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Executive summary

The Working Group on Fisheries-induced Evolution (WGEVO) is a continuation of the Study Group on Fisheries Induced Adaptive Change (SGFIAC) that started in 2007 and has set the agenda on this research topic within ICES. The Working Group's 2012 meeting focused on (i) updates on new developments in research on fisheries-induced evolution (FIE); (ii) 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; (iii) developing simple tools for estimating, from commonly available data, fisheries-induced selection differentials; and (iv) applying these tools to key life-history traits in a range of important stocks.

Related to (ii), the following WGEVO-prepared article is now in press: Laugen A.T., Engelhard G.H., Whitlock R., Arlinghaus R., Dankel D.J., Dunlop E.S., Eikeset A.M., Enberg K., Jørgensen C., Matsumura S., Nusslé S., Urbach D., Baulier L., Boukal D.S., Ernande B., Johnston F.D., Mollet F., Pardoe H., Therkildsen N.O., Uusi-Heikkilä S., Vainikka A., Heino M., Rijnsdorp A.D. and Dieckmann U. (2012). **Evolutionary impact assessment: Accounting for evolutionary consequences of fishing in an ecosystem approach to fisheries management.** *Fish and Fisheries*, in press.

1 Opening and closing of the meeting

The Chairs opened the meeting on Tuesday, 1 May, at 09.00 and closed it on Friday, 4 May, at 18.00. The meeting was held at the Institute of Marine Research in Bergen, Norway.

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 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 10 June 2012 (via SSGSUE) for the attention of SCICOM and ACOM.

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

- Updates on new developments in FIE research.
- Final discussions on two WGEVO-prepared manuscripts titled *“Evolutionary impact assessment: Accounting for evolutionary consequences of fishing in an ecosystem approach to fisheries management”* and *“Can fisheries-induced evolution shift reference points for fisheries management?”*.
- Development of computational tools (R scripts) for estimating fisheries-induced selection differentials in exploited stocks, and application of these scripts to the comparison of the thus-estimated fisheries-induced selection differentials among a wide range of exploited stocks.

The corresponding developments are described in Sections 3 to 5 below.

3 Updates on new developments in FIE research

During this meeting, six presentations were given on new research developments related to FIE. The title and co-authors are listed below, with the name of the presenter being underlined:

- Boukal D.S., Dieckmann U., Enberg K., Heino M., Jørgensen C. Versatile growth model for fish reveals the importance of getting reproductive investment right: life-history implications of allometric scaling relationships.
- Devine L., Heino M. Investigating the drivers of maturation dynamics in Barents Sea haddock (Devine and Heino, 2011).
- Díaz Pauli B., Utne Palm A.C., Reznick D., Heino M. Experimental evidence of fisheries-induced evolution? The guppy experiment.
- Heino M., Johansen T., Edvardsen R.B., Furmanec T., Torrissen O. Genomic signature of fisheries-induced evolution in Northeast arctic cod?
- Rijnsdorp A.D., van Overzee H., Poos J.J. Ecological and economic trade-offs in the management of mixed fisheries: A case study of spawning closures in flatfish fisheries (Rijnsdorp et al. 2012)
- Vainikka A., Niemelä P., Kortet R. Theory of fishing-induced evolution of animal personality.

4 Working Group manuscripts

The work initiated by the Study Group on Fisheries Induced Adaptive Change (SGFIAC), to develop a framework for evolutionary impact assessment, has resulted in the manuscript "*Evolutionary impact assessment: Accounting for evolutionary consequences of fishing in an ecosystem approach to fisheries management*", which was submitted to *Fish and Fisheries* in autumn 2011. During the present Working Group meeting, the comments of the reviewers were discussed and the final manuscript was prepared. In July 2012, this manuscript has been accepted for publication in *Fish and Fisheries* (Laugen *et al.*, 2012). 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.

At its meeting in 2008, the Study Group initiated a second joint manuscript project on the effects of FIE on reference points for fisheries management. The manuscript "*Can fisheries-induced evolution shift reference points for fisheries management?*" (Heino *et al.*, in preparation) takes its point of departure from the observation 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 system. The former implies that "true" reference points are changing, whereas the latter implies that the yardstick used to quantify a system's status is changing. Unac-

counted 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. The qualitative analysis presented in the manuscript 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}). These 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 discussed the manuscript and the comments were used to update the manuscript, which is now being circulated for final consolidation. Submission to the *ICES Journal of Marine Science* is foreseen within the next month.

The Working Group further discussed the idea to produce a publication on FIE targeted at a wider scientific audience and the general public, ideally co-produced by ICES. It was agreed that the Working Group chairs will contact ICES to discuss the options for such a publication.

5 Computational tools for estimating selection differentials

The work on the estimation of selection differentials, started in 2010, has been continued during the present meeting. The estimation of selection differentials from data on life-history traits (growth, maturation, and reproduction) and exploitation patterns (fishing mortality by age/length class), which are readily available for many stocks; allow fisheries scientists and managers to anticipate the direction of FIE and to assess the evolutionary vulnerability of specific traits and stocks to fishing.

During the meeting, the R scripts made available by Shuichi Matsumura and Mikko Heino have been further developed to improve their performance and to make them more generic. Based on the Working Group's testing of these scripts, using data from a number of ICES stocks, the scripts will be made available to all WGEVO members, with the goal of applying these tools to a range of important stocks. The eventual product of this project will be a WGEVO-prepared manuscript, envisaged again to be written with suitable collective authorship.

