FISHERIES TECHNIQUES
THIRD EDITION

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Dedication

The editors dedicate this book to our mentors and most important professional influences, namely H. Franklin Percival and Dick Neves (AVZ), F. Joseph Margraf and Roy A. Stein (DLP), and John Ney and Dave Willis (TMS).
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# List of Species

## Fish

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<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
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<tr>
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cabezon ................................................................. Scorpaenichthys marmoratus

canary rockfish .......................................................... Sebastes pinniger

capelin ................................................................. Mallotus villosus

catfishes ................................................................. Family Ictaluridae

chain pickerel ........................................................... Esox niger

channel catfish ........................................................ Sebastes nebulosus

China rockfish ........................................................ Oncorhynchus tschawytscha

Chinook salmon ........................................................ Oncorhynchus keta

cisco ................................................................. Coregonus artedi

ciscoes ................................................................. Family Salmonidae

cods ................................................................. Family Gadidae

coho salmon ............................................................. Oncorhynchus kisutch

common carp ........................................................... Cyprinus carpio

common shiner ........................................................ Lucioperca cornutus

common snook ............................................................ Centropomus undecimalis

crappies ................................................................. Pomoxis spp.
creek chub ................................................................. Semotilus atromaculatus
cutthroat trout .......................................................... Oncorhynchus clarkii
darkblotched rockfish .................................................. Sebastes crameri
darters ................................................................. Family Percidae
delta smelt ............................................................... Hypomesus transpacificus
dover sole ................................................................. Microstomus pacificus
eels ................................................................. Anguilla spp.

emerald shiner ............................................................ Notropis atherinoides

English sole ............................................................... Parophrys vetulus

Eurasian perch .......................................................... Perca fluviatilis

European eel ............................................................... Anguilla anguilla

European plaice .......................................................... Pleuronectes platessa

fathead minnow .......................................................... Pimephales promelas

flannelmouth sucker ..................................................... Catostomus latipinnis

flathead catfish .......................................................... Pylopterus olivaris

flounders ................................................................. Order Pleuronectiformes

freshwater drum ......................................................... Aplodinotus grunniens
gag ................................................................. Mycteroperca microlepis
gars ................................................................. Family Lepisosteidae
gizzard shad ............................................................... Dorosoma cepedianum
golden shiner ............................................................. Notemigonus crysoleucas
golden trout ............................................................. Oncorhynchus mykiss aguabonita
goliath grouper ........................................................ Epinephelus itajara

grayling ................................................................. Thymallus thymallus

greater amberjack ........................................................... Seriola dumerili
green sunfish ............................................................. Lepomis cyanellus
grenadiers ................................................................. Family Macrouridae
LIST OF SPECIES

- **groupers** ............................................................. Family Serranidae
- **Gulf butterfish** .................................................. *Peprilus burti*
- **Gulf sturgeon** .......................................................... *Acipenser oxyrinchus desotoi*
- **haddock** ............................................................... *Melanogrammus aeglefinus*
- **half-banded sea perch** ........................................... *Hypoplectrodes maccullochi*
- **Hawaiian anchovy** ................................................. *Stolephorus purpureus*
- **herrings** ......................................................... Family Clupeidae
- **hogfish** ................................................................. *Lachnolaimus maximus*
- **horned whiff** .......................................................... *Citharichthys cornutus*
- **humpback chub** ................................................... *Gila cypha*
- **Iowa darter** .......................................................... *Etheostoma exile*
- **johnny darter** ..................................................... *Etheostoma nigrum*
- **kelp greenling** ........................................................ *Hexagrammos decagrammus*
- **king mackerel** .................................................... *Scomberomorus cavalla*
- **kokanee** ............................................................... *Oncorhynchus nerka*
- **Lake sturgeon** ..................................................... *Acipenser fulvescens*
- **Lake Tanganyika sardine** ...................................... *Limnothrissa miodon*
- **Lake trout** ............................................................. *Salvelinus namaycush*
- **Lake whitefish** .................................................... *Coregonus clupeaformis*
- **lampreys** ............................................................. Family Petromyzontidae
- **largemouth bass** ................................................... *Micropterus salmoides*
- **lemon shark** .......................................................... *Negaprion brevirostris*
- **lingcod** ................................................................. *Ophiodon elongatus*
- **longnose gar** ........................................................ *Lepisosteus osseus*
- **longnose sucker** .................................................. *Catostomus catostomus*
- **longspine thornyhead** ............................................ *Sebastolobus altivelis*
- **Mediterranean horse mackerel** ................................ *Trachurus mediterraneus*
- **minnows** ............................................................... Family Cyprinidae
- **mountain whitefish** .............................................. *Prosopium williamsoni*
- **mullets** ................................................................. Family Mugilidae
- **mummichog** ............................................................ *Fundulus heteroclitus*
- **muskellunge** .......................................................... *Esox masquinongy*
- **northern anchovy** .................................................. *Engraulis mordax*
- **northern pike** ....................................................... *Esox lucius*
- **northern pikeminnow** ............................................. *Ptychocheilus oregonensis*
- **Ohrid riffle minnow** ................................................ *Alburnoides ohridanus*
- **orange roughy** ...................................................... *Hoplostethus atlanticus*
- **orangespotted sunfish** ........................................... *Leposomus humilis*
- **Owens pupfish** ..................................................... *Cyprinodon radiosus*
- **Pacific cod** ............................................................ *Gadus macrocephalus*
- **Pacific hake** .......................................................... *Merluccius productus*
- **Pacific halibut** ..................................................... *Hippoglossus stenolepis*
- **Pacific herring** .................................................... *Clupea pallasii*
- **Pacific ocean perch** ............................................ *Sebastes alutus*
- **Pacific salmon** .................................................... *Oncorhynchus spp.*
List of Species

