Two chapters are presented that offer a perspective of mathematical modeling to gain an understanding of spotted seatrout. These two, very different approaches underline the fact that the spatial and temporal scales within which the spotted seatrout exists are considerable and will require the special skills that modelers can provide to facilitate understanding. Lastly, the relevancy of these data and perspectives to the overall objective to establish the life history attributes of the spotted seatrout as potential indicators of estuarine condition is examined.

The goal is ambitious and fraught with complications, but the end result gives large-scale perspective to a plethora of studies, independent examinations, and bits of information on a species that could serve as a significant indicator of the future of estuarine ecosystems to a major part of the world. If successful, it is hoped that other species that qualify with similar features will become

established in other coastal areas as potential indicators of estuarine conditions. A vigilant assessment of appropriate life history information should allow us to repair some estuarine ecosystems and return them to fully functional systems. Moreover, through the integration of several levels of inspection, we will be able to maintain our estuaries at a level appropriate for sustaining their natural resources while retaining their biological integrity.

REFERENCES

- Bortone, S.A. Ed., 2000. *Seagrasses: Monitoring, Ecology, Physiology, and Management*. CRC Press. Boca Raton, FL.
- Bortone, S.A., M.A. Wilzbach, and C.D. Beedee. 1997. Indexed bibliography to the biology and life history of the spotted seatrout (*Cynoscion nebulosus*). Florida Center for Environmental Studies, Technical Series 1:i-iii, 1-74. Florida Atlantic University.
- Johnson, D.R., and W. Seaman, Jr. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Florida) – spotted seatrout. *U.S. Fish and Wildl. Serv. Biol. Rep.* 82(11.43). U.S. Army Corps of Engineers, TR EL-82-4. 18 pp.
- Kennish, M.J. 1991. *Ecology of Estuaries: Anthropogenic Effects*. CRC Press. Boca Raton, FL.
- Robins, C.R., et al., 1991. *Common and Scientific Names of Fishes from the United States and Canada*. 5th Edition. Special Publication No. 20. American Fisheries Society. Bethesda, Maryland. 183 pages.
- Roff, D.A. 1992. *The Evolution of Life Histories*. Chapman & Hall. New York.
- Stearns, S.C. 1992. *The Evolution of Life Histories*. Oxford University Press. Oxford, England.

2 Taxonomy of the Seatrout, Genus *Cynoscion* (Pisces, Sciaenidae), with Artificial Keys to the Species

Ning Labbish Chao

CONTENTS

Introduction	5
Genus <i>Cynoscion</i> Gill 1861	6
Diagnosis.....	6
Synonyms	7
Valid Species.....	8
Western Atlantic Species.....	8
Key to Atlantic Species of <i>Cynoscion</i>	10
Eastern Pacific Species	11
Key to Pacific Species of <i>Cynoscion</i>	12
Future Studies and Conservation of Seatrout	14
Acknowledgments	14
References	15

INTRODUCTION

Sciaenid fishes are an important fishery resource in the shallow warm seas and estuaries of the world. The family Sciaenidae is the seventh largest among the 150 families of Perciformes and includes about 80 genera and 300 species. Four recognized genera with 20 plus species have adapted to living in the freshwater rivers and lakes of the Americas. Many marine species use the estuarine environment as a nursery and feeding ground for the young. Sciaenid body forms and mouth positions are among the most diverse of the percoids and appear to be the result of adaptations related to different feeding modes and life history patterns (Chao and Musick, 1977).

The family is characterized by an elongated soft dorsal fin separated from the spinous dorsal fin by a deep notch (rarely well spaced) and two anal spines (rarely one, never three); the lateral line extends to the tip of caudal fin. Sciaenid fishes have large otoliths and often complex gas bladders that are usually associated with well-developed drumming muscles in males or in both sexes. Many species have cavernous skulls and enlarged slits and pores on the snout and underside of the lower jaw. The lower jaw may also bear one or more mental barbels (also see Sasaki, 1989, for synapomorphies).

Species of the genus *Cynoscion* are commonly known as seatrout or weakfishes due to their tender flesh. Along the West Coast of the U.S., they are also known as corbina or corvina. Most species

of *Cynoscion* are popular food and sport fishes usually found along inshore waters, lower reaches of estuaries, salt marshes, and mangrove swamps. Two eastern Pacific *Cynoscion* species may also be found in deeper coastal waters of 100 to 200 m in depth (e.g., *C. nannus* and *C. nortoni*).

Studies on phylogenetic relationships among species of *Cynoscion* are still incomplete (Aguirre-Maldonado, 2000; Moshin, 1973; Paschall, 1986; Schwarzahans, 1993; Weinstein and Yerger, 1976). Phylogenetic relationships of *Cynoscion* and other genera of Sciaenidae reported by Sasaki (1989) and Casatti (2000) are in accord with the observations of Trewavas (1962) and Chao (1978, 1986). That is, the genera *Atractoscion*, *Cynoscion*, *Isopisthus*, and *Macrodon* form a monophyletic tribe, the Cynoscionini. It is endemic to the tropical and warm temperate regions of the Americas, with the exception of *Atractoscion aequidens* (Cuvier), which is distributed along the eastern Atlantic coast of southern Africa and off southern and eastern Australia. All four genera have an elongated body form and a pair of variably developed large horn-like appendages at the front of the gas chamber (Figure 2.1; also see the diagnosis below). *Atractoscion* can be further distinguished from other genera of Cynoscionini by lack of enlarged canine-like teeth at the tip of the upper jaw and a much thicker sagittal otolith (Chao, 1986; Schwarzahans, 1993).

The Indo-Pacific genus *Otolithes* Oken 1817 (written *Otolithus* by Cuvier 1829 and later authors) has a pair of canine-like teeth on upper and lower jaws; this is probably why several authors included American seatrouts in this genus. The genus *Otolithes* (tribe Otolithini) is not closely related to *Cynoscion*.

