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Volume 25

*Variations in Maturation, Growth,
Condition and Spawning Stock Biomass
Production in Groundfish*

J. Morgan, J. Burnett, and E. Aro

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Foreword

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 notes on original research, and *NAFO Scientific Council Studies*, which contains papers of topical interest and importance. Each year since 1981, the Scientific Council has held at least one Special Session on a topic of particular interest, and many of the contributions to those sessions have been published in either of these NAFO Publications. For 1998, the Scientific Council initiated this Special Session titled "Variations in Maturation, Growth, Condition and Spawning Stock Biomass Production in Groundfish", as a Symposium of topical interest to NAFO. The Symposium was hosted by the NAFO Scientific Council in conjunction with the NAFO 20th Annual Meeting held at the Hotel Altis, Lisbon, Portugal. In accordance with the decision of the Scientific Council in September 1998 (*NAFO Sci. Coun. Rep.*, 1998, pg. 152), this volume of the *Journal of Northwest Atlantic Fishery Science* contains papers presented at the Symposium.

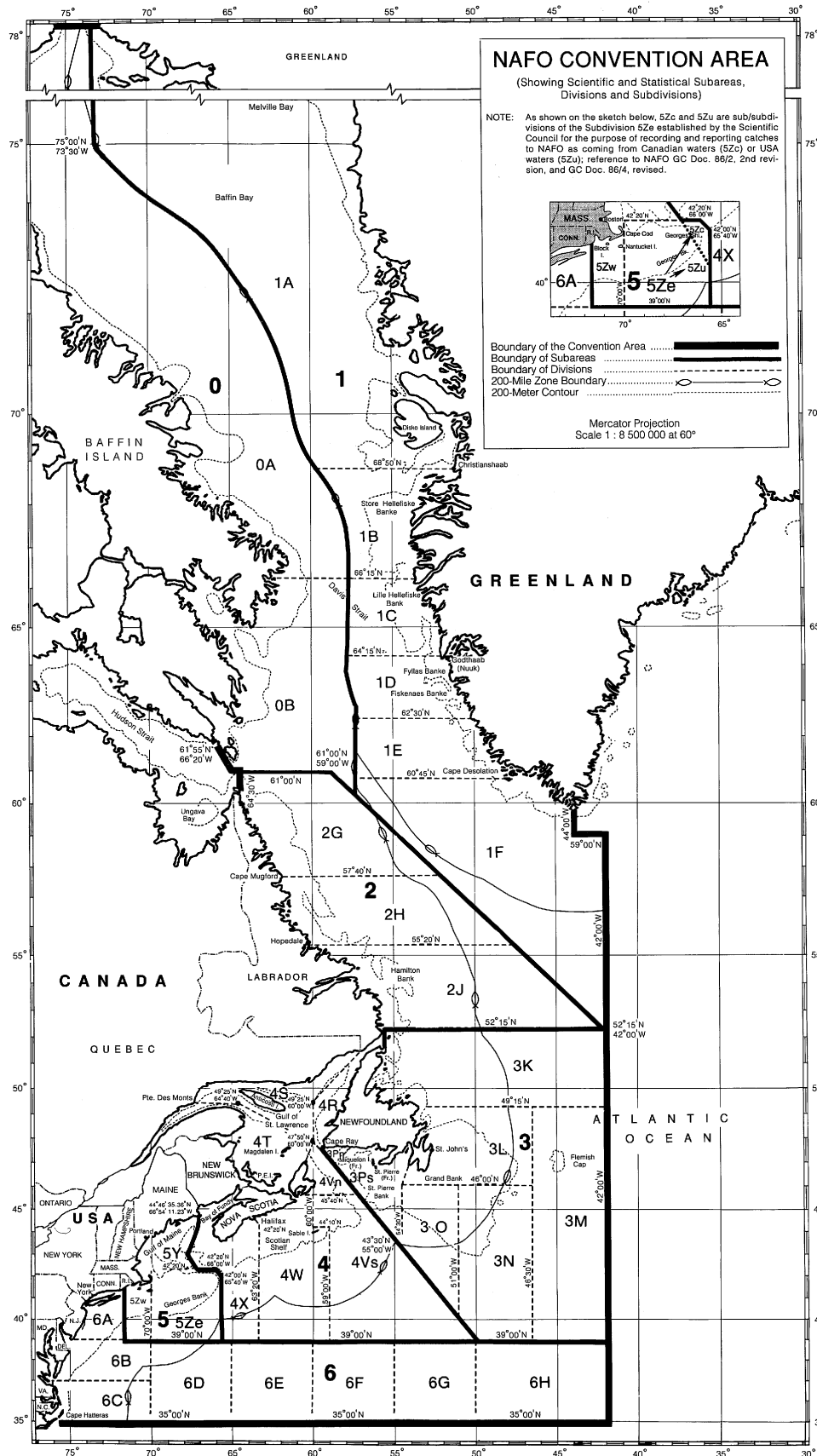
The Symposium was jointly convened by E. Aro, Finnish Game and Fisheries Research Institute, Helsinki, Finland; J. Burnett, Northeast Fisheries Science Center, Massachusetts, USA; and J. Morgan, Northwest Atlantic Fisheries Center, St. John's, Newfoundland, Canada, with J. Morgan taking the lead role.

