ICES WGEVO REPORT 2015

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Report of the Working Group on Fisheries-Induced Evolution (WGEVO)

8–10 September 2015

Boulogne-sur-Mer, France

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

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Contents

Executive summary

The Working Group on Fisheries-induced Evolution (WGEVO) strives to (i) 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, (ii) apply and extend the framework for evolutionary impact assessments, and (iii) 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. From 2013 to 2015, WGEVO worked on three main projects.

Firstly, it produced an overview of the expected individual-, population-, and fishery-level consequences of fisheries-induced evolution and of their impacts on reference points for fisheries management. Reference points used under the MSY approach and the precautionary approach, as employed in the advice by ICES assessment working groups, were specifically addressed.

Secondly, WGEVO developed a general framework for assessing the management implications of fisheries-induced evolution through Evolutionary Impact Assessments (EvoIAs). These allow evaluating the consequences of fisheries-induced adaptive change for stakeholder utilities and for current management objectives. The EvoIA framework was then applied to North Sea plaice as a first case study.

Finally, WGEVO developed a general framework for assessing fisheries-induced selection pressures. R scripts for estimating (i) input parameters and (ii) fisheries-induced selection pressures have been developed together with a user manual for dissemination within the ICES community and the wider scientific community. This framework has now already been applied to 31 exploited stocks and further estimates of fisheries-induced selection pressures are in progress for a range of additional stocks.

These outcomes have been disseminated through three peer-reviewed publications (Heino *et al.* 2013; Laugen *et al.* 2014; Mollet *et al.* 2015; see full references in Section 4), the organization of a dedicated theme session at the 2014 ICES ASC (Theme Session E "Stocks in flux: From selection pressures via phenotypic and genetic adaptive responses to impacts on ecosystem service"), two oral contributions to this Session (Matsumura *et al.* 2014; Mollet *et al.* 2014), and a poster (Heino *et al.* 2014).

The working group suggests that continuing WGEVO for a three-year term is advisable. One benefit will be the completion of the ongoing work on systematically estimating fisheries-induced selection pressures across a large number of exploited stocks.

1 Administrative Details

Working group name

Working Group on Fisheries-Induced Evolution

Year of appointment within the current three-year cycle

2013

Reporting year concluding the current three-year cycle

2015

Chairs

Ulf Dieckmann, Austria

Bruno Ernande, France

Mikko Heino, Norway

Meeting venues and dates

Annual meeting: 20–22 August 2013, IIASA, Laxenburg, Austria (5 participants)

Annual meeting: 7–11 July 2014, Wageningen IMARES, IJmuiden, the Netherlands (8 participants)

Inter-session meeting: 2-4 December 2014, IIASA, Laxenburg, Austria (7 participants)

Inter-session meeting: 21–23 April 2015, IIASA, Laxenburg, Austria (7 participants and 1 remote participant)

Annual meeting: 8–10 September 2015, IFREMER, Boulogne-sur-Mer, France (6 participants)

Inter-session meeting: 15–17 December 2015, IIASA, Laxenburg, Austria (5 participants and 2 remote participants)

Inter-session meeting: 29 February to 4 March 2016, Wageningen IMARES, IJmuiden, the Netherlands (6 participants and 3 remote participants)

2 Terms of Reference

ToR	Description	Background	Science plan topics addressed	Duration	Expected deliverables
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-	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	

	induced adaptive change need to be taken into account in ecosystem approach to management.				
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
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

3 Summary of Work Plan

Year	Main deliverable
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
2	Review of selection differentials of exploited fish stocks
3	Evolutionary Impact Assessment (EvoIA) of a selected case study

4 Summary of Achievements

- **Publications**
  - Heino, M., Baulier, L., Boukal, D. S., Ernande, B., Johnston, F. D., Mollet, F. M., Pardoe, H., Therkildsen, N. O., Uusi-Heikkilä, S., Vainikka, A., Arling-

haus, 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., and Dieckmann, U. 2013. **Can fisheries-induced evolution shift reference points for fisheries management?** *ICES Journal of Marine Science*, 70: 707–721.

(***Outcome of ToRs a and b)***

- 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. 2014. **Evolutionary impact assessment: accounting for evolutionary consequences of fishing in an ecosystem approach to fisheries management.** *Fish and Fisheries*, 15: 65–96.

  (***Outcome of ToR c)***

- Mollet, F.M., Poos, J.J., Dieckmann, U., and Rijnsdorp, A.D. 2015. **Evolutionary impact assessment of the North Sea plaice fishery.** *Canadian Journal of Fisheries and Aquatic Sciences*, published online on 26 November 2015, doi:10.1139/cjfas-2014-0568.

  (***Outcome of ToR c)***

- **2014 ICES ASC Theme Session E "*Stocks in flux: From selection pressures via phenotypic and genetic adaptive responses to impacts on ecosystem service*".**

  (***Outcome of ToRs a and b)***

  - Conveners: Ulf Dieckmann, IIASA, Austria; Mikko Heino, University of Bergen, Norway; and Filip Volckaert, University of Leuven, Belgium.
  - 15 oral contributions and 10 posters.

