Journal of Northwest Atlantic Fishery Science

Volume 41
2008–2009

Reproductive and Recruitment Processes of Exploited Marine Fish Stocks

Printed and Distributed in April 2009
Northwest Atlantic Fisheries Organization
P. O. Box 638, Dartmouth, Nova Scotia
Canada B2Y 3Y9
Tel.: (+1 902) 468–5590 • Fax: (+1 902) 468–5538
Email: journal@nafo.int • Website: www.nafo.int

Journal of Northwest Atlantic Fishery Science

Scientific publications by ICNAF and NAFO have been in existence since ICNAF began in 1949 with the ICNAF Special Publication series dealing with proceedings of scientific symposia. The *ICNAF Research Bulletin* was started in 1964 to provide a means of publishing results of scientific research relevant to ICNAF. The ICNAF Research Bulletin was terminated in September 1979 after the issue of Number 14. The first volume of the NAFO *Journal of Northwest Atlantic Fishery Science* was published in December 1980, after NAFO came into force replacing ICNAF in 1979.

The Northwest Atlantic fisheries have a rich history, and a great deal of research has been sponsored and encouraged by NAFO and its predecessor ICNAF. NAFO has been a leader in international organizations in the application of science to fishery management and in the regulation of fisheries. In accordance with its mandate to disseminate information on fisheries research to the scientific community, the Scientific Council of NAFO publishes the *Journal of Northwest Atlantic Fishery Science*, which contains peer-reviewed primary papers, and *NAFO Scientific Council Studies*, which contains unrefereed papers of topical interest and importance to the Scientific Council. Lists of these and other NAFO publications are given on the back of this issue.

Editorial Policy

The Journal provides an international forum for the primary publication of original research papers, with emphasis on environmental, biological, economic and social science aspects of fisheries and their interactions with marine habitats and ecosystems. While the Journal is intended to be regional in scope, papers of general applicability, and methodological and review papers, irrespective of region, are considered. Space is available for notes and letters to the editor to facilitate scientific discussion of published papers. Both practical and theoretical papers are eligible. All papers are peer-reviewed to determine their suitability for primary publication. Associate Editors arrange for the peer-reviews and ensure that the papers accepted for publication meet the high standards required for the Journal. Manuscripts approved for publication are accepted with the understanding that they are not copyrighted, published or submitted elsewhere except in abstract form. There are no page charges.

Editorial Board

Foreword

The Scientific Council of NAFO publishes the *Journal of Northwest Atlantic Fishery Science*, which contains peer-reviewed primary papers on original research. In 2005, Scientific Council took steps necessary to modernize the journal's publication medium and introduced a more appropriate copyright notice. Articles are now published electronically and all are freely available at http://journal.nafo.int. The bound print volumes are treated as a compilation of the web-based articles. Additionally, the journal supports the use of the digital object identifiers (doi) for electronic media and encourages others to support open-access principles and the doi initiative.

In 2007, the NAFO Scientific Council joined forces with PICES and ICES to hold a symposium on "*Reproductive and Recruitment Processes of Exploited Marine Fish Stocks*". The objective of this Symposium was to bring together scientists from different regions and working on different marine species. Significant advances in our understanding of the reproductive biology and the integration of these finding in to fisheries management highlight the timeliness of this meeting. This is reflected in the choice of theme sessions:

