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Executive summary

The Working Group on Fisheries-induced Evolution (WGEVO) continues the efforts of the Study Group on Fisheries Induced Adaptive Change (SGFIAC), which started in 2007 and since then has set the agenda on this research topic within ICES. The Working Group's 2010 meeting focused on (i) updates on new developments in research on fisheries-induced evolution (FIE), on (ii) discussions about two manuscripts initiated during the group's 2008 meeting and jointly prepared by the group's members intersessionally, one on *Evolutionary Impact Assessments* (EvoIAs) and the other on the influence of FIE on reference points for fisheries management, and on (iii) the development of simple tools for estimating fisheries-induced selection differentials from commonly available data for key life-history traits in a range of important stocks.

1 Opening and closing of the meeting

The Chairs opened the meeting on Tuesday, 27 April, at 09.00 and closed it on Thursday, 29 April, at 18.00.

2 Adoption of the agenda

The Terms of Reference for the Working Group on Fisheries-Induced Evolution (WGEVO) are listed below:

- a) Provide a forum for international collaboration and exchange of emerging scientific insights on fisheries-induced evolution;
- b) Assemble and review empirical evidence of fisheries-induced evolution and its consequences for the conservation of biodiversity and sustainable exploitation of marine species within an ecosystem context;
- c) Develop the Evolutionary Impact Assessment (EvoIA) framework and apply it to the specific challenges arising from fisheries-induced evolution and its consequences, including the following subtasks: (i) evaluate the impact of existing management measures and tools, such as minimum mesh and landing sizes, precautionary reference points, marine protected areas, and effort regulations, on fisheries-induced evolution; (ii) relate consequences of fisheries-induced evolution to stakeholder utilities and to current management objectives and explore possible more specific objectives for managing fisheries-induced evolution;
- d) Develop scientific and methodological tools to monitor and respond appropriately to risks to biodiversity and sustainable exploitation posed by fisheries-induced evolution, with a particular emphasis on making these tools readily available for a broader range of scientists and managers;
- e) Develop terms of references based on a work plan for the next three years, which complement the objectives of the ICES science plan.

WGEVO will report by 15 May 2010 (via SSGSUE) for the attention of SCICOM and ACOM.

During this meeting, work on fisheries-induced evolution (FIE) was organized in five parts:

- Updates on new developments in FIE research
- Evolutionary Impact Assessment
- Effects of FIE on reference points for fisheries management
- Comparison of selection differentials of exploited stocks

The corresponding developments are described in Sections 3 to 6 below.

3 Updates on new developments in FIE research

During this meeting, group participants gave three presentations on new research developments related to FIE. Titles and co-authors are listed below, with the names of presenters being underlined:

- Ken Andersen and Keith Brander: *Expected rate of fisheries-induced evolution is slow*

- Katja Enberg, Christian Jørgensen, and Marc Mangel: *Fishing-induced evolution and changing reproductive ecology of fish: The evolution of steepness*
- Bruno Ernande: *Assessing temporal quantitative genetic differentiation in exploited populations by combining data on phenotypes and neutral genetic markers*
- Mikko Heino, Torild Johansen, Asgeir Aglen, and Knut Jørstad: *Life history variation in Atlantic cod along the Norwegian coast*

4 Evolutionary impact assessment

The work initiated by SGFIAC in 2008, to develop a framework for evolutionary impact assessment, has now resulted in a manuscript "*Evolutionary impact assessment: Accounting for evolutionary consequences of fishing in an ecosystem approach to fisheries management.*" The manuscript describes an evolutionary impact assessment (EvoIA) as a structured approach for assessing the evolutionary consequences of fishing and for evaluating the merits of alternative management options. EvoIA will (i) contribute to the ecosystem approach to fisheries management by clarifying how evolution alters stock properties and ecological relations, (ii) support the precautionary approach to fisheries management by addressing a previously overlooked source of uncertainty and risk, and (iii) help realize the Johannesburg summit's commitment to the restoration of sustain-able fisheries.

During the Working Group meeting, the manuscript was discussed in detail. After receiving the comments of co-authors who were unable to participate in this year's meeting, the core group of co-authors will update the manuscript and circulate it for further comments and eventual approval. Submission to the journal *Fish and Fisheries* is foreseen within the next couple of months.

5 Effects of FIE on reference points for fisheries management

At its meeting in 2008, SGFIAC initiated a joint project on the effects of FIE on reference points for fisheries management and by now has intersessionally produced a manuscript "*Can fisheries-induced evolution shift reference points for fisheries management?*" The manuscript discusses why that fisheries-management reference points are not static, but may change when a population's environment is changing or when the population itself is changing. Fisheries-induced evolution is one mechanism that can drive changes in population characteristics, leading to "shifting" reference points through two possible pathways: by changing the underlying biological processes and by leading to changes in the perception of a stock's status. The former implies that "true" reference points are changing, whereas the latter implies that the yardstick used to quantify a stock's status is changing. Unaccounted shifting of either kind means that reference points gradually lose their intended meaning. This can lead to increased precaution, which is safe, but may be costly. Shifting can also occur in the direction of danger, such that actual risks are higher than accepted. Our qualitative analysis suggests that all commonly used reference points are susceptible to shifting through fisheries-induced evolution, including the widely used limit and precautionary reference points for spawning-stock biomass (B_{lim} and B_{pa}) and fishing mortality (F_{lim} and F_{pa}). Our findings call for increased awareness of fisheries-induced evolution and highlight the value of specifying reference points based on adequately updated information, to capture changes in the biological processes that drive fish population dynamics.