- **Oral contributions**

  - Matsumura S., Heino, M., Ernande, B., Rijnsdorp, A., Dieckmann, U., and the WGEVO participants. **How strong is fisheries-induced selection? An assessment of selection differentials caused by fishing.** *ICES Annual Science Conference (A Coruña, Spain), September 15-19, 2014, E:02.*

    (***Outcome of ToR d)***

  - Mollet, F.M., Poos, J.J., Dieckmann, U., and Rijnsdorp, A.D. **Evolutionary impact assessment of the North Sea plaice fishery.** *ICES Annual Science Conference (A Coruña, Spain), September 15-19, 2014, E:23.*

    (***Outcome of ToR c)***

- **Posters**
  - Heino, M., Ernande, B., Matsumura, S., Rijnsdorp, A., Dieckmann, U., and the WGEVO participants. **How strong is fisheries-induced selection? A general framework for estimating fisheries-induced selection differentials.** *ICES Annual Science Conference (A Coruña, Spain), September 15-19, 2014, E:06*.

    (***Outcome of ToR d)***

- **Methodological developments**
  - Development of a general framework for assessing the management implications of fisheries-induced evolution through Evolutionary Impact Assessments (EvoIAs; Laugen *et al.* 2014).

    (***Outcome of ToR c)***

  - Development of a general framework for assessing fisheries-induced selection pressures: R scripts and a user manual have been developed for dissemination within the ICES community and the wider scientific community.

    (***Outcome of ToR d)***

- **Assessment products**
  - An EvoIA has been developed and published for the North Sea plaice fishery (Mollet *et al.* 2015).

    (***Outcome of ToR c)***

  - The framework for estimating fisheries-induced selection pressures has been applied to 31 exploited fish stocks and is currently in progress for 7 additional stocks (see table below).

    (***Outcome of ToR d)***

	Species	M/F[1]	Stock/region	Division type	Area	Status
1	American plaice	M	NW Atlantic	NAFO	3LNO	Completed
2	Blue whiting	M	NE Atlantic	ICES	I–IX,XII,XIV	Completed
3	Brill	M	North Sea	ICES	IV	Completed
4	Capelin	M	Barents Sea	ICES	I	Completed
7	Cod	M	E Baltic Sea	ICES	IIId	Completed
8	Cod	M	North Sea	ICES	IV	Completed
5	Cod	M	NW Atlantic	NAFO	3NO	Completed
6	Cod	M	W Baltic Sea	ICES	IIIb-c	Completed
9	Haddock	M	North Sea	ICES	IV	Completed
10	Herring	M	E Baltic Sea	ICES	IIId	Completed
11	Herring	M	North Sea	ICES	IV	Completed

12	Herring	M	North Sea	ICES	IV	Completed
13	Horse mackerel	M	NE Atlantic			Completed
14	Mackerel	M	NE Atlantic	ICES	II–IX,XII,XIV	Completed
15	Northern pike	F	Wisconsin Lakes		n.a.	Completed
16	Norway pout	M	North Sea	ICES	IV	Completed
17	Pikeperch	F	Archipelago Sea		n.a.	Completed
18	Plaice	M	North Sea		IV	Completed
19	Saithe	M	North Sea	ICES	IV	Completed
23	Sole	M	Bay of Biscay	ICES	VIIIa	Completed
21	Sole	M	E. Channel	ICES	VIId	Completed
20	Sole	M	North Sea	ICES	IV	Completed
22	Sole	M	W. Channel	ICES	VIIe	Completed
24	Sprat	M	Baltic Sea			Completed
25	Turbot	M	North Sea	ICES	IV	Completed
26	Walleye	M	Wisconsin Lakes	Escabana Lake	n.a.	Completed
27	Walleye	M	Wisconsin Lakes	Several lakes	n.a.	Completed
28	Whitefish (*C. lavaretus*)	F	Lake Constance		n.a.	Completed
29	Whitefish (*C. palaea*)	F	Switzerland		n.a.	Completed
30	Whiting	M	North Sea	ICES	IV	Completed
31	Yellow perch	F	Lake Erie	Lake Erie	West Basin	Completed
32	Cod	M	Flemish Cap		n.a.	In progress
33	Cod	M	NE Arctic	ICES	I-II	In progress
34	Cod	M	NW North Sea		n.a.	In progress
35	Haddock	M	Barents Sea	ICES	I	In progress
36	Haddock	M	NW North Sea		n.a.	In progress
37	Herring	M	NSS/Norwegian Sea	ICES	II	In progress
38	Sardine	M	Portugal		n.a.	In progress

[1] Marine/Freshwater

5 Final Report

Progress and Fulfilment by ToR

- *ToR 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 working group has met once per year for its annual meeting. A total of four additional inter-session meetings were organized during the second and third years.

