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Report of the Study Group on Fisheries Induced Adaptive Change (SGFIAC)

21-25 January 2008

ICES, Copenhagen, Denmark

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive summary

During its 2008 meeting, the Study Group on Fisheries Induced Adaptive Change (SGFIAC) reviewed the scientific evidence for fisheries-induced evolution (FIE) and proposed evolutionary impact assessment (EvoIA) as a tool for quantifying the evolutionary effects of management measures on the utility components defined by managers. Based on the 2007 Study Group report, the Policy Forum article "Managing Evolving Fish Stocks" was published by the journal *Science* in November 2007 (Vol. 318: 1247-1248). The Study Group's 2008 meeting focused on (i) updates on new developments in FIE research, (ii) computational tools for dealing with FIE, (iii) effects of FIE on reference points for fisheries management, and (iv) evolutionary impact assessment. The Study Group agreed to collectively prepare two manuscripts for publication on topics (iii) and (iv) before its next meeting.

1 Opening and closing of the meeting

The Chairs opened the meeting on Monday, 21 January, at 13.00 and closed it on Friday, 25 January, at 13.00.

2 Adoption of the agenda

The Terms of Reference for the Study Group on Fisheries Induced Adaptive Change (SGFIAC), unchanged from last year, are as follows:

a) Assemble and review empirical evidence of fisheries-induced adaptive change and its consequences for conservation of biodiversity and sustainable exploitation of marine species, within an ecosystem context, including previous work by WGAGFM and WGECO;

b) Evaluate the impact of existing management measures and tools, such as minimum mesh and landing sizes, precautionary reference points and marine protected areas, effort regulations, on fisheries-induced adaptive change;

c) Develop appropriate scientific and methodological tools to monitor and respond appropriately to risk to biodiversity and sustainable exploitation posed by fisheries-induced adaptive change;

d) Relate consequences of fisheries-induced adaptive change to current management objectives and evaluate possible more specific objectives for managing fisheries-induced adaptive change.

At a concrete level, work relating to fisheries-induced evolution (FIE) was organized in four parts during the meeting:

- Updates on new developments in FIE research
- Computational tools for dealing with FIE
- Effects of FIE on reference points for fisheries management
- Evolutionary impact assessment

The corresponding developments are described in Sections 3 to 6 below. A more detailed agenda of the meeting is provided in Annex 2.

3 Updates on new developments in FIE research

Based on its 2007 report, SGFIAC prepared the manuscript "Managing Evolving Fish Stocks," which was published in November 2007 as a Policy Forum article in the journal *Science* (Jørgensen *et al*., 2007).

Study group participants gave 10 short presentations on new research developments related to FIE. Titles and co-authors are listed below, with the name of the presenter being underlined.

- Mikko Heino, Loïc Baulier, David S. Boukal, Erin S. Dunlop, Sigrunn Eliassen, Katja Enberg, Christian Jørgensen & Øystein Varpe: *Fisheries-induced evolution of growth*
- Sébastien Nusslé, Christophe Bornand, Patrick Presi & Claus Wedekind: *Fishery-induced selection on alpine whitefish: quantifying genetic and environmental effects on growth rate*

- Georg Engelhard, Bruno Ernande, Fabian Mollet, Anssi Vainikka & Adriaan Rijnsdorp: *Geographic variation in growth and maturation of female sole*
- Christian Jørgensen & Øyvind Fiksen: *Death*
- Shuichi Matsumura, Robert Arlinghaus & Ulf Dieckmann: *Exploitation pattern in spatially-structured fisheries: a result from modelling of fish-angler interactions*
- Silva Uusi-Heikkilä: *Experimental study of adaptive changes in size-selectively exploited wild zebrafish populations*
- Anna Maria Eikeset, Erin S. Dunlop, Eric Nævdal, Nils Christian Stenseth & Ulf Dieckmann: *Economic repercussions of fishing*
- Anssi Vainikka, Åke Brännström, Anna Gårdmark, David Boukal & Ulf Dieckmann: *Maximum evolutionarily stable yield (MESY) and size-selective fishing*
- Dorothy Dankel, Ulf Dieckmann & Mikko Heino: *Can stakeholder conflicts of objectives be reconciled in marine fisheries management?*
- Adriaan Rijnsdorp: *Arms race between fishers and fish*

4 Computational tools for dealing with FIE

In recent years, considerable effort has been invested into integrating the computational tools fisheries scientists are relying on into a single framework, so that different tools can benefit from common data formats and other forms of linkage. A prominent development along these lines is the FLR framework (Fisheries Library for R; Kell *et al*., 2007). This framework includes not only conventional stock assessment tools, but also modules covering the whole fishery system such that the evaluation and development of management strategies is possible.