The Working Group meeting discussed the manuscript in detail and the comments will be used by the core group of co-authors to update the manuscript and circulate it for further comments and eventual approval. Submission to the *ICES Journal of Marine Science* is foreseen within the next couple of months.

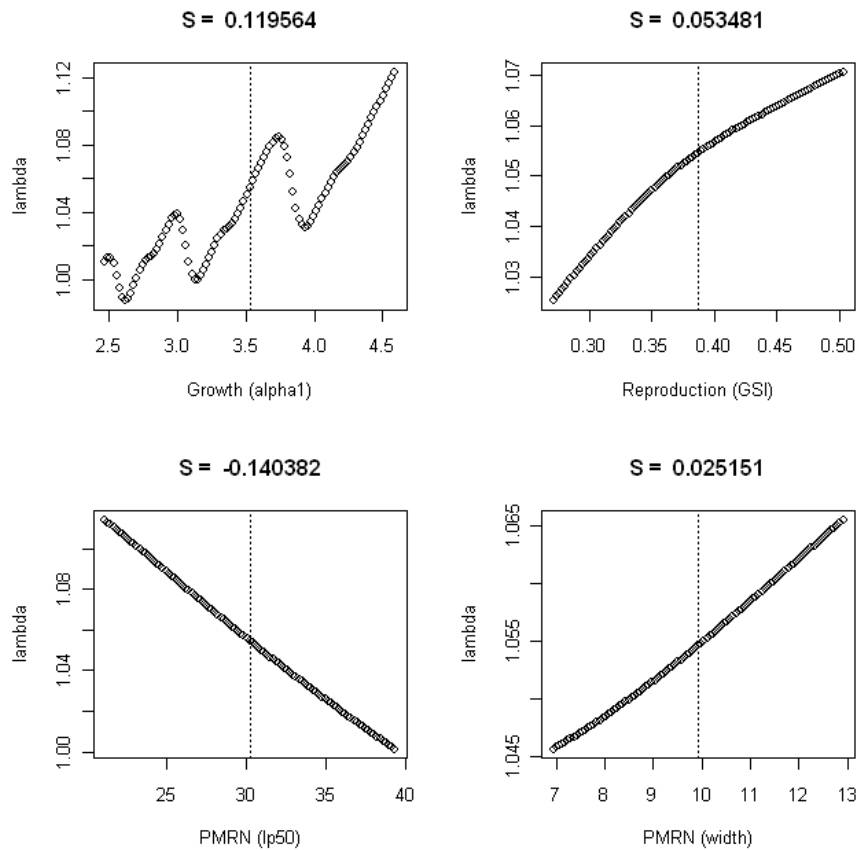


Figure 1. Standardized selection differentials (S) and the influence of variation in life-history traits for growth (alpha1), reproduction (GSI), and maturation (PMRN midpoint Lp50 and width) on the population's growth ratio (lambda) for North Sea plaice. Dotted vertical lines indicate the population's current mean trait values used for calculating the selection differentials. Results are tentative.

6 Selection differentials underlying FIE

Estimation of selection differentials allows fisheries scientists and managers to anticipate the direction of FIE and to assess the evolutionary vulnerability of specific traits and stocks to fishing. At the 2009 SGFIAC meeting, a workplan was agreed upon to develop software to estimate selection differentials from information on life-history traits (for growth, maturation, and reproduction) and exploitation patterns (in terms of fishing mortality as a function of age or length) that are readily available for many stocks.

Prior to the 2010 WGEVO meeting, R-scripts have been made available by Shuichi Matsumura and Mikko Heino. Selection differentials are estimated based on the Leslie-matrix approach (Arlinghaus *et al.*, 2009) for four evolving traits: growth, reproduction (GSI), and maturation (reaction norm intercept and width). The input parameters for this analysis can be estimated from length-age-maturity data from

surveys and/or commercial-fisheries samples and from estimates of fishing mortality and natural mortality-at-age or length.

An illustration of a preliminary analysis for female North Sea plaice (1995-1999) is given in Figure 1. It shows that the fishery selects for an increase in the energy acquisition rate (growth, α_1), reproductive investment (GSI), a decrease in the maturation reaction norm's midpoint (PMRN intercept, L_{p50}) and an increase in the maturation reaction norm's width (PMRN width). Selection is strongest on the maturation reaction norm midpoint (standardized selection differential $S = -0.14$) and on growth ($S = 0.12$).