Genus *Cynoscion* consists of 24 species: 12 species in the eastern Pacific and 12 in the western Atlantic. Distribution records of *Cynoscion* for the eastern Pacific extend from southern California (*C. parvipinnis*) to northern Chile (*C. analis*) and in the western Atlantic from the Bay of Fundy (*C. regalis*) to northern Patagonia (*C. guatacupa*). Most species are found in the tropical and subtropical regions of Central and South America.

This review presents an updated taxonomy of *Cynoscion* species and provides artificial keys for species identification. Primary synonyms, references to original authors, type localities, and sizes of examined type specimens are listed. Complete references to the original species descriptions are readily available in Eschmeyer (1998). Museum collection acronyms follow Leviton et al. (1985).

GENUS CYNOSCION GILL 1861

DIAGNOSIS

The body is elongate, moderately compressed, and the predorsal profile nearly straight, ventral evenly arched. The head is conical, snout pointed. The mouth is large and oblique, with the lower jaw projecting; teeth are sharp and set in narrow ridges — the tip of the upper jaw usually with a pair

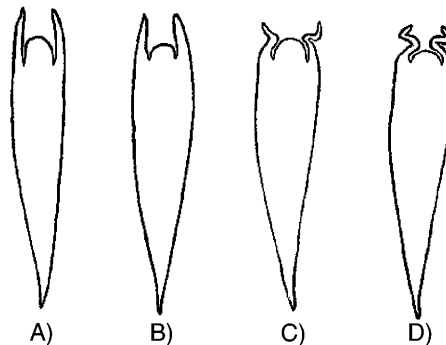


FIGURE 2.1 Gas bladder of *Cynoscion* has a pair of stout horn-like appendages. A: *C. microlepidotus*; B: *C. nothus*; C: *C. virensense*; D: *C. leiarchus*.

of large canines at least twice the size of other teeth, tapering from base to tip (no obviously enlarged teeth in *C. steindachneri*). The preopercular margin is membranous or ciliate, never with spines. Gill rakers are moderately long and slender. Vertebrae are usually $13(12) + 12(13) = 25$, except $15 + 12 = 27$ in *C. nothus* and $12 + 10 = 22$ in *C. microlepidotus*. The gas bladder has a pair of stout, horn-like appendages arising anteriorly from the gas chamber; the horns are mostly directing straight forward, but a few are curved medially (Figure 2.1). Sagitta (saccular otolith) are usually oval and elongate (Figure 2.2) with a tadpole-shaped sulcus mark. The head portion (ostium) is broad, not reaching the anterior margin of the sagitta in most species; the tail portion (cauda), not deeply grooved, is usually long and often expanded toward the tip in adults.

SYNONYMS

Cestreus Gronow in Gray 1854:49 (type-species: *Cestreus carolinensis* Gronow in Gray 1854, by monotypy, preoccupied by *Cestreus* McClelland 1842)

Cynoscion Gill 1861: 81 (type-species: *Johnius regalis* Bloch and Schneider 1801, by original designation)

Apsuedobranchus Gill 1862:18 (type-species: *Otolithus toeroe* Cuvier in Cuvier and Valenciennes 1830 = *Cynoscion acoupa* (Lacepède 1801), by original designation and monotypy)

Archoscion Gill 1862:18 (type-species: *Otolithus analis* Jenyns 1842, by original designation and monotypy)

Cynoscion (*Buccone*) Jordan and Evermann 1896:394 (type-species: *Cestreus praedatorius* Jordan and Gilbert in Jordan and Eigenmann 1889, by original designation and monotypy)

Symphysoglyphus A. Miranda Ribeiro 1915, Sciaenidae: 43 (type-species: *Otolithus bairdi* Steindachner 1879 = *Cynoscion microlepidotus* (Cuvier), by monotypy)

Paralarimus Fowler and Bean 1923:18 (type-species: *Paralarimus patagonicus* Folwer and Bean 1923 = *Cynoscion acoupa* (Lacepède 1801), by original designation and monotypy)

Cynoscion (*Eriscion*) Jordan and Evermann 1927:506 (type-species: *Cynoscion nebulosus* Cuvier in Cuvier and Valenciennes 1830, by original designation, also monotypy)

Remarks — Based on the sagitta morphology of recent and fossil *Cynoscion*, Schwarzzhans (1993) used the available names of the genus and divided *Cynoscion* into four subgenera: *Cynoscion*, *Apsuedobranchus*, *Buccone*, and *Archoscion*. He also defined the subgenus *Archoscion* (including *C. analis* and *C. orthonopterus*) as intermediate between the genera *Cynoscion* and *Isopisthus*. This relationship was consistent with the phylogenetic relationship of *C. analis* and *Isopisthus remifer* inferred from mitochondrial DNA sequence data by Aguirre-Maldonado (2000). Since the related genera *Atractoscion* and *Macrodon* were not included in either analysis as out groups, the subgeneric divisions within the *Cynoscion* probably need further scrutiny.

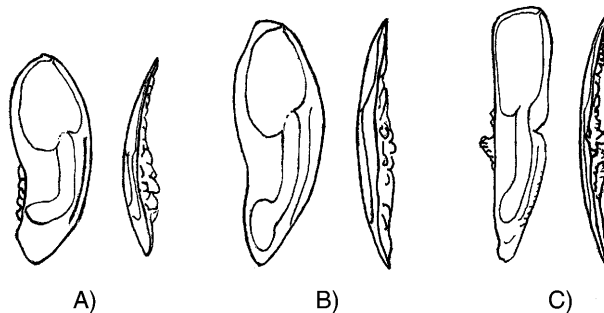


FIGURE 2.2 Sagitta otoliths of *Cynoscion* are mostly oval elongated, with few exceptions. A: *C. nebulosus*; B: *C. regalis*; C: *C. virensense*.