A natural question therefore is whether computational tools for dealing with FIE can be included in FLR. Such computational tools currently include statistical tools for estimating probabilistic maturation reaction norms (PMRNs) and dynamic population models for studying FIE in strategic and tactic contexts.

The estimation of PMRNs requires specific tools because standard statistical methods are usually insufficient for estimating PMRNs from survey and fisheries data. At present, most scientists estimating PMRNs are using R for implementing the published methods and algorithms (Heino *et al*., 2002a,b; Barot *et al*., 2004; Dieckmann and Heino, 2007; Heino and Dieckmann, 2008). R scripts can be exchanged, but there is no standard set of quality-controlled scripts available for new users.

Similarly, modelling fisheries-induced evolution requires a modelling framework that goes beyond simple life-history models. The bulk of modelling work is now taking place under the 'eco-genetic' modelling framework (Dunlop *et al*., 2008), aiming at balancing ecological and genetic detail in order to understand and predict short-term FIE in sufficiently realistic settings; other frameworks typically have focused on either genetic or ecological detail.

After an introduction to management-strategy evaluation in FLR, the possibility of integrating the aforementioned tools into FLR was discussed. Since none of the participants was familiar with both FLR and the existing computational tools for dealing with FIE, no concrete plans were devised. However, a subgroup of

participants working on the evolutionary enlightened management of flatfish is planning to proceed in this direction some time later during this year.

5 Effects of FIE on reference points for fisheries management

Reference points are commonly used inside and outside the ICES area to characterize desirable and undesirable values of indicators of the status of fish stocks and fisheries, and to facilitate communicating advice to managers and stakeholders. SGFIAC had highlighted already during its meeting in 2007 that reference points based on spawning stock biomass are likely to change when a stock's demographic characteristics are changing under the influence of FIE. For example, in the ICES area the biomass limit reference point B_{lim} is derived from spawning stock–recruitment relationships. This discussion was brought further during the meeting in 2008. The study group concluded that it is possible to gain qualitative insights into this question even without having to reply on specific quantitative models.

Given the prominent role reference points have in the present management advice, the study group agreed to present these insights in a short research paper, to be written as a collaborative and collective project. The tentative title of this paper is 'Slipping reference points driven by fisheries-induced evolution'. The paper is planned to include the following sections:

1) Introduction
2) Consequences of fisheries-induced evolution on the productivity and dynamics of fish stocks
3) Reference points based on stock-recruitment relationships
4) Reference points based on yield-per-recruit relationships
5) Other types of reference point
6) Indicators and reference points for evolutionarily enlightened fisheries management
7) Discussion

A first draft of this paper is planned to be available for internal discussion in April 2008.

6 Evolutionary impact assessment

Ensuring evolutionarily sustainable fisheries contributes to ecosystem-based fisheries management. Identifying and mitigating the evolutionary impact of fishing is also required by the precautionary approach and by the goal of rebuilding fisheries so as to provide maximum sustainable yield. Evolutionary impact assessment (EvoIA) has thus been proposed as a tool for the management of evolving resources (Jørgensen *et al.*, 2007). An EvoIA involves two steps. The first relies on biological information and describes how fishing leads to trait changes. The second addresses how trait changes affect a stock's utility to society. Evolutionary impact is then assessed as the change in utility of a stock as a result of FIE.

Since EvoIA is a new approach, the study group agreed to introduce its detailed specification in a dedicated research paper, to be written as a collaborative and collective project. The tentative title of this paper is 'Evolutionary impact assessment: a tool for evolutionary enlightened fisheries management'. The paper is planned to include the following sections:

1) Introduction

2) Processes in the fisheries system

3) Impacts of evolution on the utility of living aquatic resources

4) Evolutionary impact assessment

5) Methods and tools for evolutionary impact assessment

6) Discussion

A first draft of this paper is planned to be available for internal discussion in April 2008.