Based on the Working Group's explorations of the scripts, using data from a number of ICES stocks, an improved version of the scripts was prepared and circulated among the WGEVO members, with the goal of applying these tools to key life-history traits in a range of important stocks. It is planned to present the first results of these analyses at the theme session on FIE at the 2010 ICES Annual Science Conference. The eventual product of this project will be a paper, envisaged again to be written with suitable collective authorship.

7 Future agenda of the Working Group

The Working Group recognized that good progress in addressing the terms of reference has been made and that significant challenges remain in bridging the gap towards the management of concrete fish stocks. The current terms of reference are an adequate reflection of the ambitions of the group and are clearly linked with the ICES science plan, in particular with the themes Impacts of fishing on marine ecosystems and Development of options for sustainable use of ecosystems.

8 References

- Andersen, K.H., Brander, K. 2009. Expected rate of fisheries-induced evolution is slow. Proceedings of the National Academy of Sciences of the United States of America 106, 11657–11660.
- Arlinghaus, R., Matsumura, S., Dieckmann, U. 2009. Quantifying selection differentials caused by recreational fishing: development of modeling framework and application to reproductive investment in pike (*Esox lucius*). Evolutionary Applications 2, 335–355.

Annex 1: List of participants

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Annex 2: WGEVO terms of reference for the next meeting

The **Working Group on Fisheries-Induced Evolution** (WGEVO), chaired by M. Heino, Norway, U. Dieckmann, Austria, and A. D. Rijnsdorp, The Netherlands, will meet at ICES Headquarters, Copenhagen, Denmark, 2–6 May 2011 to:

- a) Provide a forum for international collaboration and exchange of emerging scientific insights on fisheries-induced adaptive changes;
- b) Assemble and review empirical evidence of fisheries-induced adaptive change and its consequences for the conservation of biodiversity and sustainable exploitation of marine species within an ecosystem context;
- c) Develop the Evolutionary Impact Assessment framework and apply it to the specific challenges arising from fisheries-induced adaptive change and its consequences, including the following subtasks: (i) evaluate the impact of existing management measures and tools, such as minimum mesh and landing sizes, precautionary reference points, marine protected areas, and effort regulations, on fisheries-induced adaptive change; (ii) relate consequences of fisheries-induced adaptive change to stakeholder utilities and to current management objectives and evaluate possible more specific objectives for managing fisheries-induced adaptive change;
- d) Develop scientific and methodological tools to monitor and respond appropriately to risks to biodiversity and sustainable exploitation posed by fisheries-induced adaptive change, with a particular emphasis on making these tools readily available for a broader range of scientists and managers.

WGEVO will report by 21 May 2011 for the attention of SCICOM and ACOM.

Supporting Information

Priority	The activities of the Working Group on Fisheries-induced Evolution will provide ICES with a basis for advice on whether and how the effects of fisheries-induced adaptive change need to be taken into account in future management. Such advice is needed in relation with the precautionary approach, the ecosystem approach, biodiversity conservation, and the evaluation of risk and uncertainty.
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Scientific justification	<p>Linkages exist with all three 'Thematic areas' in the ICES Science Plan 2009–2013:</p> <ul style="list-style-type: none"> • Understanding Ecosystem Functioning (research topics 'Fish life-history information in support of EAM' and 'Biodiversity and the health of marine ecosystems'). • Understanding of Interactions of Human Activities with Ecosystems (research topic 'Impacts of fishing on marine ecosystems'). • Development of Options for Sustainable Use of Ecosystems (research topic 'Marine living resource management tools'). <p>Term of Reference a) An international forum transcending individual research projects and geographically limited activities has proven very valuable, as investigations of fisheries-induced adaptive changes have broad geographic relevance and require bringing together a wide range of expertise.</p> <p>Term of Reference b) Significant research efforts are currently being invested within this area in several countries. The subject area will therefore benefit from a continual review of the progress being made, a joint evaluation of results obtained, and a free exchange of information for guiding future research and management.</p> <p>Term of Reference c) The new framework of Evolutionary Impact Assessments (EvoIAs) introduced by SGFIAC provides an integrative platform for assessing the consequences of fisheries-induced adaptive changes and for evaluating how these are influenced by current and alternative management measures. WGEVO is in an excellent position to develop this framework further and to apply it to selected case studies.</p> <p>Term of Reference d) A basic set of statistical and modelling tools for dealing with fisheries-induced adaptive change are now available, but these need to be developed further for greater flexibility, transparency, and ease of use. This includes establishing quality-controlled packages of software and scripts, linkage to other standardized platforms such as the Fisheries Library in R (FLR), and making selected tools available through the web.</p>
Resource requirements	The research activities providing input to WGEVO are ongoing, and corresponding resources have been committed by the engaged institutions. The resources for convening the annual WGEVO meeting are negligible.
Participants	WGEVO is normally attended by 10–20 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	ACOM
Linkages to other committees or groups	For management implications: Working Group on Fishery Systems (WGFS). For more fundamental aspects: Working Group on the Application of Genetics in Fisheries and Mariculture (WGAGFM); Working Group on Ecosystem Effects of Fishing Activities (WGECE).
Linkages to other organizations	None.