VALID SPECIES

A total of 24 species of *Cynoscion* are recognized here. The 12 western Atlantic and Caribbean species are *C. acoupa*, *C. guatucupa*, *C. arenarius*, *C. jamaicensis*, *C. leiarchus*, *C. microlepidotus*, *C. nebulosus*, *C. nothus*, *C. regalis*, *C. similis*, *C. steindachneri*, and *C. virescens*. The 12 eastern Pacific species are *C. albus*, *C. analis*, *C. nannus*, *C. nortoni*, *C. parvipinnis*, *C. orthonopterus*, *C. phoxocephalus*, *C. praedatorius*, *C. reticulatus*, *C. squamipinnis*, *C. stolzmanni*, and *C. xanthulus*.

Remarks — Two large sciaenids, *Atractoscion nobilis* (Ayres, 1860) and *Totoaba macdonaldi* (Gilbert, 1890), were commonly included in the *Cynoscion* until a new genus, *Totoaba*, was recently described (Villamar, 1980). Both species lack large canine-like teeth on their jaws. Furthermore, *T. macdonaldi* has a distinct gas bladder with a pair of thick, long, tubular appendages running along the sides of the main gas chamber (Villamar, 1980). Trewavas (1962) included Indo-Pacific monotypic *Atractoscion aequidens* in the tribe Cynosionini for its gas bladder, which is the same type as that of *C. regalis* and more abdominal than caudal vertebrae (14 + 11 = 25), which is not diagnostic for the tribe. Trewavas (1977) also included the eastern Pacific *Cynoscion nobilis* in the genus *Atractoscion* for lack of large canine-like teeth. *C. nobilis* and *C. aequidens* have distinctly thicker sagittal otoliths than all other *Cynoscion* species; including them in a separate genus *Atractoscion* is valid. The adults of Brazilian *C. steindachneri* (Jordan) also lack enlarged canine-like teeth on the upper jaw. *Cynoscion fusiformes* Borodin (1933) from the Florida Keys (holotype: VMM1267, 215 mm TL, now at AMNH) is not a sciaenid. A photo of the holotype resembles the *Stizostedion* species (Percidae).

WESTERN ATLANTIC SPECIES

Cynoscion acoupa (Lacepède)

Cheilodipterus acoupa Lacepède 1801, Cayenne, French Guiana (holotype: MNHN 5502, 262 mm SL, Cayenne, other syntypes from Surinam and Brazil; also see Bauchot and Desoutter, 1987)

Lutjanus cayenensis Lacepède 1802, Cayenne, French Guiana (holotype: MNHN 5502, 262 mm SL)

Otolithus rhomboidalis Cuvier 1829, Cayenne, French Guiana (based on “Lutjan de Cayenne,” Lacepède)

Otolithus toeroe Cuvier in Cuvier and Valenciennes 1830, Cayenne, French Guiana (syntypes: MNHN 4616, 347 mm SL, Cayenne; MNHN 5500, 175 mm SL, Brazil; MNHN A.4518, two specimens, 493 and 485 mm SL, Cayenne; also see Bauchot and Desoutter, 1987)

Paralarimus patagonicus Fowler and Bean 1924, Patagonia, Argentina (holotype: USNM 83222, 136 mm SL)

Remarks — The specimen was collected during the Wilkes expedition and catalogued on 1 March 1919. I suspect the stated locality of the holotype was incorrectly registered.

Cynoscion maracaiboensis Schultz 1949, Rio Agua Caliente, 2 to 3 km above Lake Maracaibo, Venezuela (holotype: USNM 12742, 251 mm SL, paratypes: see Eschmeyer, 1998).

Cynoscion arenarius Ginsburg

Cynoscion arenarius Ginsburg 1929, Texas (holotype: USNM 89385, 245 mm SL)

Remarks — Two independent electrophoresis studies of four western North Atlantic *Cynoscion* (Weintein and Yerger, 1976; Paschall, 1986) have suggested that *C. arenarius* and *C. regalis* formed one phyletic line. These authors questioned the species status of *C. arenarius* and have suggested that *C. arenarius* may be a subspecies of *C. regalis*.

Cynoscion guatucupa (Cuvier)

“Guatucupa” Marcgrave 1648, Brazil (non-binominal)

Otolithus striatus Cuvier 1829 (after Marcgrave)

Otolithus guatucupa Cuvier in Cuvier and Valenciennes 1830, Montevideo (syntypes: MNHN 7517, two specimens, 358 and 366 mm SL; also see Bauchot and Desoutter, 1987)

Remarks — Figueiredo (1992) correctly regarded *Cynoscion striatus* (Cuvier, 1829) as a *nomen dubium* that is valid as *Cynoscion guatucupa* (1830).

***Cynoscion jamaicensis* (Vaillant and Bocourt)**

Otolithus jamaicensis Vaillant and Bocourt 1883, Jamaica (holotype: MNHN A.557, 205 mm SL)
Archoscion petranus A. Miranda Ribeiro 1913, Campo Grande, Brazil (no type known)

***Cynoscion leiarchus* (Cuvier)**

Otolithus leiarchus Cuvier in Cuvier and Valenciennes 1830, Brazil (syntypes: MNHN 5503, two specimens, 152 and 234 mm SL; MNHN A.2690, 187 mm SL; MNHN A.5422, a dried stuffed specimen, 112 mm SL, Brazil; also see Bauchot and Desoutter, 1987).

