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SCIENTIFIC COUNCIL MEETING – JUNE 2010

Report of the NAFO Scientific Council Working Group on Reproductive Potential

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Progress of the NAFO Working Group on Reproductive Potential was provided by E.A. Trippel (Chair). The establishment of the Working Group on Reproductive Potential followed a recommendation of the Symposium on "Variations in Maturation, Growth, Condition and Spawning Stock Biomass Production in Groundfish" hosted by NAFO Scientific Council from 9-11 September 1998, Lisbon, Portugal. The Working Group is comprised of 21 members representing 10 countries (Canada, Denmark, Germany, Greece, Iceland, Norway, Russia, Spain, United Kingdom, and USA).

The 9th Meeting of the NAFO WG on Reproductive Potential was held at the Parthenon Hotel in Athens, Greece, March 15-19, 2010 to address the ToRs approved by Scientific Council in June 2008. There were 16 WG participants spanning 7 countries: Joanne Morgan (Canada), Olav Kjesbu (Norway), Rosario Dominguez (Spain), Loretta O'Brien, (USA), Yvan Lambert (Canada), Tara Marshall (UK), Rick Rideout (Canada), Jonna Tomkiewicz (Denmark), Hilario Murua (Spain), Peter Wright (UK), Alexandre Alonso-Fernández (Spain), Richard McBride (USA), Stylianos Somarakis (Greece), Fran Saborido-Rey (Spain) and Ed Trippel (Canada). A meeting of the EU COST Research Network Action Fish Reproduction and Fisheries (FRESH) (Coordinator: Fran Saborido-Rey) was also held during this period. Mutual benefits of having the two groups meet together were achieved as both have complimentary science and management advice objectives. To facilitate this arrangement the meeting was co-chaired by Ed Trippel and Fran Saborido-Rey. Local arrangements were greatly appreciated for the meeting of 21participants (6 specific to FRESH) and were provided by Stylianos Somarakis and Katerina Anastasopoulou (Institute of Marine Biological Resources, Hellenic Centre for Marine Research, Crete Subdivision, Greece).

The objectives of the WG meeting were to address the proposed set of milestones and deliverables associated with each Term of Reference and document a list of proposed, ongoing and completed deliverables. The meeting was comprised of plenary and break-out group sessions, the former led by the Chairs and the latter by the ToR Co-Leaders. A larger than normal set of accomplishments has been achieved in the last year and very fine detail has been given towards outlining the content and participants of remaining target outputs which include a hands-on workshop on incorporating stock reproductive potential into scientific advice.

The joint meeting of FRESH and NAFO, as done in the 8th WG meeting, permitted a broad spectrum of scientists to address the issues of relevance to NAFO Scientific Council. The synergy of work activities between these two scientific bodies has enhanced the progress made in this subject area. It was decided, due to the holding of the 9th meeting in March 2010, that it would be best to work inter-sessionally by correspondence during the summer and fall of 2010 as a lead up to a workshop and symposium planned for early 2011 which are described below in the relevant ToR sections.

A brief summary of progress and future plans of each ToR are given below.

3rd Set of Terms of Reference

ToR 1: Explore and conduct evaluation of underlying assumptions of protocols used to estimate total realized egg production of selected marine species and stocks

Co-Leaders: Rick Rideout (DFO, Canada) and Rosario Dominguez (CSIC, Spain)

Several marine laboratories in the North Atlantic have initiated routine fecundity estimation for key fish stocks. This information is being used to (i) help improve the estimation of stock reproductive potential (ii) understand

population productivity and (iii) predict stock recovery rates. However, there is a lack of standarization and calibration of various methods to estimate fecundity among laboratories. For example, some laboratories have only recently initiated the autodiametric method and are developing appropriate calibration curves. On the other hand, observations have been made that indicate atresia and timing of sampling can influence estimates of total egg production. Techniques to quantify atresia (vitellogenic oocyte resorption) will be developed and evaluated in this ToR. This will involve histological analyses accompanied by computerized image analysis.