7 References

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Annex 1: List of participants

Name	Address	Phone/Fax	Email
Robert Arlinghaus	Leibniz-Institute of Freshwater Ecology and Inland Fisheries Dept of Biology and Ecology of Fishes Müggelseedamm 310 D-12587 Berlin Germany		arlinghaus@igb-berlin.de
Loïc Baulier	Institute of Marine Research EvoFish P.O. Box 1870 N-5817 Bergen Norway		loic.baulier@imr.no
David Boukal	Institute of Marine Research EvoFish P.O. Box 1870 N-5817 Bergen Norway		david.boukal@imr.no
Dorothy Dankel	Institute of Marine Research Pelagic Section Nordnesgt 33 P.O. Box 1870 N-5817 Bergen Norway	+47 55 23 85 00 +47 55 23 86 87	dorothy@imr.no
Ulf Dieckmann *Co-Chair*	International Institute for Applied Systems Analysis Schlossplatz 1 A-2361 Laxenburg Austria		dieckmann@iiasa.ac.at
Erin Dunlop	Institute of Marine Research EvoFish Nordnesgt 33 P.O. Box 1870 N-5817 Bergen Norway		erin.dunlop@imr.no
Anne Maria Eikeset	University of Oslo Centre for Ecological and Evolutionary Synthesis Blindern P.O. Box 1066 N-0316 Oslo Norway		a.m.eikeset@bio.uio.no

Name	Address	Phone/Fax	Email
Katja Enberg	University of Bergen Dept of Biology EvoFish P.O. Box 7800 N-5020 Bergen Norway		katja.enberg@bio.uib.no
Georg Engelhard	CEFAS Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom		georg.engelhard@cefas.co.uk
Bruno Ernande	IFREMER Port-en-Bessin Station Avenue du Général De Gaulle P.O. Box 32 F-14520 Port-en-Bessin France	+ 33 (0)2 31 51 56 42 + 33 (0)2 31 51 56 01	Bruno.Ernande@ifremer.fr
Mikko Heino *Co-Chair*	University of Bergen Dept of Biology EvoFish P.O. Box 7800 N-5020 Bergen Norway	+47 55 58 45 44 +47 55 58 4450	mikko.heino@imr.no
Fiona Johnston	International Institute for Applied Systems Analysis Schlossplatz 1 A-2361 Laxenburg Austria	+43 22 36 807 590	johnston@iiasa.ac.at
Christian Jørgensen	University of Bergen Dept of Biology EvoFish P.O. Box 7800 N-5020 Bergen Norway		christian.jorgensen@bio.uib.no
Laurence Kell	CEFAS Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	+44 1502 562244 +44 1502 513865	laurence.kell@cefas.co.uk
Ane Laugen	IFREMER Port-en-Bessin Station Avenue du Général de Gaulle P.O. Box 32 F-14520 Port-en-Bessin France		ane.laugen@ifremer.fr

Name	Address	Phone/Fax	Email
Shuichi Matsumura	International Institute for Applied Systems Analysis Schlossplatz 1 A-2361 Laxenburg Austria	+43 22 36 807 321	matsumur@iiasa.ac.at
Fabian Mollet	IMARES, Wageningen UR P.O. Box 68 NL-1970 AB Ijmuiden Netherlands		Fabian.Mollett@wur.nl
Sébastien Nusslé	University of Lausanne Department of Ecology & Evolution Le Biophore Lausanne CH-1015 Switzerland		Sebastien.Nussle@unil.ch
Heidi Pardoe	Marine Research Institute Skúlagata 4 IS-121 Reykjavík Iceland		heidi@hafro.is
Adriaan Rijnsdorp *Co-Chair*	IMARES, Wageningen UR P.O. Box 68 NL-1970 AB Ijmuiden Netherlands	+31255564670 +31255564644	Adriaan.Rijnsdorp@wur.nl
Nina Therkildsen	Danish Institute for Fishery Research/ DTU Aqua Department of Inland Fisheries Vejlsøvej 39 DK-8600 Silkeborg Denmark		nit@difres.dk
Davnah Urbach	University of Lausanne Department of Ecology & Evolution Le Biophore Lausanne CH-1015 Switzerland		davnah.urbach@unil.ch
Silva Uusi-Heikkilä	Leibniz-Institute of Freshwater Ecology and Inland Fisheries Dept of Biology and Ecology of Fishes Müggelseedamm 310 D-12587 Berlin Germany		silva.uusi-heikkila@igb-berlin.de

Name	Address	Phone/Fax	Email
Anssi Vainikka	Swedish Board of Fisheries Institute of Coastal Research Box 109 SE-742 22 Öregrund Sweden	+46 173 46479 +46 173 464 90	Anssi.vainikka@fiskeriverket.se
Rebecca Whitlock	International Institute for Applied Systems Analysis Schlossplatz 1 A-2361 Laxenburg Austria		whitlock@iiasa.ac.at