***Cynoscion microlepidotus* (Cuvier)**

Otolithus microlepidotus Cuvier in Cuvier and Valenciennes 1830:79, Surinam (holotype: ZMB; see Bauchot and Desoutter, 1987)

Otolithus bairdii Steindachner 1879, Santos, Brazil (syntypes: one of several examined NMW 51130, 152 mm SL, label states - donated by Steindachner)

***Cynoscion nebulosus* (Cuvier)**

Labrus squetaegue var. *maculatus* Mitchill 1815, New York (not *Labrus maculatus* Bloch 1793; no type known)

Otolithus nebulosus Cuvier in Cuvier and Valenciennes 1830, locality unknown (holotype: MNHN 7527, 233 mm SL)

Otolithus carolinensis Valenciennes in Cuvier and Valenciennes 1833, Charleston, South Carolina (holotype: MNHN 7507, 335 mm SL)

Otolithus drummondii Richardson 1836, New Orleans, Louisiana (holotype: whereabouts unknown)

***Cynoscion nothus* (Holbrook)**

Otolithus nothus Holbrook 1855, South Carolina (no type known)

***Cynoscion regalis* (Bloch and Schneider)**

Johnius regalis Bloch and Schneider 1801, New York (holotype: ZMB 8700, not examined)

Roccus comes Mitchill 1814, New York (no type known)

Labrus squetaegue Mitchill 1815, New York (no type known)

Cestreus carolinensis Gronow in Gray 1854, off the Carolinas, U.S. (holotype: BMNH 1853.11.12.42, a dried skin, 344 mm TL not of *Otolithus carolinensis* Valenciennes)

Otolithus thalassinus Holbrook 1855, Charleston, South Carolina (no type known)

Otolithus obliquatus Valenciennes in Sauvage 1879, Martinique Island, West Indies (lectotype: MNHN 7632, 209 mm SL; paralectotypes: MNHN1987-151 [ex MNHN 7632], 182 mm SL; also see Bauchot and Desoutter, 1987).

Remarks — The identity of *Otolithus obliquatus* (Valenciennes) was discussed by Jordan and Evermann (1898), Randall and Cervigón (1968), and Chao (1978). The types were collected by M. Plée from Martinique and are the only records of *C. regalis* from the West Indies. They have higher soft dorsal and anal ray counts (30 dorsal rays, 12 anal rays in MNHN 7632 and 28 dorsal rays, 11 anal rays in MNHN 1987-151), whereas the *C. jamaicensis* has 23 to 25 dorsal rays and 8 to 10 anal rays.

***Cynoscion similis* (Randall and Cervigón)**

Cynoscion similis Randall and Cervigón 1968:170, Isla de Margarita, Venezuela (holotype: USNM 201382, 284 mm SL)

***Cynoscion steindachneri* (Jordan)**

Cestheus steindachneri Jordan in Jordan and Eigenmann 1889: 372, Brazil (MCZ 10922, 318 mm SL)

***Cynoscion virescens* (Cuvier)**

Otolithus virescens Cuvier in Cuvier and Valenciennes 1830, Surinam (holotype: ZMB, not examined)

Remarks — Chao's (1978) inclusion of *Otolithus microps* Steindachner 1879 as a synonym of *C. virescens* is doubtful. The locality, Porto Alegre, Rio Grande do Sul, is in southern Brazil and is not a coastal city; I have not examined the holotype (NMW 31111) to verify its identity.

KEY TO ATLANTIC SPECIES OF *CYNOSCION*

- 1a. Scales on body cycloid, much smaller than pored lateral line scales; more than 100 transverse rows above lateral line..... 2
- 1b. Scales on body ctenoid, about same size or larger than pored lateral line scales; fewer than 70 transverse rows of scales above lateral line.....4
- 2a. Caudal fin truncate in adults; inner row of lower jaw teeth slightly enlarged, uniform in size and closely set: anal fin with 10 to 12 soft rays; about 110 transverse scale rows above lateral line*C. leiarchus*
(Caribbean coast to southern Brazil)
- 2b. Caudal fin rhomboidal in adults; inner row of lower jaw teeth distinctly larger, gradual increase in size posteriorly and widely spaced; anal fin with 7 to 10 soft rays; about 140 transverse scale rows above lateral line 3
- 3a. Soft dorsal fin almost entirely covered with small scales; 22 to 25 dorsal fin soft rays; gas bladder with a pair of long, straight, horn-like appendages; 22 vertebrae
.....*C. microlepidotus*
(Caribbean coast of South America to northeastern Brazil)
- 3b. Soft dorsal fin unscaled, except 1 to 2 rows of small scales at base; 27 to 31 dorsal fin soft rays; gas bladder with a pair of curved horn-like appendages; 25 vertebrae
.....*C. virescens*
(Caribbean coast to southeastern Brazil)
- 4a. Body with spots or stripes on back, dorsal, or caudal fins; caudal fin truncate or emarginated in adults5
- 4b. Body uniformly silver, may have some faint streaks on back, but never with spots or stripes; caudal fin rhomboidal or double emarginated in adults.....9
- 5a. Back with distinct spots scattered randomly on dorsal and caudal fins; soft dorsal fin unscaled; pectoral fin shorter than pelvic fin *C. nebulosus*
(Atlantic coast from Nova Scotia to Florida and Gulf of Mexico coast from Florida to Texas)
- 5b. Back with numerous small spots forming oblique and undulating lines, usually not extending to dorsal or caudal fins; pectoral fin slightly longer than pelvic fin6
- 6a. Dotted stripes on trunk irregular or reticulated; anal fin with 11–13 soft rays.. *C. regalis*
(Atlantic coast from Virginia to Florida and Gulf of Mexico coast of Florida)