In accordance with the decision of the Scientific Council (*NAFO Sci. Coun. Rep.*, 1998, pg. 153), the co-conveners were invited to undertake the normal Journal editorial process/peer review of the papers. At the NAFO Secretariat some final editorial work was done as needed, and this issue of the Journal was printed at the Secretariat. The editors are congratulated in achieving the Scientific Council's objectives of completing the editorial process within one year of the Symposium.

The quality of the presentations and the stimulating discussions at the Symposium, highlighted the scientific importance of the proceedings. A Scientific Council Working Group has been struck to further address the issues identified at this Symposium.

October, 1999

Tissa Amaratunga
Technical Editor, Journal



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Introduction

The set of papers that appears in this special volume is a result of the Symposium entitled '*Variations in Maturation, Growth, Condition and Spawning Stock Biomass Production in Groundfish*' that was organized by the Scientific Council of the Northwest Atlantic Fisheries Organization. A total of 28 oral and 7 poster presentations were made at the Symposium. A summary Report of the Symposium follows with details of general conclusions and recommendations of the Symposium. Nineteen papers from this Symposium appear in this volume. All papers were subject to the normal peer review process of the *Journal of Northwest Atlantic Fisheries Science*.

The papers presented at the Symposium represent a wide variety of research and demonstrates that this is clearly an active field. Some general conclusions were evident but it was also clear that we have a long way to go before we can accurately incorporate a stock's true reproductive potential into its assessment and management.

This volume would not have been possible without the dedicated work of the NAFO Secretariat. As well, many people gave of their time to provide thorough peer review of the submitted papers. A list of the reviewers follows: J. Anderson (Canada), G. Bolz (USA), J. Bratley (Canada), W. Brodie (Canada), J. Brown (Canada), R. Brown (USA), S. Cadrin (USA), S. Clark (USA), A. Gundersen (Norway), H. Heessen (Netherlands), L. Hendrickson (USA), A. Howe (USA), S. Junquera (Spain), F. Köster (Germany), H.-L. Lai (USA), K. Lang (USA), H. Lehtonen (Finland), J. Link (USA), T. Marshall (Norway), D. Mountain (USA), K. Nedreaas (Norway), A. Nissling (Sweden), R. Parmanne (Finland), P. Pepin (Canada), D. Pierce (USA), O. Rechlin (Germany), M. Ross (USA), D. Schnack (Germany), P. Shelton (Canada), G. Shepherd (USA), M. Showell (Canada), S. Smith (Canada), K. Sosebee (USA), M. Terceiro (USA), J. Tomkiewicz (Denmark), E. Trippel (Canada), L. Urho (Finland), K. Wieland (Germany), S. Wigley (USA).

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Report of the Symposium

The Symposium on '*Variations in Maturation, Growth, Condition and Spawning Stock Biomass Production in Groundfish*' was held during 9–11 September 1998 at Hotel Altis, Lisbon, Portugal. The symposium was hosted by Scientific Council in conjunction with the 20th Annual Meeting of NAFO. E. Aro (Finland), J. Burnett (USA) and J. Morgan (Canada) were co-convenors of the symposium. There were 77 participants from 17 countries (Brazil, Canada, Denmark, Faroe Islands, Finland, France, Federal Republic of Germany, Greenland, Iceland, Japan, Norway, Portugal, Russian Federation, Spain, Turkey, United Kingdom and the United States of America). The list of participants is given at the back of this volume.

The Symposium was opened by H.P. Cornus (EU–Germany), Chairman of Scientific Council, who on behalf of the Scientific Council welcomed participants to Lisbon. In a brief presentation, the Chairman described the NAFO structure and the general objectives of the Symposium.