  WGEVO was also centrally involved in organizing a theme session at the 2014 ICES Annual Science Conference (Session E "Stocks in flux: From selection pressures via

phenotypic and genetic adaptive responses to impacts on ecosystem service"), providing an even wider forum for the exchange of results and ideas with 15 oral contributions and 10 posters.

WGEVO also worked on and provided an overview of the consequences of fisheries-induced evolution for reference points used for fisheries management, and more specifically those used under the MSY approach and the precautionary approach, as implemented in the advice of ICES assessment working groups. The results of this work were published in a peer-reviewed article (Heino *et al.* 2013; full reference in Section 4).

- *ToR b: Assemble and review empirical evidence of fisheries-induced adaptive change and its consequences for the conservation of biodiversity and sustainable exploitation of ma-rine species within an ecosystem context.*

  The working group is keeping a database on published studies on fisheries-induced evolution, in particular in age and size at maturation.

  Theme Session E at the 2014 ICES ASC offered an opportunity to provide the ICES community and the scientific community at large with an overview of ongoing developments in the field.

  The paper by Heino *et al.* (2013) presented the most up-to-date overview of the expected individual, population, and fishery-level consequences of fisheries-induced evolution.

  By constantly reviewing and monitoring developments in the field, WGEVO identifies knowledge gaps, methodological gaps, and monitoring gaps in regard to fisheries-induced adaptive changes and their consequences for biodiversity and stock productivity. WGEVO develops scientific and monitoring tools to fill these gaps. As such, it contributes to priority 27 of the ICES Science Plan. WGEVO also assembles and reviews empirical evidence of fisheries-induced adaptive changes, notably through time-series analyses that provide historic baselines for assessing changes in life-history traits. In this way, it contributes to priority 10 of the ICES Science Plan.

- *ToR c: Apply the Evolutionary Impact Assessment framework to specific case studies…*

  WGEVO has developed a general framework for investigating eco-evolutionary changes in fish stocks and their utilities in terms of ecosystem services and for assessing the management implications of fisheries-induced evolution through Evolutionary Impact Assessments (EvoIAs). This framework was published in a peer-reviewed article (Laugen *et al.* 2014; full reference in Section 4).

  Members of the working group have applied the EvoIA framework to North Sea plaice. The results were published in a peer-reviewed article (Mollet *et al.* 2015; full reference in Section 4) and presented in Theme Session E at the 2014 ICES ASC (Mollet *et al.* 2014).

  The EvoIA framework allows investigating linear and nonlinear eco-evolutionary changes in fish stocks and their utilities in terms of ecosystem services, and thus contributes to priority 6 of the ICES Science Plan. WGEVO applies the EvoIA framework to specific case studies to (i) evaluate the impact of fishing and 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 and mitigating fisheries-induced adaptive change; and (iv) evaluate the impact of fisheries-induced adaptive changes on the utilities of fish stocks, which include ecosystem services related to ecology, economics, and social aspects. These different objectives contribute to priorities 11, 12, 14, and 15 of the ICES Science Plan.

- *ToR d: Develop scientific and methodological tools to monitor and respond appropriately to risks to biodiversity and sustainable exploitation posed by fisheries-induced adaptive change…*

  WGEVO has developed a general framework for assessing fisheries-induced selection pressures. Specifically, R scripts for estimating (i) input parameters and (ii) fisheries-induced selection pressures have been developed and enhanced by a user manual for dissemination within the ICES community and the wider scientific community.

  The framework has now attained maturity and has so far been applied to 31 exploited stocks, with further estimations being in progress for additional stocks. The framework was presented as a poster (Heino *et al.* 2014) and preliminary results as an oral contribution (Matsumura *et al.* 2014) in Theme Session E at the 2014 ICES ASC.

  The estimation of fisheries-induced selection pressures allows monitoring risks to biodiversity and sustainable exploitation posed by fisheries-induced adaptive changes, and as such estimates of these pressures can be considered as indicators contributing to priority 9 of the ICES Science Plan. The evaluation of fisheries-induced selection pressures for a large range of exploited stocks also contributes to priority 11 of the ICES Science Plan.

Science Highlights

- The three journal articles produced by WGEVO (Heino *et al.* 2013; Laugen *et al.* 2014; Mollet *et al.* 2015) present the following science highlights:

  i) The most up-to-date overview of the expected individual-, population-, and fishery-level consequences of fisheries-induced evolution and of their impacts on reference points for fisheries management (Heino *et al.* 2013; full reference in Section 4).

  ii) A general framework for assessing the management implications of fisheries-induced evolution through Evolutionary Impact Assessments (EvoIAs; Laugen *et al.* 2014; full reference in Section 4).

  iii) An application of EvoIA to North Sea plaice (Mollet *et al.* 2015; full reference in Section 4).