- 6b. Dotted stripes on trunk follow oblique scale rows; anal fin with 8 to 10 soft rays7
- 7a. Soft dorsal fin with 18 to 21 rays; 21 to 26 gill rakers, longer than gill filaments on first gill arch*C. guatucupa*
(Southeast Brazil to Patagonia, Argentina)
- 7b. Soft dorsal fin with more than 23 rays; fewer than 13 gill rakers, shorter than gill filaments on first arch8
- 8a. Lower jaw teeth closely set, similar in size; unscaled soft dorsal fin membranes, except two to three rows of small scales along its base.....*C. similis*
(Caribbean coast of South America to northeastern Brazil)
- 8b. Lower jaw teeth widely spaced, gradually increasing in size posteriorly; soft dorsal fin covered with small scales $\frac{3}{4}$ of fin height*C. jamaicensis*
(West Indies and from Caribbean coast of South America to Mar del Plata, Argentina)
- 9a. Pectoral fin shorter than pelvic fin, two times or more in head length.10
- 9b. Pectoral fin about equal to or longer than pelvic fin, less than two times in head length11
- 10a. Large canine-like teeth often absent from tip of upper jaw; soft dorsal fin with 21 to 24 rays and almost entirely covered with small scales; 25 vertebrae..... *C. steindachneri*
(Caribbean coast of South America to northeastern Brazil)
- 10b. A pair of large canine-like teeth always present; dorsal fin with 26 to 31 soft rays, covered with small scales to half of fin height; 27 vertebrae.....*C. nothus*
(Atlantic coast of U.S. from Virginia to Florida and Gulf of Mexico coast to Texas)
- 11a. Dorsal fin with 17 to 22 soft rays; anal fin with 7 to 9 soft rays*C. acoupa*
(Caribbean coast of South America to northeastern Brazil)
- 11b. Dorsal fin with 25 to 29 soft rays; anal fin with 10 to 12 soft rays.*C. arenarius*
(Gulf of Mexico coast from Florida to Texas)

EASTERN PACIFIC SPECIES

Cynoscion albus (Günther)

Otolithus albus Günther 1864, Chiapam, Guatemala (holotype: BMNH 1864.1.26.240, 305 mm SL)

Cynoscion analis (Jenyns)

Otolithus analis Jenyns 1842, Callao, Peru (holotype: BMNH 1917.7.14.44, 242 mm SL)
Otolithus peruanus Tschudi 1845, coast of Peru (syntypes: ZMB 864, not examined)

Cynoscion nannus (Castro-Aguirre and Arvizu-Matinez)

Cynoscion nannus Castro-Aguirre and Arvizu-Matinez 1976, off Rio Baluuarte, Sinaloa, Mexico (holotype: L.E.M. (Lab. Ecol. Mar. Cole) 4109, 137 mm SL; paratypes: L.E.M. 4108, 10, 86 to 123 mm SL, not examined)

Cynoscion nortoni (Béarez)

Cynoscion nortoni Béarez 2001, Puerto López fish market at Manabí, Ecuador (holotype: MNHN 99–0961, 260 mm SL; paratypes: CAS 208889,1, 272 mm SL; MCZ 156126, 1, 280 mm SL; MNHN 99–0962, 7, 250–293 mm SL; USNM 357280, 1, 303 mm SL; and SIO 83–75,1, 380 mm SL Paita, Peru)

***Cynoscion orthonopterus* (Jordan and Gilbert)**

Cynoscion orthonopterus Jordan and Gilbert 1881, Punta San Felipe, Gulf of California, Mexico (holotype: USNM 29385, 56 cm SL)

***Cynoscion parvipinnis* (Ayres)**

Cynoscion parvipinnis Ayres 1861, coast of Baja, California, 27°N (no types known)

***Otolithus magdalenae* (Steindachner)**

Otolithus magdalenae Steindachner 1876, Magdalena Bay, Baja, California, Mexico (syntypes: MCZ 10880, 3, 265 to 308 mm SL; NMW 32256, 1, 408 mm SL and others, not examined)

***Cynoscion phoxocephalus* (Jordan and Gilbert 1881)**

Cynoscion phoxocephalum Jordan and Gilbert 1881, Panama Bay, Panama (syntypes: USNM 29339, 1, 230 mm SL; not examined USNM 29296, 1; USNM 29724, 1; USNM 29389, 1, missing?)

***Cynoscion praedatorius* (Jordan and Gilbert)**

Cestreus praedatorius Jordan and Gilbert in Jordan and Eigenmman 1889, Panama (syntypes: MCZ 10901, 2, 315 and 402 mm SL); MCZ 10902, 1, 332 mm SL, labeled as *Otolithus panamensis* Steindachner

***Cynoscion reticulatus* (Günther)**

Otolithus reticulatus Günther 1864, San José, Guatemala (holotype; BMNH 1864.1.26.324, 316 mm SL)

***Cynoscion squamipinnis* (Günther)**

Otolithus squamipinnis Günther 1867, Panama (syntypes: BMNH 1865.7.20.20–21, 2, 223 to 266 mm SL)

***Cynoscion stolzmanni* (Stendachner)**

Otolithus stolzmanni Stendachner 1879 Tumbes, Peru (several syntypes: MW3113, 1, 315 mm SL examined)

***Cynoscion xanthulus* (Jordan and Gilbert)**

Cynoscion xanthulum Jordan and Gilbert 1881, Mazatlán, Mexico (holotype: USNM 28109: not located)

KEY TO PACIFIC SPECIES OF *CYNOSCION*

- 1a. Second dorsal fin with small scales covering at least to the basal half of the membranes between rays2
- 1b. Second dorsal fins without scales extending on membranes, some with one to three rows of small scales forming a low sheath along the base.....6
- 2a. Scales all cycloid.3
- 2b. Scales ctenoid on at least posterior $\frac{3}{4}$ of body, cycloid on head or breast..... 4