The following report was prepared and presented to the Scientific Council during the 20th NAFO Annual Meeting by the co-convenors.

Introduction

Changes in maturation, growth and condition, duration of the spawning season and the spatial distribution of the spawning stock have been observed in several groundfish stocks, particularly in the North Atlantic. These variations have direct implications for spawner biomass production per recruit and management strategies that incorporate these parameters. The purpose of this Symposium was to discuss the causes and consequences of such variations, including evidence of environmental, density-dependent, predation or size-selective fishing effects and consequences for spawner biomass per recruit and population growth rate, as well as implications for management strategies.

Three invited keynote speakers made thematic presentations and an invited presentation was made by 2 invited speakers to introduce the concluding discussions. There were 35 contributed papers, 28 of which were oral presentations and 7 were posters. A complete list of papers presented at the symposium in the sequence the papers were presented is given at the end of this report; the papers that appear in this volume are highlighted.

Papers covered a wide range of topics related to the symposium theme. There were some clear conclusions that could be drawn from the symposium presentations. It was also clear that variations in maturation, growth, condition and spawning stock biomass production have major implications for the assessment and management of groundfish stocks. Participants of the symposium also recognised the need for further research and made recommendations for such research and on the use of information on growth, maturation and condition in the assessment of stocks.

I. General Conclusions

- Realized fecundity (number of eggs spawned) is a function of energetic status of fish
- Size and condition of spawning female affect quality and viability of eggs – and hence net reproductive output
- Egg and larval mortality is significantly lower in second time spawners than first time spawners
- Determination of maturity should be accomplished (or at least verified) by microscopic means, not macroscopically
- Temporal and spatial fishing patterns may alter age/size at maturity, fecundity, egg size and growth rates – thereby affecting stock-recruitment relationships and biological reference points
- Stock density can influence maturation rates

- Properly measuring and including parent-progeny relationships into stock assessments and scientific advice is essential for the proper management of fishery resources
- Spawning stock biomass (SSB) as such may not be the best estimate for stock reproductive potential
- Large fish generally produce larger and more viable eggs and larvae than smaller fish; large fish produce more batches of eggs per spawning and spawn over a longer period of time than smaller fish
- The proportion of fish mature at age and size are interrelated with large fish at a given age more likely to be mature and older fish at a given size more likely to be mature. Annual population egg production rates are more sensitive to variations in fecundity than variations in sex ratio or female maturity ogives
- Periodicity in recruitment and stock abundance can be caused by cyclical patterns of climate variability
- Onset of maturity occurs only when fish accumulate enough energy, or have sufficient energetic reserves, to undertake spawning and migration in the following year
- Not all adult fish participate in spawning
- Accounting for unequal sex ratios is important in calculating SSB, particularly when male fish often mature earlier than females and do not live as long (perhaps due to spawning mortality)
- Fish can be more susceptible to capture just after spawning – because of their condition – than at other times
- Productivity of cold water stocks can differ substantially from warm water stocks due to slower growth and reduced condition
- Variations in annual growth rates can have a significant impact on calculations of biomass and SSB. However, predicting these changes can be very difficult
- Liver condition (HSI) may be a good barometer of stock reproductive potential
- Reproduction has very significant energetic costs and consequences

II. Implications for Assessment and Management

For the management of fish stocks, changes in demographic parameters and vital rates of fish stocks can profoundly affect the assessment and management of these resources. Changes in these parameters have implications for all areas of stock assessment, including short-term projections, equilibrium calculations, retrospective analyses, and rebuilding strategies. The nature of the variability observed for these parameters (i.e., high or low frequency, trended, predictability) may dictate which methodological approaches to assessment calculations should be undertaken (e.g. running averages, annual estimates, predictive models).

III. Recommendations

In recent decades, stock assessment and management has taken into account Quadrant 1 and some factors in Quadrant 2 in the Figure below. However, it is evident that more research is needed to fill the gaps in Quadrant 3 and 4 as well as gaps between Quadrants.