- For the first time, fisheries-induced selection pressures on maturation (described by a probabilistic maturation reaction norm; PMRN), growth (described by juvenile growth potential), and reproductive investment (described by the gonadosomatic index) were estimated for roughly 30 exploited stocks. This comprehensive analysis enables the following three novel findings:

  i) The general pattern found through these empirical analyses agrees with theoretical expectations: on average, fisheries-induced selection pressures favour earlier maturation (Figure 1, PMRN midpoint), slower somatic growth

(Figure 1, Growth), and higher reproductive investment (Figure 1, Gonadosomatic index).

ii) The variation in standardized selection pressures is highest for the juvenile growth potential, also as expected (Figure 1, Growth).

iii) Selection pressures appear to be organized according to two orthogonal (i.e., statistically independent) axes (Figure 2). A 'maturation axis' (along which the selection pressures on PMRN midpoints on the one hand, and PMRN slopes and widths on the other, co-vary negatively) and a 'growth-reproduction axis' (along which the selection pressures on juvenile growth potential and gonadosomatic index co-vary negatively).

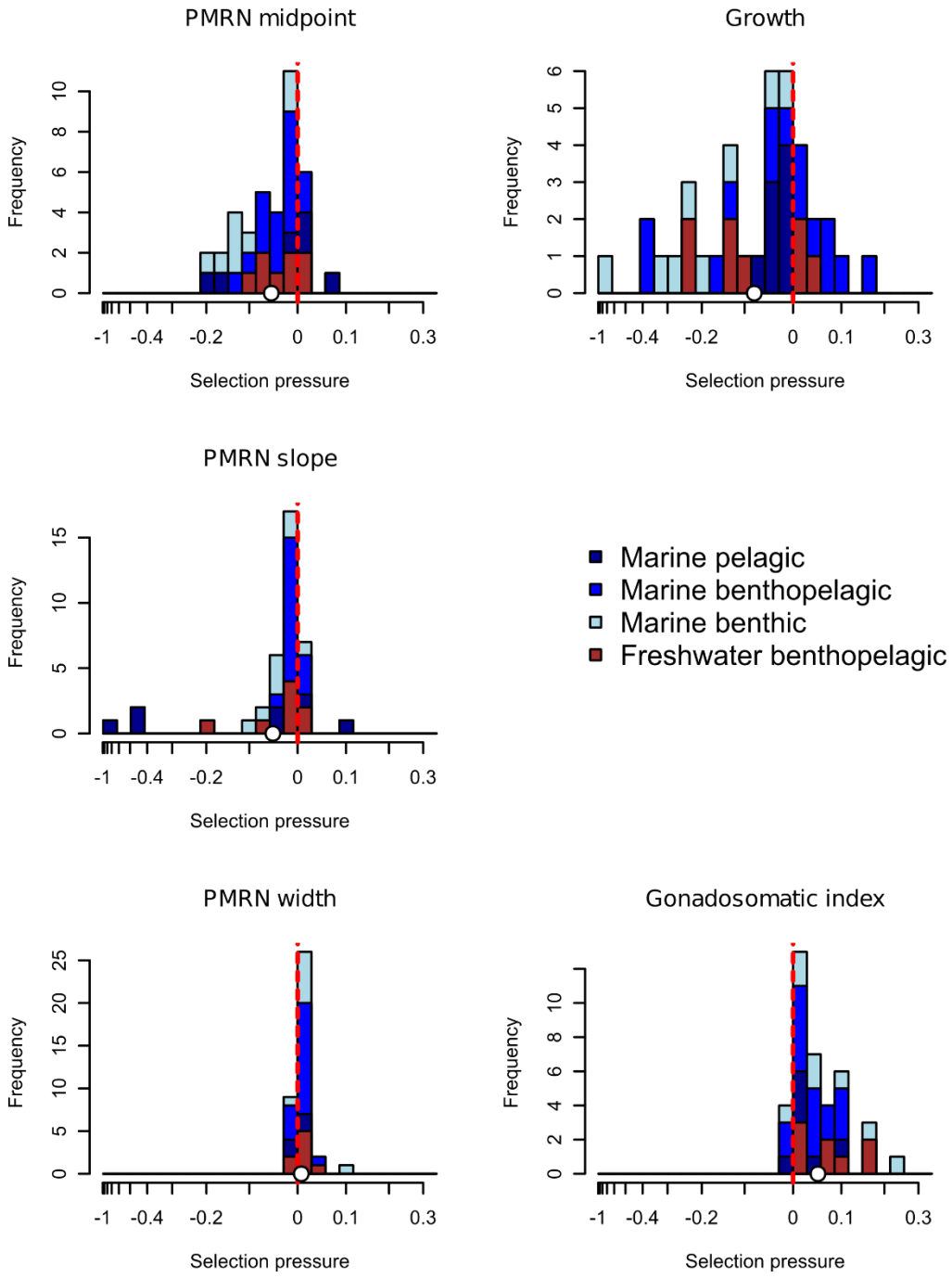

Figure 1. Frequency distributions of the standardized fisheries-induced selection pressures on the probabilistic maturation reaction norm (PMRN) midpoints, PMRN slopes, PMRN widths, juvenile growth potentials (Growth), and gonadosomatic indices of 32 exploited fish stocks. Different colours indicate different biomes, as specified by the inset legend. For each distribution, the white circle on the horizontal axis indicates the distribution's mean, while the dashed red vertical line indicates the absence of selection (i.e., a selection pressure of 0).