- 3a. Anal fin long, with 13 to 15 soft rays, 22 to 24 dorsal rays; head 2.8 to 3.5 times in standard length; caudal fin emarginated *C. analis*
(Ecuador to Chile)
- 3b. Anal fin with 8 to 10 soft rays; 18 to 21 dorsal rays; head 3.5 to 3.9 in standard length; caudal fin double truncate *C. predatorius*
(Costa Rica to Panama)
- 4a. Roof of mouth black; head large, 2.6 to 2.8 in. standard length; eye 4.4 to 5.3 times in head *C. nanus*
(Southern Gulf of California to Guatemala)
- 4b. Roof of mouth pale; head 3.1 or more in standard length; eye more than six times in head 5
- 5a. Posterior end of maxilla reaching beyond the hind margin of eye; dorsal fin with VII-VIII + I spines, 21 to 23 soft rays; gill rakers 12 to 16; caudal fin double truncate. *C. squamipinnis*
(Gulf of California to northern Peru)
- 5b. Posterior end of maxilla short of the hind margin of eye; dorsal fin with IX-X + I spines, 23 to 27 soft rays; gill rakers 24 to 27; caudal fin emarginated *C. othonopterus*
(Gulf of California, Mexico)
- 6a. Scales small, cycloid on body and head; tip of mouth pointing upward, above the mid level of the eye; gill rakers much shorter than gill filaments at the angle of gill arch *C. phoxocephalus*
(Southern Mexico to northern Peru)
- 6b. Scales ctenoid on at least posterior $\frac{3}{4}$ of body, tip of mouth below the mid level of eye; gill rakers about equal to or longer than filaments at the angle of first gill arch 7
- 7a. Back with prominent stripes and reticulation; pectoral fin tip extends beyond that of pelvic fins; second dorsal fin long, with 25 to 29 rays *C. reticulatus*
(Gulf of California to northern Peru)
- 7b. Back uniformly bluish-gray, some backs with faint stripes never reticulated; pectoral fin length about equal to or much shorter than the pelvic fins; second dorsal with 24 or fewer rays 8
- 8a. Scales mostly ctenoid on body and head; pectoral fin short, 2.0 or more times in head length, its tip falling short of tip of pelvic fins; a dark lunate band median to lower 9
- 8b. Scales ctenoid on body, cycloid below pectoral fins and on head; pectoral fin 1.8 times or less in head length; its tip reaching to or beyond that of pelvic fins. 11
- 9a. Lining of gill cover and pectoral axils dark but never black; dorsal fin with VIII-IX + I spines, and 21 to 23 soft rays; caudal fin emarginated *C. parvipinnis*
(Southern California, Gulf of California to Mazatlán, Mexico)
- 9b. Inside mouth and gill chamber black; dorsal fin with X - XI + I spines 10
- 10a. Soft dorsal fin with 23 to 26 rays; caudal fin truncate *C. nortoni*
(Ecuador and Peru)
- 10b. Soft dorsal fin with 20 to 21 rays; caudal fin nearly rhomboidal *C. stolzmanni*
(Southern Mexico to Peru)
- 11a. Pectoral fin tip reaching as far back as pelvic fin tip; first dorsal fin with usually 10 spines, few ctenoid scales on opercle; 54 to 58 pored lateral line scales, 64 to 69 parallel scale rows above lateral line; inside mouth pale to yellowish *C. albus*
(Gulf of California to Ecuador)
- 11b. Pectoral fin tip reaching much short of pelvic fin tip; first dorsal fin usually with nine spines; scales cycloid on opercle; 58 to 68 pored lateral pored scales, 74 to 86 parallel scale rows above lateral line; inside mouth bright orange *C. xanthulus*
(Gulf of California to Guerrero, Mexico)

FUTURE STUDIES AND CONSERVATION OF SEATROUT

Phylogenetic and life history studies of the *Cynoscion* species and populations are still lacking over most of their geographic range, except for those of the Atlantic and Gulf of Mexico coasts of the U.S. Because seatrout are also a group of important sport fish, seatrout studies are well funded in the U.S., but the knowledge of impacts of recreational fishing on seatrouts and their management is lacking in Central and South America. For example, studies of possible population structuring of the broader ranged and highly exploited South American species such as *C. acoupa*, *C. jamaicensis*, and *C. virescens* are urgently needed for local fishery management.

One of the largest seatrout species, *Cynoscion acoupa*, is still abundant along the northeastern Atlantic coast of South America from Venezuela to northern Brazil, or roughly between the Orinoco and south of the Amazon delta (Figure 2.3). The inshore habitats of *C. acoupa* are often associated with mangrove swamps and the historically small artisan fisheries of the region, which may have helped preserve it. However, local fishery managers should be aware that this large seatrout could be rapidly overfished to critical levels if more efficient fishing and processing techniques are implemented. The first endangered seatrout-like species, the Totoaba (*Totoaba macdonaldi*), is an example *not* to follow (Villamar, 1980).

ACKNOWLEDGMENTS

This article was “thrust” upon me by Steve Bortone and has been prepared practically in the middle of the Amazon (Manaus), where I have had extremely limited access to recent literature. I have used the fish collections at the USNM and MCZ to update the keys provided here and in the species identification sheets that I prepared for the FAO (Chao 1977, 1995). Bruce B. Collette (Systematics Laboratory, NMFS at USNM) has let me use the same bench space in the NMFS fish preparation room, where I started my studies of the Sciaenidae in the early 1970s. I also wish to thank colleagues in the basement of the Fish Division (USNM) for keeping things almost the same for 30 years for the return of this still “young” VIMS student. I also thank W. E. Aguirre-Maldonado (SUNY, Sony Brook) and Karsten Hartel (MCZ) for reviewing drafts of this article; Karsten also remeasured types and searched references for me. Scott Schaefer and Damaris Rodriguez (AMNH) sent me the digital images and x-ray film of the holotype *C. fusiformes*.



FIGURE 2.3 “Snapper,” *Cynoscion acoupa*, is apparently abundant in Georgetown, Guyana (5 December 2000, at Georgetown Fishermen’s Co-op landing area).