Pacific sardine .......................................................... Sardinops sagax
Pacific tomcod .......................................................... Microgadus proximus
paddlefish ............................................................. Polyodon spathula
paddlefishes ............................................................ Family Polyodontidae
pallid sturgeon ........................................................ Scaphirhynchus albus
palmetto bass ............................................................. male Morone chrysops × female M. saxatilis
pejerrey ................................................................. Odontesthes bonariensis
pickerels .................................................................. Family Esocidae
pikes .......................................................................... Family Esocidae
pink salmon ............................................................... Oncorhynchus gorbuscha
pollock .......................................................... Pollachius virens
porbeagle ................................................................. Lamna nasus
pugnose shiner .......................................................... Notropis anogenus
pumpkinseed ............................................................. Lepomis gibbosus
rainbow smelt ............................................................ Osmerus mordax
rainbow trout ............................................................. Oncorhynchus mykiss
razorback sucker ..................................................... Xyrauchen texanus
red drum ................................................................. Trachurus ocellatus
red grouper .............................................................. Epinephelus morio
red hind .................................................................. Epinephelus guttatus
redbreast sunfish ........................................................ Lepomis auritus
redear sunfish ........................................................... Lepomis microlophus
rex sole .................................................................. Glyptocephalus zachirus
river carpsucker ........................................................... Carpiodes carpio
rock bass .................................................................. Ambloplites rupestris
rockfishes .................................................................. Sebastes spp.
rough scad ................................................................. Trachurus lathami
round goby ................................................................. Neogobius melanostomus
roundtail chub ................................................................ Gila robusta
sablefish ................................................................. Anoplopoma fimbria
salmons .................................................................. Family Salmonidae
sardines .................................................................. Family Clupeidae
sauger ................................................................... Sander canadensis
saugeye .................................................................. Sander canadensis × S. vitreus
sculpins .................................................................. Family Cottidae
sea lamprey ................................................................. Petromyzon marinus
shads .................................................................. Family Clupeidae
shorthead redhorse .......................................................... Moxostoma macrolepidotum
shortnose sturgeon ........................................................ Acipenser brevirostrum
shortspine thornyhead ................................................... Sebatothus alascanus
shoalnose sturgeon ........................................................ Scaphirhynchus platyrinchus
silver carp ................................................................. Hypophthalmichthys molitrix
skates .................................................................. Family Rajidae
smallmouth bass .......................................................... Micropterus dolomieu
smallmouth buffalo .......................................................... Ictiobus bubalus
sockeye salmon ............................................ Onchorhynchus nerka
South American lungfish ..................................... Lepidosiren paradoxa
spearfishes ...................................................... Tetraodontidae spp.
spiny dogfish .................................................. Squalus acanthias
splake .......................................................... Salvelinus fontinalis × S. namaycush
spot .............................................................. Leiostomus xanthurus
spotted bass ................................................... Micropterus punctulatus
spotted gar ........................................................ Lepisosteus oculatus
spotted seatrout ................................................ Cynoscion nebulosus
steelhead .......................................................... Onchorhynchus mykiss
striped bass ...................................................... Morone saxatilis
striped marlin ................................................... Tetraodontidae spp.
striped mullet .................................................. Mugil cephalus
sturgeons .......................................................... Family Acipenseridae
suckers .............................................................. Family Catostomidae
sunfishes .......................................................... Family Centrarchidae
swordfish .......................................................... Xiphias gladius
threadfin shad .................................................. Dorosoma petenense
tiger muskellunge ............................................. Esoc lucius × E. masquinongy
tilefish ........................................................... Lopholatilus chamaeleonticeps
trots .............................................................. Family Salmonidae
tunas .............................................................. Thunnus spp.
walleye ............................................................ Sander vitreus
walleye pollock .................................................. Theragra chalcogramma
warmouth ........................................................... Lepomis gulosus
weakfish ............................................................ Cynoscion regalis
whale shark ....................................................... Rhincodon typus
white bass .......................................................... Morone chrysops
white catfish ........................................................ Ameiurus catus
white crappie ........................................................ Pomoxis annularis
white perch .......................................................... Morone americana
white sturgeon ................................................... Acipenser transmontanus
white sucker ........................................................ Catostomus commersonii
winter flounder .................................................. Pseudopleuronectes americanus
yellow bass ....................................................... Morone mississippiensis
yellow bullhead .................................................. Ameiurus natalis
yellow perch ........................................................ Perca flavescens
yelloweye rockfish ............................................. Sebastes ruberrimus
yellowfin tuna ................................................... Thunnus albacares
yellowtail rockfish ............................................... Sebastes flavidus