Establish Standard Operating Procedures:
- Provide uniform and standarized procedures for routine fecundity analyses in laboratories using a variety of methods, i.e. autodiametric method, image analysis
- Evaluate histological techniques for assessment of atresia

Validation of Assumptions:
- Test assumptions of different fecundity methods (i.e. the autodiametric method) and parameters associated with fecundity estimation
- Estimate down regulation of fecundity and quantification of atresia and non-annual spawning

Three extensive review papers targeted for the primary literature are planned and include the topic areas of (i) fish reproductive strategies (F. Sabordio-Rey), (ii) oocyte atresia (R. Rideout), and reproductive potential of indeterminate spawners (S. Somarakis). There is also an initiative underway tentatively titled: Handbook of Reproductive Ecology Studies for Fish Stock Assessment (co-editors R. Domínguez-Petit, H. Murua, F. Saborido-Rey, E. Trippel) that will involve >30 co-authors. This includes chapters in the following areas: (i) fish reproductive ecology, (ii) data collection and statistics for reproductive ecology studies, (iii) maturity, (iv) egg production, (v) sperm production, and (vi) elasmobranch reproductive potential.

The following outputs of ToR 1 have been achieved since the last meeting that concentrate on improvement and validation of the application of the auto-diametric method for rapid assessment of fecundity in fishes:

Witthames P. R., A. Thorsen, H. Murua, F. Saborido-Rey, L. N. Greenwood, R. Dominguez, M. Korta, and O. S. Kjesbu. 2009. Advances in methods for determining fecundity: application of the new methods to some marine fishes. Fishery Bulletin 107(2): 148-164.

Kurita, Y., and Kjesbu, O.S. 2009. Fecundity estimation by oocyte packing density formulae in determinate and indeterminate spawners: Theoretical considerations and applications. J. Sea Res. 61(3): 188-196.

Korta, M., Murua, H., Kurita, Y., and Kjesbu, O.S. In press. How are the oocytes recruited in an indeterminate fish? Applications of stereological techniques along with advanced packing density theory on European hake (Merluccius merlucssius L.). Fish. Res.

Kjesbu, O.S., Thorsen, A., Fonn, M. Submitted. Quantification of primary and secondary oocyte production in Atlantic cod (Gadus morhua) by simple oocyte packing density theory. Mar. Coast. Fish.

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The 4th Workshop on Gonadal Histology of Fishes was held in Cádiz, Spain, June 16-19, 2009 during which a number of deliverables to ToR 1 were presented with some achieving publication in theAmerican Fisheries Society scientific journal Marine and Coastal Fisheries. Collectively, a solid year of achievements was made by this ToR that facilitates the present and future work activities of ToRs 2 and 3.

ToR 2: Explore and investigate the potential effects of changes in water temperature and food supply on reproductive success in selected marine species and stocks

Co-Leaders: Richard McBride (NMFS, USA) and Stylianos Somarakis (HCMR, Greece)

Environmental factors can modify the reproductive potential of fish stocks and thereby influence recruitment. Annual variations in water temperature and potential increases due to climatic warming will presumably act strongly to influence gonadal development and reproductive success. Prey resources also vary and influence fish condition which in turn affects reproductive output. In this ToR, using data on specific stocks and laboratory experiments, the influence of specific abiotic and biotic factors on gonadal development and spawning will be evaluated pending available data.

Abiotic: Examine changes in water temperature (short and long-term) and their effects on timing and duration of spawning, fecundity, egg size and fertilization success

Biotic: Assess variation in prey resource type and abundance and their effects on egg production and gamete quality

Two key review articles have been planned (i) effects of water temperature on reproduction and early life history traits of marine fishes and (ii) the potential effects of changes in food supply on reproductive success in selected marine species and stocks. Three other initiatives are also underway that are more specific in nature and include: (i) an examination of the effects of age, temperature and condition on timing and duration of spawning using research survey time series of specific cod and haddock stocks of the Northwest Atlantic and North Sea, (ii) an analysis of reproductive potential, growth and total egg production of cod in 3M and 3NO, and (iii) experimental research through a Canada/Spain scientific collaborative agreement to investigate the effects of water temperature on egg incubation of Greenland halibut.