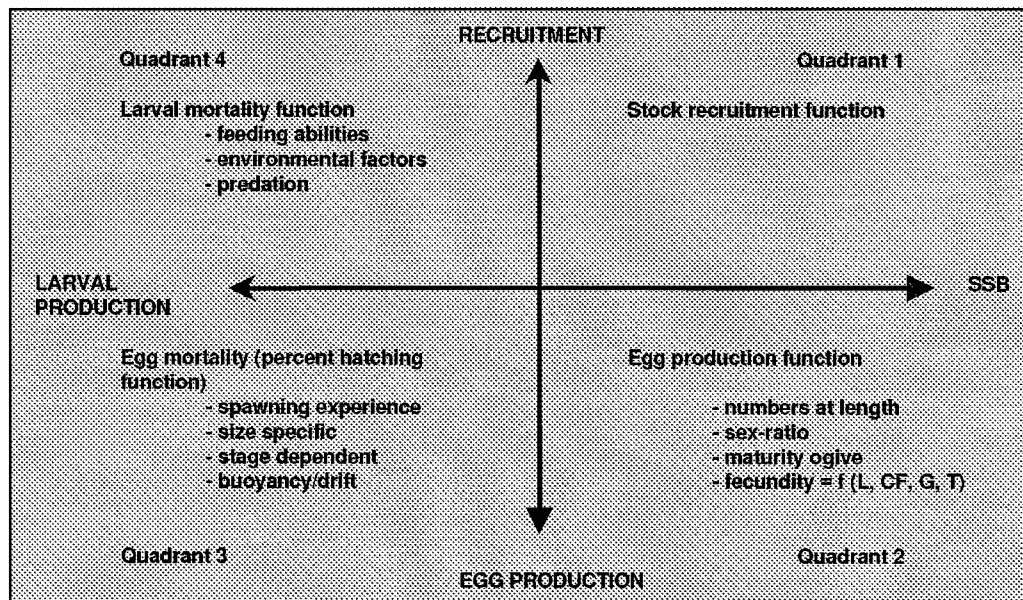
The Symposium **recommends** that the NAFO Scientific Council should establish a Working Group in order to:

- Explore and review availability of information and existing data on reproduction potential by area and species
- Explore possibilities to develop standard internationally co-ordinated research protocols to estimate egg and larval production
- Explore and evaluate alternative methods to estimate reproductive potential annually as part of routine monitoring and sampling schemes (such as HSI)

- Review possibilities to develop methods and applications to estimate stock's reproductive potential for assessment and management

The Symposium also **recommends** that; whenever possible, stock assessments should take into account the following points and information when evaluating a stock's reproductive potential:

- Age and length at maturity
- Changes in mean weights at age
- The use of annual maturity ogives rather than "knife-edge" ogive for all years to estimate SSB
- Estimation of SSB
- Stock-Recruitment relationship plot
- Condition factor data – trends if possible
- Age and sex specific condition factors
- Fecundity estimates
- Egg quality (size, viability), in relation to reproductive history and/or condition
- Apply maturity, fecundity, condition and egg quality data to compile stock reproductive potential
- Establish minimum safe threshold level of stock reproductive potential (conservation threshold)



Symposium Presentations

Oral Presentations

Kjesbu, O.* Reproductive investment in Atlantic cod (*Gadus morhua* L.): comparisons between two different stocks and wild, captive and artificially reared specimens.

Session 1:

Ouellet, P., I. Berube, and Y. Lambert. Cod egg characteristics and viability related to maternal size and nutritional condition.

Solemdal, P., O. S. Kjesbu, and M. Fonn. Long-term studies on reproduction in cod: egg and early larvae mortality related to the batch spawning and the effect of multiple spawning.

Ajiad, A., O. Nakken, and T. Jakobsen. Sexual difference in maturation of Northeast Arctic cod.

Saborido-Rey, F., O. S. Kjesbu, and A. Thorsen. Buoyancy of Atlantic cod (*Gadus morhua*) larvae in relation to spawning experience: first and second time spawners.

Junquera, S., E. Roman, and X. Paz. Changes in Greenland halibut growth, condition and fecundity in Flemish Cap – Flemish Pass area.

Gundersen, A.C., O. S. Kjesbu, A. Stene, and K. H. Nedreaas. Fecundity of Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*).

Korsbrekke, K. Variations in maturity of haddock in the Barents Sea in relation to year class strength, age, size, sex and area.

Rochet, M-J. Fishing effects on maturity and fecundity in teleosts: their consequences for stock-recruitment relationships and spawning biomass per recruit.

O'Brien, L. Factors influencing rates of maturation in the Georges Bank and Gulf of Maine Atlantic cod stocks.

Murawski, S. A., P. J. Rego, and E. A. Trippel. Why are western Atlantic groundfish maturing younger?

Walsh, S. J. and M. J. Morgan. Variation in maturation, sex ratios and age/size composition of yellowtail flounder (*Pleuronectes ferruginea*) on the Grand Bank.