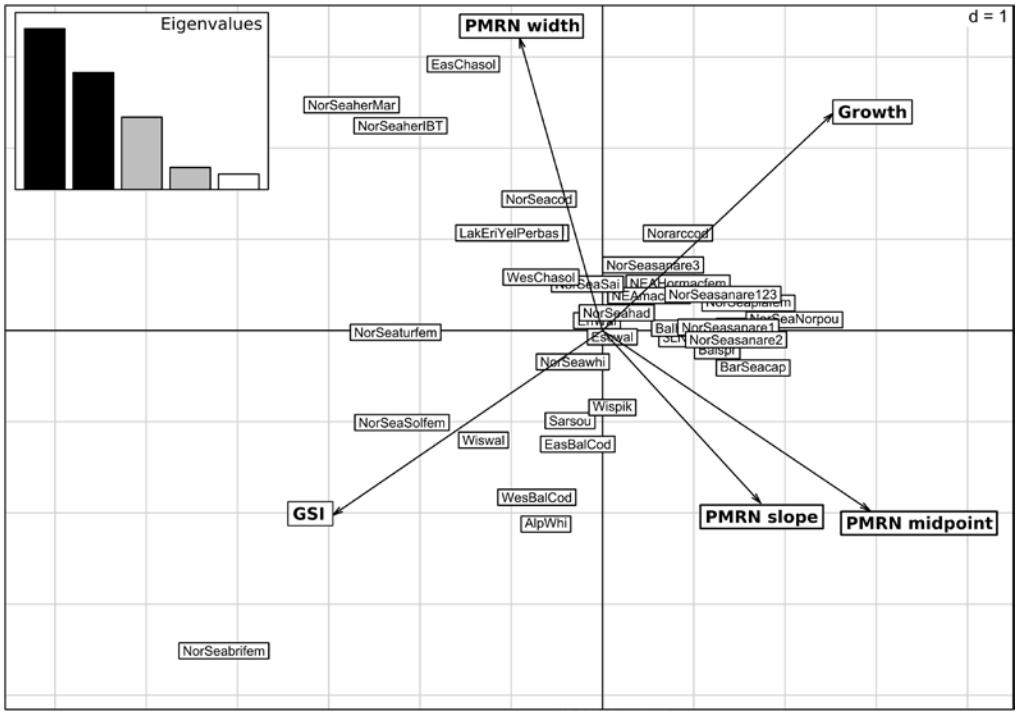

Figure 2. Principal components of the standardized fisheries-induced selection pressures on probabilistic maturation reaction norm (PMRN) midpoints, PMRN slopes, PMRN widths, juvenile growth potentials (Growth), and gonadosomatic indices (GSI) of 32 exploited fish stocks. Solitary labels represent the selection pressures on the five considered traits for each of the analysed stocks, while labelled arrows represent the resultant averages of these selection pressures. Stock-specific and average selection pressures are shown in relation to the first two principal components, represented by the horizontal and vertical axes, respectively. The inset shows the decreasing contributions of the first five principal components (left to right).

6 Summary of Self-Evaluation

A copy of the full working group self-evaluation is provided in Annex 3.

WGEVO contributed actively to the fulfilment of 8 priorities of the ICES Science Plan (Priorities 6, 9, 10, 11, 12, 14, 15, and 27). The principal outcomes over the group's three-year term are as follows:

- An overview of the expected individual-, population-, and fishery-level consequences of fisheries-induced evolution and of their impacts on reference points for fisheries management.
- The development of a general framework for assessing the management implications of fisheries-induced evolution through Evolutionary Impact Assessments (EvoIA) and its application to North Sea plaice as a case study.
- The development of a general framework for assessing fisheries-induced selection pressures and its application to 31 exploited fish stocks.

These outcomes have been disseminated through three peer-reviewed publications (Heino *et al.* 2013; Laugen *et al.* 2014; Mollet *et al.* 2015; see full references in Section 4), the organization of a dedicated theme session at the 2014 ICES ASC (Theme Session E "Stocks in flux: From selection pressures via phenotypic and genetic adaptive responses to impacts on ecosystem service"), two oral contributions to this session (Matsumura *et al.* 2014; Mollet *et al.* 2014) and a poster (Heino *et al.* 2014).

The group suggests that continuing WGEVO for a three-year term is advisable. The development and application of the framework for estimating fisheries-induced selection pressures have taken longer than anticipated. An appreciable number of stocks could already be assessed, and the necessary extra work for producing a comprehensive review of the results is planned to be completed and delivered during the forthcoming three-year period.