Five products have been completed in the last year and reflect progress in the two key elements of ToR 2; water temperature and food supply, the latter more simply represented by condition factor:

Morgan, M.J. and R.M. Rideout. 2009. Time of spawning in subdivision 3Ps cod (*Gadus morhua*). CSAS res doc 2009/102

Morgan, M.J., R.M. Rideout and E.B. Colbourne. 2010. Impact of environmental temperature on Atlantic cod (*Gadus morhua*) energy allocation to growth, condition and reproduction. Mar. Ecol. Progr. Ser. 404: 185-195.

Pérez, A, J. Morgan and F. Saborido-Rey. 2009. Comparison of demographic and direct methods to calculate probabilistic maturation reaction norms for Flemish Cap cod (*Gadus morhua*). Evolutionary Applications 2(3): 291-298

Kjesbu, O.S., Righton, D., Krüger-Johnsen, M., Thorsen, A., Michalsen, K., Fonn, M., and Witthames, P.R. 2010. Thermal dynamics of ovarian maturation in Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 67: 605-625.

Purchase, C.F., I.A.E. Butts, A. Alonso-Fernández, and E.A. Trippel. 2010. Thermal reaction norms in sperm performance of Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 67: 498-510.

ToR 3: Undertake appraisal of methods to improve fish stock assessments and fishery management advice that incorporate new biological data for highly exploited and closed fisheries

Co-Leaders: Joanne Morgan (DFO, Canada) and Loretta O'Brien (NMFS, USA)

The depressed and age-altered state of many marine fish stocks has led to reduced landings and in some instances fishery closures. New biological data associated with these altered states will be used to forecast recruitment and improve the accuracy of stock assessment advice. Building on information from previous WG ToRs, the intrinsic rate of population increase will be utilized to assess the timeframe for selected stocks to recover under various fishing and environmental conditions.

Recruitment prediction: Improve prediction of incoming year class size and develop new stock-recruitment models and biological reference points based on better estimates of stock reproductive potential. This includes testing whether more complex indices of reproductive potential result in better estimates of recruitment and limit reference points. Develop scenarios which model population reproductive responses to extrinsic factor data developed in ToR 2.

Stock recovery: Evaluate the intrinsic rate of increase of selected stocks under differing conditions of reproductive potential and levels of fishing mortality to aid in the development of reopening criteria. Estimate recovery time for specific stocks to achieve target biomass levels.

Egg production methods can estimate spawner biomass and/or stock numbers independently of commercial fisheries data. Improved information on stock reproductive potential is improving the accuracy of these methods. The daily egg production method is being explored to evaluate adult stock size for determinate spawning species in the Baltic and North Seas.

Ten initiatives are underway in ToR 3 that when completed will make a large contribution towards evaluating and implementing stock reproductive potential into scientific advice. These are summarized below:

(i) Determine if better estimates of stock reproductive potential (SRP) improve biological reference points (BRP) or can be used to develop new BRPs.

(ii) Test the applicability and robustness of the daily egg production method on determinate species.

(iii) Determine if better estimates of SRP improve recruitment prediction and develop new S-R models based on better estimates of SRP.

(iv) Evaluate the intrinsic rate of increase of selected stocks under differing conditions of reproductive potential.

(v) Estimate recovery time for depleted stocks to achieve target biomass levels.

(vi) Compare estimates of lifetime reproductive value (R_0) and intrinsic rates of population growth (r) computed by stochastic matrix modelling assuming stable age distribution to more highly resolved cohort-specific estimates of R_0 and r using simulated datasets.

(vii) Develop a simple method to model spatial correlation on S-R relationships across areas and their relationship with the spatial variation of reproductive variables.

(viii) Comparison (concerning different case studies) of the stock status under new BRPs to the status under BRPs not derived with reproductive information.

(ix) Evaluate management strategies based on "spawn at least once" for application on ICES stocks (meta analyses). Use an Alaskan rockfish species as a case study, develop an operational model that includes maternal effects and spatial patterns of recruitment. Use MSE simulations to compare the status quo management control role to spatial management, under the assumption that maternal effects occur in the operational model.

(x) Methods to compute alternative indices of Stock Reproductive Potential (SRP) will be assembled. Collaborators are to provide a mathematical description and any relevant document to help implementation in FLR. This will be

used as an opportunity to review how the FLBiol class in FLR can accommodate the necessary methods and data structures.