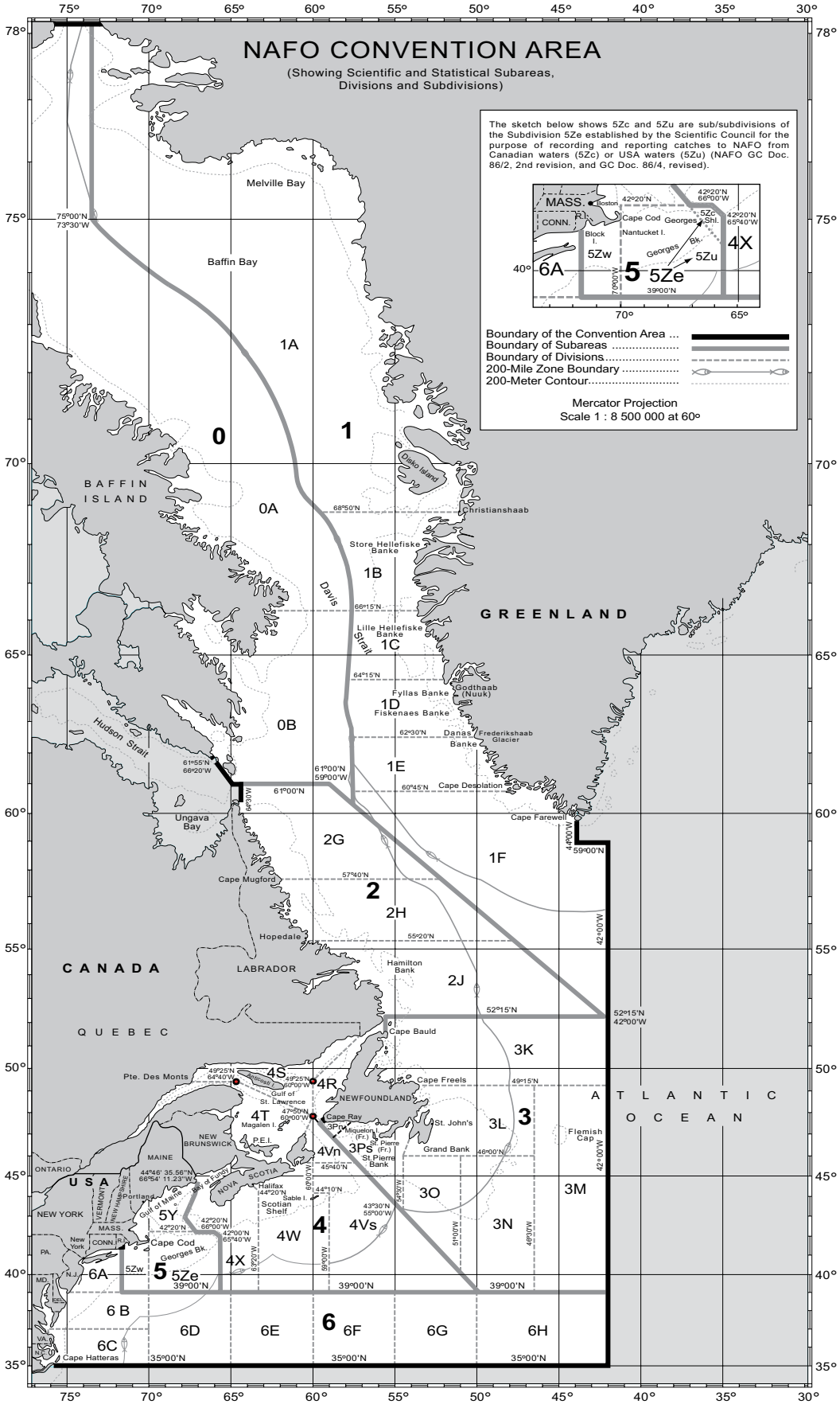
- Age and Size at Sexual Maturation,
- Fecundity and Spawning Success,
- Survival of Eggs and Larvae, and
- Stock Assessment and Management Implications.

It takes many people to organise a symposium: Convenors, Steering Committee members, Secretariat staff, Meeting facility staff, *etc*. However, and on behalf of the Co-convenors, I would particularly like to acknowledge the important contributions made by the reviewers of the articles contained within this volume and pass on a "big thank you" to:

Anthony Thompson
Bernard Sainte Marie
Bradley Stevens
Brian MacKenzie
Dan Nichol
David Brickman
David Somerton
Ed Trippel
Elizabeth Logerwell
Fabian Mollet
Gerd Kraus
Ian Butts
James Kennedy
Jay Burnett
Joanne Morgan
Katja Enberg
Keith Brander
Kevin Bailey
Mark Dickey-Collas
Mark Payne
Michael Sinclair
Mikio Moriyasu
Myron Peck
Olav Rune Godø
Pam Jensen
Paul Smith
Peter Witthames
Reinier Hille Ris Lambers
Richard McBride
Richard Nash
Rick Methot
Rick Rideout
Rudi Voss
Sarah Kraak
Shelley Armsworthy
Steve Parker
Steven Beggs
Suam Kim
Tara Marshall
Thomas Brunel
Timothy Loher
Trond Kristiansen