The working group decided to adjust the timeline for preparing an ICES document providing an overview of fisheries-induced evolution for a wider scientific audience and the general public, a deliverable originally foreseen for 2013. The idea is to resume this task once the project on fishing-induced selection pressures has been completed, so the results from that project can be included in that overview document during the next three-year term.

Annex 1: List of participants

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Annex 2: WGEVO terms of reference 2016–2018

The **Working Group on Fisheries-Induced Evolution** (WGEVO), chaired by Bruno Ernande, France, will work on ToRs and generate deliverables as listed in the table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2016	TBA	TBA	Interim report one month after the meeting to SSGEPD	
Year 2017	TBA	TBA	Interim report one month after the meeting to SSGEPD	
Year 2018	TBA	TBA	Final report two months after the meeting to SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan priorities addressed	Duration	Expected deliverables
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.	6, 9, 10, 11, 12, 14, 15, 27	Years 1, 2, 3	Organisation of a dedicated Theme session at ICES ASC in Year 3 Provision of summary recommendations about which stocks assessed by ICES are at most risk in terms of fisheries-induced evolution in Year 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 WGs	10, 27	Years 2, 3	1 ICES publication for general audience and 1 Wikipedia article in Year 3
c	Apply the Evolutionary Impact Assessment (EvoIA) framework to	a) Research beyond current Science Plan requirements	6, 12, 14, 15	Years 1, 2, 3	1 peer-reviewed publication over the 3 years

	specific case studies in order 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.	b) Research for MSFD and GES requirements c) Links with relevant Assessment WGs required			
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	6, 9, 11	Years 1, 2, 3	Tools (R-scripts), accompanied by 1 peer-reviewed publication over the 3 years

Summary of the Work Plan

Year 1	R scripts and table of selection differentials estimates for a range of exploited fish stocks
Year 2	Review of selection differentials of exploited fish stocks
Year 3	ICES document providing an overview of fisheries-induced evolution for a wider scientific audience, and Wikipedia article

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 present and 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 5–10 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	Linkage to Assessment WGs under ACOM
Linkages to other committees or groups	Linkage to SCICOM
Linkages to other organizations	None.

Annex 3: Self-Evaluation

Working group name

Working Group on Fisheries-Induced Evolution

Year of appointment

2013

Chairs

Ulf Dieckmann, Austria

Bruno Ernande, France

Mikko Heino, Norway

Meeting venues and dates

Annual meeting: 20-22 August 2013, IIASA, Laxenburg, Austria (5 participants)

Annual meeting: 7–11 July 2014, Wageningen IMARES, IJmuiden, the Netherlands (8 participants)

Inter-session meeting: 2-4 December 2014, IIASA, Laxenburg, Austria (7 participants)

Inter-session meeting: 21-23 April 2015, IIASA, Laxenburg, Austria (7 participants and 1 remote participant)

Annual meeting: 8-10 September 2015, IFREMER, Boulogne-sur-Mer, France (6 participants)

Inter-session meeting: 15-17 December 2015, IIASA, Laxenburg, Austria (5 participants and 2 remote participants)

Inter-session meeting: 29 February to 4 March 2016, Wageningen IMARES, IJmuiden, the Netherlands (6 participants and 3 remote participants)

Working Group Evaluation

Contributions to ICES Science Plan

The main contributions of WGEVO to research priorities of the ICES Science Plan are listed below:

6. *Investigate linear and non-linear ecological responses to change, the impacts of these changes on ecosystem structure and function and their role in causing recruitment and stock variability, depletion and recovery.*

   WGEVO has developed a framework for Evolutionary Impact Assessment (Laugen *et al.* 2014) that allows investigating linear and nonlinear eco-evolutionary changes in fish stocks and their utility in terms of ecosystem services (ToR c).

9. *Identify indicators of ecosystem state and function for use in the assessment and management of ecosystem goods and services*

WGEVO works on developing scientific and methodological tools to monitor and respond appropriately to risks to biodiversity and sustainable exploitation posed by fisheries-induced adaptive changes (ToRs c and d).

10. *Develop historic baseline of population and community structure and production to be used as a basis for population and system level reference points.*

    WGEVO assembles and reviews empirical evidence of fisheries-induced adaptive changes, notably through time-series analyses that provide historic baselines for assessing changes in life-history traits (ToR b).

11. *Develop methods to quantify multiple direct and indirect impacts from fisheries as well as from mineral extraction, energy generation, aquaculture and other anthropogenic activities and estimate the vulnerability of ecosystems to such impacts.*

    WGEVO is currently developing methodological tools to estimate fisheries-induced selection pressures and applying them to a range of exploited freshwater and marine fish stocks (ToR d).

    WGEVO applies the Evolutionary Impact Assessment (EvoIA) framework to specific case studies to (i) evaluate the impact of fishing and existing management measures on fisheries-induced adaptive change; and (ii) relate consequences of fisheries-induced adaptive change to stakeholder utilities and to current management objectives (ToR c).