REFERENCES

- Aguirre-Maldonado, W.E. 2000. Phylogenetic vs. ecophenotypic influences on interspecific variability of sagittae in the genera *Cynoscion* and *Isopisthus* (Teleostei: Sciaenidae). M.S. thesis, University of Southern Mississippi.
- Bauchot, M. -L. and M. Desoutter. 1987. Catalogue critique des types de poissons du muséum national d'histoire naturelle. (Suite) (Famille des Sciaenidae). *Bull. Mus. Natl. Hist. Nat. Ser. 4, Sect. A, 9, no. 3 (suppl.):* 1-43.
- Borodin, N.A. 1934. Fishes: scientific results of the yacht "Alva" Mediterranean cruise, 1933 in command of William K. Vanderbilt. *Bull. Vanderbilt Mar. Mus.* V.1 (art. 4): 102-123.
- Casatti, L. 2000. Taxonomia e relações filogenéticas das corvinas de água doce sul-americanos (Sciaenidae: Perciformes). Ph.D. thesis, Universidade Estadual Paulista, Campus de Botucatu.
- Chao, L.N. 1977. Sciaenidae. in Fischer, W. Ed. *Identification sheets of Central West Atlantic, Fishing area 30 and 31*. FAO, U.N. 48 p.
- Chao, L.N. 1978. A basis for classifying western Atlantic Sciaenidae (Pisces: Perciformes), NMFS, Technical Report, Circular no. 415, 64 p.
- Chao, N.L. 1986. A synopsis on zoogeography of Sciaenidae. p.570-589. in: *Indo-Pacific Fish Biology. Proceedings of the Second Indo-Pacific Fish Conference*, July 28-August 3, 1985, Tokyo, Japan.
- Chao, N.L. 1995. Sciaenidae, p.1427-1518, in Fischer W. et al., Eds., *Guía FAO para la identificación de especies para los fines de la pesca. Pacífico-centro Oriental, vol. III. Vertebrados-Parte II*. FAO. Roma.
- Chao, N.L. and J. A. Musick. 1977. Life history, feeding habits and functional morphology of juvenile sciaenid fishes in the York River estuary, Virginia. *Fish. Bull., U.S.*, 75 (4): 657-702.
- Eschmeyer, W.L., Ed., 1998. *Catalog of Fishes*. California Academy of Science, San Francisco.
- Figueiredo, J.L. de 1992. Sobre a aplicação dos nomes *Cynoscion striatus* (Cuvier, 1829) e *Cynoscion guatcupa* (Cuvier, 1830) (Teleostei: Sciaenidae). *Comum. Mus. Ciência PUCRS, Sér. Zool.* Porto alegre, 5 (8):117-121.
- Jordan, D.S. and B.W. Evermann. 1898. The fishes of North and Middle America. *Bull. U. S. Natl. Mus.* No. 47, pt.2: 1241-2183.
- Leviton, A.E., et al., 1985. Standards in herpetology and ichthyology: Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. *Copeia* 1985 (3): 802-832.
- Moshin, A.K.M. 1973. Comparative osteology of weakfishes (*Cynoscion*) of the Atlantic and Gulf coasts of the United States, Ph.D. dissertation. Texas A & M University.
- Paschall, R.I., Jr. 1986. Biochemical systematics of seatrouts of the western Atlantic genus *Cynoscion*, MSc thesis, University of New Orleans.
- Randall, J. and F. Cervigón M. 1968. Un nuevo pez del género *Cynoscion* de Venezuela y notas sobre *C. jaimaicensis* y *C. obliquatus*. *Mem. Soc. Cienc. Nat., La Sale*, 27:176-192.
- Sasaki K. 1989. Phylogeny of the family Sciaenidae, with notes on its zoogeography (Teleostei: Perciformes). *Mem. Fac. Fish. Hokkaido Univ.* 36: 1-137.
- Schwarzhan, W. 1993. A comparative morphological treatise of recent and fossil otoliths of the family Sciaenidae (Perciformes). *Picium Catalogus: Part Otolithi Piscium*, Vol. 1, p. 1-245. Verlag Dr. Friedrich Pfeil, München, FRG.
- Trewavas, E. 1962. A basis for classifying the sciaenid fishes of tropical West Africa. *Ann. Mag. Nat. Hist.*, ser. 13, 5:157-176.
- Trewavas, E. 1977. The sciaenid fishes (croaker or drum) of the Indo-West Pacific. *Trans. Zool. Soc. Lond.*, 33:253-541.
- Vilamar, A. 1980. Totoaba, un Nuevo género de la familia Sciaenidae del golfo de California, México. *An. Esc. Nac. Cienc. Biol. Mex.* V. 23 (nos. 1 / 4): 129-133.
- Weinstein, M.P. and R.W. Yerger. 1976. Protein taxonomy of the Gulf of Mexico and Atlantic coasts seatrouts, genus, *Cynoscion*. *Fish. Bull. U.S.*, 74:599-607.

3 Population Structure of Spotted Seatrout (*Cynoscion nebulosus*) along the Texas Gulf Coast, as Revealed by Genetic Analysis

John R. Gold, Leah B. Stewart, and Rocky Ward

CONTENTS

Abstract.....	17
Introduction	18
Materials and Methods	19
Results	21
Discussion and Conclusions	22
Acknowledgments	27
References	27

ABSTRACT

Allelic variation at (presumed) nuclear-encoded microsatellites was assayed among spotted seatrout sampled from localities along the Gulf Coast of Texas. Tests of Hardy-Weinberg equilibrium at each microsatellite within each sample and tests of genotypic equilibrium among pairs of microsatellites within and among samples were nonsignificant. Homogeneity (exact) tests of allele distributions at each microsatellite and estimates (the θ estimator of Wright's F_{ST}) of population structure were nonsignificant following correction for multiple tests executed simultaneously. The absence of a geographic pattern to microsatellite variation among spotted seatrout sampled from the Texas coast differs from that reported previously for the nuclear-encoded gene aspartate aminotransferase (*sAAT-2*) and for mitochondrial (mt)DNA: genetic divergence at *sAAT-2* and mtDNA was significant and related in part to increasing geographic distance between sample localities (isolation by distance).