Other Animals

American beaver ................................................ Castor canadensis
American eelgrass .............................................. Vallisneria americana
American lobster .............................................. Homarus americanus
Asian clam ................................................................. Corbicula fluminea
Bighorn sheep ........................................................ Ovis canadensis
Canadian waterweed .................................................. Elodea canadensis
cattails ........................................................................ Typha spp.
common stonewort ...................................................... Chara vulgaris
duckweed ....................................................................... Lemma spp.
Dungeness crab ........................................................... Metacarcinus magister
eastern king prawn ...................................................... Penaeus plebejus
eelgrasses ...................................................................... Vallisneria spp.
Eurasian watermilfoil ..................................................... Myriophyllum spicatum
fingernail clam ............................................................. Family Sphaeriidae
Florida apple snail ........................................................ Pomacea paludosa
lesser scaup ................................................................. Aythya affinis
longfin squid ............................................................... Family Chironomidae
midge ........................................................................... Family Chironomidae
musk rat ......................................................................... Ondatra zibethicus
New Zealand scampi ...................................................... Metanephrops challengeri
northern fur seal .......................................................... Callorhinus ursinus
northern tiger prawn ...................................................... Penaeus semisulcatus
phantom midge ............................................................. Family Chaoboridae
pondweed ........................................................................ Potamogeton spp.
porpoises ....................................................................... Family Phocoenidae
raccoon ........................................................................... Procyon lotor
red king crab ................................................................. Paralithodes camtschaticus
scallops .......................................................................... Family Pectinidae
sea scallop ..................................................................... Placopecten magellanicus
southern geoduck .......................................................... Panopea abbreviata
southern rock lobster ..................................................... Jasus edwardsii
spinner dolphin ............................................................. Stenella longirostris
spotted dolphins .......................................................... Stenella attenuata
Steller sea lion .............................................................. Eumetopias jubatus
water lilies ....................................................................... Nymphaea spp.
watermilfoils ................................................................ Myriophyllum spp.
zebra mussel ................................................................. Dreissena polymorpha
Preface

This edition of *Fisheries Techniques* is based on the first two editions, which were edited by Larry A. Nielsen, David L. Johnson, Brian R. Murphy, and David W. Willis. These editors selected us to edit the third edition based on our response to a call for proposals. Similarly, we selected chapter author teams based on submitted proposals. Unfortunately, many excellent proposals were narrowly edged out by others in this process. We thank all individuals and teams that submitted proposals for their contributions.

Much the same as the first two editions, the third edition has two goals. First, it is intended to serve as a comprehensive instructional volume on fisheries sampling and analysis techniques (not management) for upper-division undergraduate and graduate courses. Second, it is intended to serve as a basic reference volume for practicing fisheries professionals. The first two editions were successful at meeting both goals: they were neither too complicated for undergraduates to understand nor so simple as to be dismissed by experienced professionals. We sought to maintain that critical balance in the third edition as well. Many chapters went through multiple revisions in an attempt to achieve that goal.