12. *Develop approaches to mitigate impacts from these activities, particularly reduction of non-target mortalities and enhancement/restoration of habitat and assess the effects of these mitigations on marine populations*

    WGEVO applies the Evolutionary Impact Assessment (EvoIA) framework to specific case studies to evaluate possible more specific objectives for managing and mitigating fisheries-induced adaptive change (ToR c).

14. *Evaluate ecological, economic and social trade-offs between ecosystem protection and sustainable use to advise on management of human activity in marine ecosystems*

    WGEVO applies the Evolutionary Impact Assessment (EvoIA) framework to specific case studies to evaluate the impact of fisheries-induced adaptive changes on fish stocks utility, which includes ecosystem services related to ecology, economics, and social aspects (ToR c).

15. *Develop tactical and strategic models to support short and long term fisheries management and governance advice and increasingly incorporate spatial components in such models to allow for finer scale management of marine habitats and populations*

    WGEVO develops both tactical and strategic models to evaluate and predict fisheries-induced changes and their impact on stock productivity, in order to provide advice for short- and long-term fisheries management (ToR c).

27. *Identify knowledge and methodological monitoring gaps and develop strategies to fill these gaps*

    By constantly reviewing and monitoring developments in the field, WGEVO identifies knowledge gaps, methodological gaps, and monitoring gaps in regard to fisheries-induced adaptive changes and their consequences for biodiversity and stock productivity. WGEVO develops scientific and monitoring tools to fill these gaps (ToR b).

Main Achievements of WGEVO during the 2013-2015 Period

- **Publications**
  - Heino, M., Baulier, L., Boukal, D. S., Ernande, B., Johnston, F. D., Mollet, F. M., 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., and Dieckmann, U. 2013. **Can fisheries-induced evolution shift reference points for fisheries management?** *ICES Journal of Marine Science*, 70: 707–721.

    ➲ ***Outcome of ToRs a and b.***
  - 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. 2014. **Evolutionary impact assessment: accounting for evolutionary consequences of fishing in an ecosystem approach to fisheries management.** *Fish and Fisheries*, 15: 65–96.

    ➲ ***Outcome of ToR c.***
  - Mollet, F.M., Poos, J.J., Dieckmann, U., and Rijnsdorp, A.D. 2015. **Evolutionary impact assessment of the North Sea plaice fishery.** *Canadian Journal of Fisheries and Aquatic Sciences*, published online on 26 November 2015, doi:10.1139/cjfas-2014-0568.

    ➲ ***Outcome of ToR c.***
- **2014 ICES ASC Theme Session E "*Stocks in flux: From selection pressures via phenotypic and genetic adaptive responses to impacts on ecosystem service*"**

  ➲ ***Outcome of ToR a and b.***
  - Conveners: Ulf Dieckmann, IIASA, Austria; Mikko Heino, University of Bergen, Norway; and Filip Volckaert, University of Leuven, Belgium
  - 15 oral contributions and 10 posters
- **Oral contributions**
  - Matsumura S., Heino, M., Ernande, B., Rijnsdorp, A., Dieckmann, U., and the WGEVO participants. **How strong is fisheries-induced selection? An assessment of selection differentials caused by fishing.** *ICES Annual Science Conference (A Coruña, Spain), September 15-19, 2014, E:02.*

    ➲ ***Outcome of ToR d.***
  - Mollet, F.M., Poos, J.J., Dieckmann, U., and Rijnsdorp, A.D. **Evolutionary impact assessment of the North Sea plaice fishery.** *ICES Annual Science Conference (A Coruña, Spain), September 15-19, 2014, E:23.*

    ➲ ***Outcome of ToR c.***
- **Posters**
  - Heino, M. Ernande, B., Matsumura, S., Rijnsdorp, A., Dieckmann, U., and the WGEVO participants. **How strong is fisheries-induced selection? A gen-**

eral framework for estimating fisheries-induced selection differentials. *ICES Annual Science Conference (A Coruña, Spain), September 15-19, 2014, E:06.*

➲ ***Outcome of ToR d.***

- **Methodological developments**
  - o Development of a general framework for assessing the management implications of fisheries-induced evolution through Evolutionary Impact Assessments (EvoIAs; Laugen *et al.* 2014).

    ➲ ***Outcome of ToR c.***
  - o Development of a general framework for assessing fisheries-induced selection pressures: R scripts and a user manual have been developed for dissemination within the ICES community and the wider scientific community.

    ➲ ***Outcome of ToR d.***
- **Assessment products**
  - o An EvoIA has been developed and published for the North Sea plaice fishery (Mollet *et al.* 2015).

    ➲ ***Outcome of ToR c.***
  - o The framework for estimating fisheries-induced selection pressures has been applied to 31 exploited fish stocks and is currently in progress for 7 additional stocks (see table below).