May 2009

Anthony Thompson
General Editor,
Journal of Northwest Atlantic Fishery Science


NAFO CONVENTION AREA
(Showing Scientific and Statistical Subareas, Divisions and Subdivisions)
The sketch below shows 5Zc and 5Zu are sub/subdivisions of the Subdivision 5Ze established by the Scientific Council for the purpose of recording and reporting catches to NAFO from Canadian waters (5Zc) or USA waters (5Zu) (NAFO GC Doc. 86/2, 2nd revision, and GC Doc. 86/4, revised).
Boundary of the Convention Area ...
Boundary of Subareas .....
Boundary of Divisions.....
200-Mile Zone Boundary .....
200-Meter Contour.....
Mercator Projection
Scale 1 : 8 500 000 at 60°
Melville Bay
Baffin Bay
BAFFIN ISLAND
GREENLAND
Disko Island
Christianshaab
Store Hellefiske Banke
Lille Hellefiske Banke
Davis Strait
Fyllas Bank
Godthaab (Nuuk)
Fiskenaes Banke
Danas Banke
Frederikshaab Glacier
Cape Desolation
Cape Farewell
Hudson Strait
Ungava Bay
Cape Mugford
Hopedale
CANADA
LABRADOR
QUEBEC
Hamilton Bank
Cape Bauld
Pte. Des Monts
Gulf of St. Lawrence
NEWFOUNDLAND
Cape Freels
Cape Ray
St. John's
Grand Bank
St. Pierre Bank
Flemish Cap
ATLANTIC OCEAN
Magdalen I.
P.E.I.
NEW BRUNSWICK
MAINE
ONTARIO
USA
SCOTIA
Halifax
Sable I.
Scotian Shelf
Bay of Fundy
NOVA
Portland
NEW YORK
VERMONT
NEW HAMPSHIRE
MASS.
CONN.
R.I.
Cape Cod
Georges Bk.
Block I.
Nantucket I.
5Zc Shl.
New York
PA.
N.J.
MD.
DEL.
VA.
N.C.
Cape Hatteras
0
1
0A
1A
1B
1C
1D
1E
1F
0B
2G
2H
2J
2
3K
3L
3
3M
3N
3O
3P
3Ps
4R
4S
4T
4Vn
4Vs
4W
4X
4
5Y
5Z
5Zw
5Ze
5Zu
5Zc
6A
6B
6C
6D
6E
6F
6G
6H
6
Boston
Georges Shl.
Georges Bk.
Miquelon (Fr.)
St. Pierre (Fr.)
75°
70°
65°
60°
55°
50°
45°
40°
35°
30°
78°
75°
70°
65°
60°
55°
50°
45°
40°
35°

Co-convenors

Edward Trippel

Ed Trippel is a Research Scientist at the St. Andrews Biological Station, Fisheries and Oceans Canada. His long-term interest lies in fish reproduction with the aim of incorporating its elements into improved fisheries management advice in order to assist in rebuilding the depleted marine fishery resources of the North Atlantic.

His extensive research in this area of stock-recruit theory includes characterizing properties of egg and sperm quality, mating behaviour and understanding the relative roles of maternal and paternal factors and temperature in shaping early life history fitness traits of marine fish larvae. These findings have implications for the establishment of biological reference points to safeguard against stock collapse and assist in fish recovery.

Richard Brodeur

Richard Brodeur is a Research Fisheries Oceanographer working in the Fish Ecology Division of the Northwest Fisheries Science Center, NOAA Fisheries, and is based in Newport, OR. He began his career working on early life history and recruitment dynamics of walleye pollock in the Gulf of Alaska and Bering Sea. He has continued to study recruitment variability and mechanisms in marine fish along the west coast of the US, particularly in reference to habitat preferences and trophic ecology of larval and juvenile fishes. He has been heavily involved with the North Pacific Marine Science Organization (PICES) serving on several committees and working groups and organizing a number of special sessions. He has published on a variety of topics ranging from satellite oceanography to fish bioenergetics to fisheries acoustics, but has focused much of his research on recruitment in relation to the ocean environment.

Mark Dickey-Collas

Mark Dickey-Collas is a Research Scientist and Scientific Adviser on Fisheries based at Wageningen IMARES in the Netherlands. His initial training in biological oceanography and then aquaculture illustrates his broad horizons and interest in the bigger picture. His research interests cover ichthyoplankton dynamics, recruitment processes, stock assessment methods, variable productivity, management strategy evaluations, pelagic fisheries and the North and Irish Seas.

Keynote Speaker

Edward Houde

Edward Houde is a Professor and fisheries scientist at the University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory in the United States. Research interests are fisheries science and management, larval fish ecology, and fisheries oceanography. Understanding causes of recruitment variability has been a particular interest in his 40-year career. He is presently the U.S.Co-Delegate to ICES.

(Presentation on pages 53–70)

Summing Up

Keith Brander

Keith Brander works at the Danish Institute for Aquatic Resources as coordinator of the ICES/GLOBEC programme on Cod and Climate Change. His first three peer reviewed papers, in 1971, were on the tides of Aldabra, sperm activation in barnacles and species diversity of coral reef infauna. His PhD (1974) was on population dynamics of Irish Sea cod and he worked at Lowestoft on fisheries assessment and management, early life history of fish, marine ecosystems and impacts of climate until 1996, when he moved to ICES. He was lead author on fisheries for the 2007 IPCC report. He has worked as an adviser on fisheries management for the EU, DEFRA (UK) and FAO and has taught in the UK, Denmark, Italy, China and Canada. He was president of the Sir Alistair Hardy Foundation for Ocean Science for six years and has taken part in the design, steering, implementation and evaluation of many EU and international research programmes.

(Presentation on pages xx–xxiv)

Contents