Most chapters in this edition were rewritten entirely, and all were updated to include technological, analytical, and philosophical advances in fisheries science since the second edition. We conducted an Internet survey before starting work on this edition to seek input from fisheries professionals, educators, and students on its content and format. More than 400 respondents, primarily managers and researchers, provided insightful guidance about specific chapters and the book in general. They recommended, and we incorporated, greater emphases on quantitative techniques, boxed examples and case histories, and estuarine and marine systems, as well as greater depth of treatment in general, explicit consideration of pros and cons of techniques, more and clearer visual representations, more references, and Internet links. Other recommendations included data sets and programs or spreadsheets on a CD to reinforce concepts presented in the boxes, as well as slide show presentations of gears and techniques. These recommendations were not embraced by the author teams, who we kept busy with multiple chapter revisions. Moreover, the CD that accompanied *Analysis and Interpretation of Freshwater Fisheries Data* (Guy and Brown 2007) addressed the need for example data sets and programs, and the images and videos available (and constantly updated) on the Internet made the canned image presentations superfluous. We sought instead to provide content that promoted understanding and that would withstand technological obsolescence. Responses to the survey also helped identify chapters that could be deleted, coalesced, or reprised and material that needed to be added or moved among chapters; we tried our best. The careful reader will note some redundancy on important topics among some chapters. Such redundancy was necessary for chapter cohesion in some cases, but in others it was retained to reveal differences in perspectives among segments of the fisheries profession. We are a diverse lot.

The third edition was created under the auspices of the Education Section of the American Fisheries Society (AFS), as were the first two editions, and exists because dedicated fisheries scientists, managers, and educators volunteered thousands of hours to produce it. Each chapter was reviewed by several academics and practitioners selected because of their expertise in the content.

Debby Lehman, Aaron Lerner, and Kurt West at AFS expertly and patiently guided our work on this edition and enabled its publication. Eva Silverfine Ott served as copy editor; she is amazingly adept at her craft. We were fortunate to have the opportunity to work with her. Elizabeth Ono Rahel created many of the figures in this edition and modified others by Betsy A. Sturm and Susan Lampton from earlier editions; Elizabeth was a joy to work with. Frank Rahel voluntarily provided her with helpful technical advice. Many figures and images were graciously provided by individuals, publishers, manufacturers, and suppliers; their contributions are credited in the figure captions. The underwater photo of bull trout Salvelinus confluentus on the cover is by Joel Sartore—National Geographic Stock with Wade Fredenberg (U.S. Fish and Wildlife Service National Digital Library). Other cover images are reprinted from the contents of this edition or were taken by the lead editor or personnel of the Oklahoma Cooperative Fish and Wildlife Research Unit or the Montana Cooperative Fishery Research Unit under his supervision.

Many chapters in this edition are based on chapters in the first two editions that were prepared by other authors. The editors and authors of this edition gratefully acknowledge their contributions. The authors of the first chapter thank D. Willis and B. Murphy for essentially instantaneous reviews of the chapter under pressing circumstances. The authors of Chapter 3 note that the South Dakota Cooperative Fish and Wildlife Research Unit is jointly supported by the U.S. Geological Survey, South Dakota State University, South Dakota Department of Game, Fish and Parks, and the Wildlife Management Institute. J. Vokoun (Chapter 4) thanks S. H. King for acquiring images and permissions and T. Meyer for information about the Global Positioning System (GPS) technologies discussed in Box 4.1. W. Fisher thanks D. Dauwalter for information for Box 4.2 on using GPS and geographical information systems to map aquatic habitats. G. Moyer (Chapter 5) acknowledges A. Snyder and S. Platania for helpful comments on earlier versions of the chapter, and B. Sloss acknowledges R. Franckowiak for useful comments. The authors of Chapter 5 note that the Georgia Cooperative Fish and Wildlife Research Unit is sponsored jointly by Georgia Department of Natural Resources, the University of Georgia, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, and the Wildlife Management Institute. Moreover, the Wisconsin Cooperative Fishery Unit is sponsored jointly by the University of Wisconsin–Stevens Point, the U.S. Geological Survey, Wisconsin Department of Natural Resources, and the Wildlife Management Institute. The authors of Chapter 6 thank E. Ono Rahel for excellent technical drawings and numerous colleagues who provided information and references. The authors of Chapter 8 thank W. Fredenberg, J. Johnson, and T. Kwak for their helpful, constructive reviews of initial drafts of this chapter. The authors of Chapter 9 thank M. Duncan and D.
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Digital textbooks are rapidly gaining popularity; the format is especially conducive to rapidly changing disciplines such as fisheries science and enables constant updating and correction and linking to references, software, Web sites, images, and video. Therefore, this edition of Fisheries Techniques may well be the last print edition, for better or worse. Until the fourth edition comes along, please forward any corrections, comments, updates, criticisms, and praise to the lead editor at zale@montana.edu for dissemination by the latest appropriate technology.

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