    ➲ ***Outcome of ToR d.***

	Species	M/F[1]	Stock/region	Division type	Area	Status
1	American plaice	M	NW Atlantic	NAFO	3LNO	Completed
2	Blue whiting	M	NE Atlantic	ICES	I–IX,XII,XIV	Completed
3	Brill	M	North Sea	ICES	IV	Completed
4	Capelin	M	Barents Sea	ICES	I	Completed
7	Cod	M	E Baltic Sea	ICES	IIId	Completed
8	Cod	M	North Sea	ICES	IV	Completed
5	Cod	M	NW Atlantic	NAFO	3NO	Completed
6	Cod	M	W Baltic Sea	ICES	IIIb-c	Completed
9	Haddock	M	North Sea	ICES	IV	Completed
10	Herring	M	E Baltic Sea	ICES	IIId	Completed
11	Herring	M	North Sea	ICES	IV	Completed
12	Herring	M	North Sea	ICES	IV	Completed
13	Horse mackerel	M	NE Atlantic			Completed
14	Mackerel	M	NE Atlantic	ICES	II–IX,XII,XIV	Completed
15	Northern pike	F	Wisconsin Lakes		n.a.	Completed
16	Norway pout	M	North Sea	ICES	IV	Completed
17	Pikeperch	F	Archipelago Sea		n.a.	Completed
18	Plaice	M	North Sea		IV	Completed
19	Saithe	M	North Sea	ICES	IV	Completed

23	Sole	M	Bay of Biscay	ICES	VIIIa	Completed
21	Sole	M	E. Channel	ICES	VIId	Completed
20	Sole	M	North Sea	ICES	IV	Completed
22	Sole	M	W. Channel	ICES	VIIe	Completed
24	Sprat	M	Baltic Sea			Completed
25	Turbot	M	North Sea	ICES	IV	Completed
26	Walleye	M	Wisconsin Lakes	Escabana Lake	n.a.	Completed
27	Walleye	M	Wisconsin Lakes	Several lakes	n.a.	Completed
28	Whitefish (*C. lavaretus*)	F	Lake Constance		n.a.	Completed
29	Whitefish (*C. palaea*)	F	Switzerland		n.a.	Completed
30	Whiting	M	North Sea	ICES	IV	Completed
31	Yellow perch	F	Lake Erie	Lake Erie	West Basin	Completed
32	Cod	M	Flemish Cap		n.a.	In progress
33	Cod	M	NE Arctic	ICES	I-II	In progress
34	Cod	M	NW North Sea		n.a.	In progress
35	Haddock	M	Barents Sea	ICES	I	In progress
36	Haddock	M	NW North Sea		n.a.	In progress
37	Herring	M	NSS/Norwegian Sea	ICES	II	In progress
38	Sardine	M	Portugal		n.a.	In progress

[1] Marine/Freshwater

Difficulties in Achieving the Work Plan

- ToR d: The development of the methodological framework for estimating the selection differentials of exploited stocks, the gathering of the necessary data, and the corresponding statistical estimations have taken longer than anticipated. An appreciable number of stocks could already be assessed (see assessment products above), and the necessary extra work for producing a comprehensive review of the results is planned to be completed and delivered during the forthcoming three-year period.
- ToR b: The working group decided to adjust the timeline for preparing the ICES document providing an overview of fisheries-induced evolution for a wider scientific audience and the general public, a deliverable originally foreseen for year 1. The idea is to resume this task once the project on fishing-induced selection pressures has been completed, so the results from that project can be included in that overview document.

Future Plans

Continuation of WGEVO

The group suggests that continuing WGEVO for a three-year term is advisable. Such an extension is indeed necessary to accomplish the following tasks:

- Finalize the estimation of fisheries-induced selection gradients for stocks that are currently in progress and add a dozen extra stocks that have been identified through an analysis of data availability (ToR d).
- Complete the comprehensive review on estimates of fisheries-induced selection gradients (ToR d)
- Produce an ICES publication about fisheries-induced evolution for a general audience, as well as a Wikipedia article that includes the conclusions of the review on fisheries-induced selection gradients (ToR b).

In addition, the suggested new three-year term will allow the further development of some ToRs as listed below:

- ToR c: Develop Evolutionary Impact Assessments (EvoIAs) for other exploited fish stocks (ToR c).
- ToR d: Automatize the estimation of fisheries-induced selection gradients directly based on stock-assessment outputs (this will benefit from a closer liaison with stock-assessment working groups; see below).

Additional Expertise Needs

Expertise in FLR and/or stock assessment would help in extending ToR d by automatizing selection-pressure estimations directly based on stock-assessment outputs.

Potential Input to the Advisory Process

Estimates of fisheries-induced selection gradients can and should be used in the advisory process. These estimates could be produced and updated on a regular basis during benchmarks and/or integrated ecosystem assessments. Estimation algorithms could then be used to forecast future selection gradients based on the projections by the stock-assessment working groups. This would allow stock assessments to cover the effects of TAC recommendations on fisheries-induced selection gradients.