In addition, following a long-standing recommendation from Scientific Council, significant advancement has been made towards a "Workshop on Implementation of Stock Reproductive Potential into Assessment and Management Advice for Harvested Marine Species". A description of the proposed activities of the Workshop is given below:

Outline of FRESH/NAFO Workshop
Spring 2011

Implementation of Stock Reproductive Potential into Assessment and Management Advice for Harvested Marine Species

Co-convenors: C.T. Marshall (Univ of Abdn, UK), M.J. Morgan (DFO, Canada), I. Mosquiera (Cefas, UK), L. O'Brien (NMFS, USA)

Background: Reproductive potential is central to the sustainability of fisheries. Variability in reproductive potential is often under-represented by conventional approaches to assessing stock status. Increased knowledge and improvements to databases allow new approaches to be developed. Consequently, there is increasing interest in implementing this knowledge into stock assessment.

Aim of the workshop: To review and recommend best practices for incorporating information about growth, maturation, condition and fecundity into assessment and advice for management of harvested marine species.

Venue for the workshop: University of Aberdeen

Timing of the workshop: 3 days in late March/early April

Format of the workshop The workshop will be organised into three sessions:

Theme 1: Estimating Stock Reproductive Potential Lead convenor: Tara Marshall (UK)

Presenting worked examples for stocks having a lot of detailed biological data; A range of stocks will be contrasted including long-lived, slow-growing stocks (Barents Sea cod) to short-lived, fast-maturing stocks (North Sea haddock). Discussion will address how to use this information for less data-rich stocks, through life history and hierarchical models. The analyses will yield insights into what new data should be collected routinely.

Invited experts: Yvan Lambert (Canada); Peter Wright (UK), Adrian Rijnsdorp/Cindy van Damme (the Netherlands), Susan Sogard (USA)

Theme 2: Implementing Estimates into Assessments Lead convenor: Loretta O'Brien (USA)

This session will focus on incorporating SRP estimates into an assessment model formulation. Model diagnostics (residuals, retrospective analyses) and time trends of various variables (e.g. SSB, recruitment) will be compared between model formulations with and without SRP estimates included in the estimation. Stock/Recruit relationships and biological reference points will be estimated and compared between model formulations and across stocks.

Invited experts: Coby Needle (UK), Paul Spencer (USA)

Theme 3: Are we doing it better, worse or just differently? Lead convenor: Joanne Morgan (Canada)

The focus of this session will be on examining whether or not we can improve our advice by incorporating SRP into assessments. The issue of the quality of biological data will be discussed. The impact of alternative estimates have on stock projections will be examined. The session will also discuss whether predictions of recruitment are improved and whether stock performance relative to reference points would be better with an alternative index of SRP.

Invited experts: Hilario Murua (Spain), Thomas Brunel (The Netherlands)

Wrap-Up Discussion: Where do we go from here?

Recommendations for best practices will be summarised with a view to preparing a publication describing state of the art including needs for future research. Participants will discuss best practices in relation to what is feasible for their own stocks. No publication outlet has yet been decided, though a potential publication outlet is the NAFO Scientific Council Studies. The Chair of the WG requested, given the long-term interest, that NAFO financially support the attendance of two individuals commonly involved in NAFO assessments to this workshop.

International Symposium

A FRESH sponsored international scientific conference is scheduled for May 2011 at which some Working Group deliverables noted above will be presented and subsequently published. The Symposium is entitled "Fish Reproduction and Fisheries" (Co-convenors F. Saborido-Rey and E. Trippel) and will act as a forum for fishery research scientists to present and discuss recent advances in the field of reproductive potential and its relevance for improving stock assessment and advice to fisheries management. The location of the symposium is Vigo, Spain during the period May 16-20, 2011. A call for abstracts is being prepared for July, 2010.

NAFO Scientific Council approved the progress made and the annual work plan. Significant progress has been made by the NAFO WG on Reproductive Potential in the in the past 12 months and this excellent progress has been in part due to the synergy developed between the WG and the EU sponsored COST Activity Fish Reproduction and Fisheries.