Annex 2: Agenda

Monday — afternoon

Opening of the meeting

Updates on new developments in FIE research

Tuesday — morning

Updates on new developments in FIE research

Tuesday — afternoon

Computational tools for dealing with FIE

Discussion of writing plans

Wednesday — morning

Discussions in small groups of ongoing research collaborations

Wednesday — afternoon

Effects of FIE on reference points for fisheries management: introduction, brainstorming in small groups, reports on group discussions, and plenary discussions

Thursday — morning and afternoon

Evolutionary impact assessment: introduction, brainstorming in small groups, reports on group discussions, and plenary discussions

Friday — morning

Group and plenary discussions of paper outlines

Closing of the meeting

Annex 3: SGFIAC terms of reference for the next meeting

The **Study Group on Fisheries Induced Adaptive Change [SGFIAC]** (Co-Chairs: M. Heino, Norway, U. Dieckmann, Austria, A. Rijnsdorp, The Netherlands) will meet at the ICES Headquarters in Copenhagen, Denmark, 30 March – 3 April 2009 (prior to the meetings of AFWG and WGNSSK) to:

a) 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, including previous work by WGAGFM and WGECO;

b) 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;

c) develop scientific and methodological tools to monitor and respond appropriately to risks to biodiversity and sustainable exploitation posed by fisheries-induced adaptive change;

d) relate consequences of fisheries-induced adaptive change to current management objectives and evaluate possible more specific objectives for managing fisheries-induced adaptive change.

SGFIAC will report by 30 April 2009 for the attention of the Resource Management Committee, and ACOM.

Supporting information

PRIORITY:	The activities of the Study Group will provide ICES with a basis for advice on whether and how the adaptive effects of fisheries need to be taken into account in future management. Such advice is needed in relation with the precautionary approach, the ecosystem approach, biodiversity, and the evaluation of risk and uncertainty. Consequently, these activities are considered to have a high priority.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	Action Plan No: 2.5 (Assess and evaluate the genetic consequences of human-induced selective factors) **Term of Reference a)** Several countries are conducting, or have recently completed, significant studies in this area, and the subject would benefit from a review of progress and an evaluation of the results obtained. **Term of Reference b)** A framework is needed for evaluating which stocks are most at risk, what level of monitoring is needed, and how to respond when fisheries-induced adaptive changes are likely to have significant negative impacts. Where management measures to mitigate such changes are required the most cost-effective management measures should be identified. **Term of Reference c)** As this is a relatively new field, methods for observing and monitoring fisheries-induced adaptive change and its consequences, as well as methods for evaluating possible management targets and thresholds, are still under development. **Term of Reference d)** Managing fisheries-induced adaptive change is implicitly included in management objectives under the precautionary approach, as sustainable harvesting must be understood to include evolutionary

	sustainability. However, explicit attention to fisheries-induced adaptive change raises new issues. For example, the World Summit on Sustainable Development (2002) stipulated that fish stocks shall be maintained or restored to levels that can produce the maximum sustainable yield by 2015, but MSY itself may be eroded through fisheries-induced adaptive changes. It is therefore important to assess the degree to which fisheries-induced adaptive changes are properly accounted for by the existing management objectives, and to what degree more specific considerations are warranted. Timeframe: 3-4 years
RESOURCE REQUIREMENTS:	No financial requirements for ICES. The research programmes that provide the main input to this Study Group are already underway, and resources are already committed (see 'Participants' below). The resources required to undertake additional activities in the framework of this Study Group are negligible.
PARTICIPANTS:	Ca. 25–30 participants. Closely related EC-funded projects are *Fisheries-induced Adaptive Changes in Exploited Fish Stocks* (2005–2009) and *Fisheries-induced Evolution* (2007–2010), as well as the *Marfish* project within the EU Network of Excellence *Marine Biodiversity and Ecosystem Functioning* (2005–2009). These will secure participation from both fisheries research institutes and universities.
SECRETARIAT FACILITIES:	None.
FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	ACOM
LINKAGES TO OTHER COMMITTEES OR GROUPS:	For management implications: Resource Management Committee (RMC), Living Resources Committee (LRC), Working Group on Fishery Systems (WGFS), Study Group on Management Strategies (SGMAS) For more fundamental aspects: Working Group on the Application of Genetics in Fisheries and Mariculture (WGAGFM)
LINKAGES TO OTHER ORGANIZATIONS:	None.

Annex 4: Recommendations

RECOMMENDATION	FOR FOLLOW UP BY:
1. To facilitate dialogue with scientists closely involved in producing advice for exploited fish stocks, SGFIAC recommends that members of ICES assessment working groups (such as AFWG and WGNSSK) also participate in the meeting of SGFIAC in 2009.	ICES Assessment Expert Groups
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