Session 2:

Trippel, E.A*. Parent-progeny relationships: challenges for groundfish stock assessments.

Saborido-Rey, F., G. Perez-Gandaras, and S. Junquera. Spawning biomass variation in Atlantic cod (*Gadus morhua*) in relation with changes in growth and maturation in Flemish Cap.

Cook, R. and P. Kunzlik. Growth and maturity for North Sea cod.

Mackenzie, B. R., J. Tomkiewicz, F. Koster, and A. Nissling. Quantifying and disaggregating the 'spawner' effect: incorporating stock structure, spatial distribution and female influences into estimates of annual population egg production.

Marteinsdottir, G., A. Gundmundsdottir, V. Thorsteinsson, and G. Steffanson. Spatial variation in abundance, size composition and viable egg production of spawning cod (*Gadus morhua* L.) in Icelandic waters.

* Keynote Speaker
Included in this publication.

- Rikhter, V. A.** On interpretation of plots of 'stock recruitment' relation of silver hake (*Merluccius bilinearis*) near the North-western Atlantic.
- Taylor, L. and G. Steffanson.** Growth and maturation of haddock in Icelandic waters.
- Godø, O. R. and T. Haug.** Growth rate and sexual maturity in cod (*Gadus morhua*) and Atlantic halibut (*Hippoglossus hippoglossus*).
- Burton, M. P. M.** Potential errors in measuring spawning stock biomass: determining the effects of non-participatory adults for some Atlantic groundfish species.
- Ajiad, A. and T. Jakobsen.** Management implications from sexual differences in maturation and spawning mortality of Northeast Arctic cod.
- Ozbilgin, H., R. S. T. Ferro, and J. R. Hutcheon.** Seasonal variation in the biological condition and trawl codend selectivity of North Sea haddock, *Melanogrammus aeglefinus*.
- Wigley, S. E., J. Burnett, and P. J. Rago.** An evaluation of maturity estimates derived from two sampling schemes: are the observed maturation changes fact or artifact?
- Morgan, M. J.** The effect of a change in perception of length distribution of a population on maturity at age, weight at age and spawning stock biomass.

Session 3:

- Dutil, J.-D., M. Castonguay, Y. Lambert, and D. Gilbert*.** Growth, condition and mortality relationships in Atlantic cod: should we factor in latitudinal and temporal variations in stock productivity?
- Shelton, P. A., G. R. Lilly, and E. Colbourne.** Patterns in annual growth of Div. 2J3KL cod and possible prediction for stock projections.
- Ratz, H.-J., M. Stein, and J. Lloret.** Variation in growth and recruitment of Atlantic cod (*Gadus morhua*) off Greenland during the second half of the 20th century.
- Yaragina, N.A. and C. T. Marshall.** Trophic influences on seasonal and interannual variation in the hepatosomatic index of Northeast Arctic cod.
- Marshall, C.T. and N. A. Yaragina.** Consequences of variation in the liver condition for recruitment dynamics of Northeast Arctic cod.
- Lambert, Y. and J.-D. Dutil.** Energetic consequences of reproduction in Atlantic cod (*Gadus morhua*) in relation to pre-spawning level of energy reserve.
- Serchuk, F. and S. Murawski.*** Implications of variations in maturation, growth, condition and spawning stock biomass production on groundfish management strategies: some real world examples.

* Keynote Speaker
Included in this publication.

Posters Presentations

Andrede, J. P., P. Santos, J. Teixeira, A. and Monteiro. The fecundity of the bastard sole, *Microchirus azevia* (Pisces: Solidae) off the Portuguese coast.

Hoines, A. S. and O. A. Bergstad. Structure and biology of exploited and unexploited populations of the lesser sandeel *Ammodytes marinus* of the North sea and the coast of Norway.

Markovic, L. M.-J. Rochet, and M. Plantagenest. Factors of variation of age and size at maturity in some North Sea gadiformes.

Stene, A., A. Gundersen, P. Solemdal, K. J. Nederaas, and O. T. Albert. Early development of Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*).

Thorsen, A., T. E. Andersen, O. S. Kjesbu, J. Klungxyr, S. Meier, and A. Svoldal. Effects of alkylphenols on reproduction of cod.

Tomas, A. Fishery biology of the cusk eel, *Ophidion holbrooki* (Ophidiiformes) in the southeastern Brazil.

Wigley, S. E. Effects of first-time spawners on stock-recruitment relationships for two groundfish species.

* Keynote Speaker
Included in this publication.