Several possibilities to account for the difference in patterns of geographic variation among these three types of genetic markers are discussed. We suggest that population structure of spotted seatrout along the Texas coast is best modeled as a series of overlapping subpopulations or stocks distributed linearly along the coastline: individual subpopulations are centered in individual (natal) estuaries, but gene flow between geographically proximate estuaries is sufficient to prevent significant genetic divergence. This type of model also has been hypothesized for red drum (*Sciaenops ocellatus*), a related sciaenid, in the northern Gulf of Mexico. Microsatellite variation also was assayed in a sample of spotted seatrout from the Atlantic coast of Florida. Significant differences in allele frequencies between the sample from the east coast of Florida and four samples from the Texas Gulf coast were detected at all five microsatellites assayed. These findings parallel results from several studies on marine fishes (including other sciaenids) where regionally distinct populations reside in the northern Gulf of Mexico and along the southeast (U.S.) Atlantic coast.

INTRODUCTION

Spotted seatrout, *Cynoscion nebulosus*, is an estuarine-dependent sciaenid fish distributed from coastal waters in Massachusetts to the Bay of Campeche on the Yucatan Peninsula in Mexico (Patillo et al., 1997), extending perhaps into the Mexican Caribbean (Aguilar-Salazar et al., 1993). The species is most abundant in the northern Gulf of Mexico (hereafter called Gulf) from Florida to Texas (Lassuy, 1983; Mercer, 1984) and at one time supported both recreational and commercial fisheries (Patillo et al., 1997). A small (~48,500 kg in 2000) commercial fishery industry still exists in western Florida, Mississippi, and Louisiana (http://www.st.nmfs.gov/st1/commercial/landings/annual_landings.html) but is dwarfed by the recreational fishery in the Gulf where more than 4 million kg were landed in 1998 and (exclusive of Texas waters) over 6,350,000 kg were landed in 2000 (http://www.st.nmfs.gov/st1/recreational/queries/catch/time_series.html; L. Green, Coastal Fisheries Division, Texas Parks and Wildlife, personal communication). Perceived declines in spotted seatrout abundance across the Gulf have led to decreases in or prohibition of commercial catches and increasing restrictions on recreational catches (references in Bortone et al., 1997). Both overfishing and loss of habitat are hypothesized (Shipp, 1986; Patillo et al., 1997) as instrumental in spotted seatrout declines.

Assessment and allocation of spotted seatrout recreational resources in the Gulf are the responsibility of individual states and vary from state to state (GSMFC, 1993). With the exception of Florida — where management of spotted seatrout is regionally based (Muller et al., 1997) — regulations in most Gulf Coast states are predicated on a single-stock model; i.e., allocation is the same across bays and estuaries within a state. Past studies asking whether a single-stock model is appropriate are equivocal. Nongenetic studies include those of Colura and King (1989), who found that shapes of scales and otoliths varied among spotted seatrout collected from several bays along the Texas coast, and Iverson and Tabb (1962), who reported different growth rates for spotted seatrout obtained from the Gulf Coast of Florida. The differences reported by Iverson and Tabb (1962), however, were hypothesized by Murphy and Taylor (1994) to stem from environmental or harvest factors, not from existence of discrete stocks. Tagging studies (Overstreet, 1983; Baker and Matlock, 1993), generally have indicated little “coastwise” movement of juveniles or adults, with most returns occurring less than 50 km from the release site. Movement of spotted seatrout from bays and estuaries does occur but appears to be primarily associated with spawning or in response to changes in salinity or temperature (Lorio and Perret, 1978; Helser et al., 1993).

Genetic studies have been less equivocal, as differences in general protein banding patterns (Weinstein and Yerger, 1976), allozymes (Ramsey and Wakeman, 1987; King and Pate, 1992), and mitochondrial (mt)DNA (Gold et al., 1999) have been reported among spotted seatrout sampled from various bays and estuaries of the Gulf. In three of these studies, i.e., Ramsey and Wakeman (1987), King and Pate (1992), and Gold et al. (1999), genetic divergence, although comparatively small, appeared to be, in part, a function of geographic distance between pairs of sample localities. In their study of 44 allozyme loci among 12 samples along the Gulf Coast of Texas and northern Mexico, King and Pate (1992) attributed this “isolation-by-distance” effect to westerly directed transport of eggs and larvae in nearshore waters. King and Zimmerman (1993) hypothesized that the difference in frequencies of alleles at the aspartate aminotransferase locus reported by King and Pate (1992) may reflect adaptation to temperature or salinity differences but that a nearshore dispersal mechanism might limit genetic divergence. Gold et al. (1999) assayed mtDNA variation across a broader geographic range, from the Lower Laguna Madre in southern Texas to Tampa Bay on the west coast of Florida, and hypothesized that the isolation-by-distance effect stemmed from factors (e.g., behavioral, physiological) that limited female dispersal from natal bays and estuaries.

In this chapter, we report results from ongoing, independent studies in our laboratories on variation in (presumed) nuclear-encoded microsatellites among geographic samples of spotted seatrout from the Gulf Coast of Texas. Briefly, microsatellites are abundant, short stretches of DNA composed of di-, tri-, or tetranucleotide arrays that are embedded in unique DNA, inherited in a Mendelian fashion, highly polymorphic, found in all eukaryotic species, and distributed evenly