More specifically, the work during the meeting was focused on the following tasks:

- Improving the script for estimating selection differentials, in particular to allow for a separate spawner fishery and for using non-horizontal probabilistic maturation reaction norms.
- Improving the parameter-estimation script, in particular to allow for the estimation of non-horizontal probabilistic maturation reaction norms.
- Updating and revising estimations of model parameters and selection differentials reported in ICES (2011) for the following stocks:
 - Western Channel sole
 - North Sea sole
 - North Sea plaice
 - North Sea turbot
 - North Sea brill
 - North Sea herring
- Estimating model parameters for the following new stocks:
 - Barents Sea haddock
 - Norwegian spring-spawning herring
 - East Baltic Sea cod
 - West Baltic Sea cod
 - North Sea cod
 - North Sea haddock
 - North Sea whiting
 - North Sea Norway pout
 - Lake Takvatn (Norway) Arctic charr
 - Lake Stuurajavri (Norway) whitefish
 - Wisconsin (USA) walleye
- Discussing further stocks to be included in this study.

6 Future of the Working Group

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

7 References

- Devine, J., Heino, M. 2011. Investigating the drivers of maturation dynamics in Barents Sea haddock (*Melanogrammus aeglefinus*). *Fisheries Research* 110: 441–449.
- ICES. 2011. Report of the Working Group on Fisheries-Induced Evolution (WGEVO), 3–5 May 2011, ICES Headquarters, Copenhagen. ICES Document CM 2011/SSGSUE:04. ICES, Copenhagen. 12 pp.
- Heino, M., Baulier, L., Boukal, D. S., Ernande, B., Johnston, F. D., Mollet, F., Pardoe, H., Therkildsen, N. O., Uusi-Heikkilä, S., Vainikka, A., Arlinghaus, R., Dankel, D. J., Dunlop, E. S., Eikeset, A. M., Enberg, K., Engelhard, G. H., Jørgensen, C., Laugen, A. T., Matsumura, S., Nusslé, S., Urbach, D., Whitlock, R., Rijnsdorp, A. D., Dieckmann, U. (in preparation). Can fisheries-induced evolution shift reference points for fisheries management?
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- Rijnsdorp, A. D., van Overzee, H., Poos, J. J. 2012. Ecological and economic trade-offs in the management of mixed fisheries: a case study of spawning closures in flatfish fisheries. *Marine Ecology Progress Series* 447: 179–194.

Annex 1: List of WGEVO Participants, Bergen, Norway, 1–4 May 2012

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Annex 2: Draft resolution for multi-annual ToRs

The **Working Group on Fisheries-Induced Evolution** (WGEVO), chaired by Mikko Heino, Norway, Ulf Dieckmann, Austria, and Adriaan D. Rijnsdorp, The Netherlands, will meet in Copenhagen during 7–11 May 2013, to work on ToRs and generate deliverables as listed in the table below.

WGEVO will report on the activities of 2013 (the working group's first year) by 31 July 2013 for the attention of SSGSUE.

ToR descriptors¹

ToR	DESCRIPTION	BACKGROUND	SCIENCE PLAN		EXPECTED DELIVERABLES
			TOPICS ADDRESSED	DURATION	
a	Provide a forum for international collaboration and exchange of emerging scientific insights on fisheries-induced adaptive changes. The activities of WGEVO 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 ecosystem approach to management.	The ecosystem approach to management is the overarching motive for ICES science and management.	121, 141, 143, 211, 311, 312, 314, 344, 345, 346	Years 1,2,3	
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.	a) Research beyond current Science Plan requirements b) Research for MSFD and GES requirements c) No requirements from other EGs	141, 143, 311, 312, 344	Years 1,2	ICES publication for general audience, Wikipedia article
c	Apply the Evolutionary Impact Assessment framework to specific case studies to: (i) evaluate the impact of existing management measures on fisheries-induced adaptive change; (ii) relate consequences of fisheries-induced adaptive change to stakeholder utilities and to current management objectives; (iii) evaluate possible more specific objectives for managing fisheries-induced adaptive change.	a) Research beyond current Science Plan requirements b) Research for MSFD and GES requirements c) Links with relevant Assessment WGs required	211, 311, 312, 314, 344, 345	Years 1,2,3	Peer-reviewed publications

¹ Avoid generic terms such as "Discuss" or "Consider". Aim at drafting specific and clear ToR, the delivery of which can be assessed

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.	a) Research beyond current Science Plan requirements b) Research for MSFD and GES requirements c) Links with relevant Assessment WGs required	121, 141, 143, 311	Years 1,2	Tools (R-scripts), potentially accompanied by peer-reviewed publications, as the need might arise
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Summary of multi-annual work plan

YEAR	MAIN DELIVERABLE
Year 1	ICES document providing an overview of FIE for a wider scientific audience and the general public; R-scripts for estimating selection differentials of exploited fish stocks
Year 2	Review of selection differentials of exploited fish stocks
Year 3	Evolutionary Impact Assessment (EvoIA) of a selected case study

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.
Resource requirements	The research activities providing input to WGEVO are ongoing, and corresponding resources have been committed by the engaged institutions. The administrative 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 ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committee or groups	ACOM and relevant Assessment WGs.
Linkages to other organizations	None.