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Report of the ICES/GLOBEC Working Group on Life Cycle and Ecology of Small Pelagic Fish (WGLESP)

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Executive summary

A conceptual biological framework is suggested to envisage changes in fish spatial distributions. Environmental forcing alone cannot be expected to explain changes in distribution, unless changes are so strong that they over-ride all other drivers. Changes in the distributions of pelagic fish were understood as resulting from the interaction between external factors to the population such as climate or ecosystem change and internal factors to the population. Internal factors to the population include total abundance, population structure, individual fish condition, aggregation behaviour, density dependence. Internal factors result in the population to be innovative or conservative in occupying its potential habitats. Change in spatial distributions can then occur because the distribution of potential habitats changed under climate change and or because the population's internal behaviour changed under internal factors such as demographic change.

Mechanisms for the change in spatial distribution can be analysed when habitats are colonised *de novo*. The colonisation of the North Sea by southern-like species since the late 1990s offers a case study to analyse these mechanisms. The colonisation of the North Sea was analysed on short-lived species in the pelagic and demersal domains (anchovy and red mullet). Variation in the spatial distributions of these species was compared to that of sprat which was a North Sea resident species. The examples showed that expansion can be obtained by different mechanisms. North Sea sprat showed no change in its spatial distribution but additional recruitment windows were observed with two waves of recruitment in certain years. In both the anchovy and red mullet cases the first colonisers observed were small fish. But the two species showed differences. The expansion of anchovy in the North Sea was understood as recruitment pulses of low abundant resident populations. In contrast, the red mullet in the North Sea was thought to come from English Channel populations and keep connections with them via movements of the larger fish.

In the North East Atlantic, the analysis of the ICES hydrographic data base since 1960 showed three periods, 1960–1988, 1989–1998, and 1999–2005 in which warming was evident. The last period is a warmer period than the others while the second period is more variable as if it was a transitory period. Temperature can play a direct role or be a proxy of ecosystem change. The approach of limiting factors was appropriate to understand the direct role of temperature as a driver of change in fish spatial distributions. Temperature alone did not explain changes in fish spatial distribution, unless it acted as limiting factor.

1 Introduction

The ICES/GLOBEC Working Group on Life Cycle and Ecology of Small Pelagic Fish (WGLESP) met at the IFREMER centre in Nantes, France from the 5–9 March 2007 back-to-back with the Working Group on Fish Ecology (WGFE). The ICES resolution 2006/2/LRC04 defined the Terms of References (ToR) for the meeting:

- a) complete specific work emanating from past activity;
- b) present and discuss new results on life cycle spatial patterns, environmental forcing on fish habitats and their modelling;
- c) maintain overview of developments in the field and report to relevant ICES WGs;
- d) provide synthetic contributions from the ICES area to the SPACC program of GLOBEC, in particular review the outcome of the ICES ASC 2006 Theme Session on Large-scale change in the migration of small pelagic fish and the factors modulating such changes;
- e) program new workshops;
- f) assess and report on changes in the distribution, population abundance and condition of pelagic fish in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature, taking account of work conducted in the fish stock assessment working groups;
- g) assess and report on the extent to which the changes reported in (f) can reliably be attributed to changes in hydrodynamics and sea temperature.

The meeting of WGLESP was initially planned to take place after the Workshop on Testing the Entrainment Hypothesis (WKTEST) which the group had set up as its main activity for 2007. But because of a request to ICES by OSPAR, WGLESP was given ToRs (f) and (g) which were similar to that given to WGFE. It was decided at the LRC Committee meeting during the ASC 2006 to give high priority to that request and jointly meet with WGFE for that purpose, thus upsetting the initial plan. WGLESP experienced lack of attendance (two participants only) at its meeting. The two participants participated for pelagic fish to the subgroup of WGFE that worked on the OSPAR request. One joint report on these ToRs was made and it can be found in the WGFE report – ICES CM 2007/LRC:03. Other WGLESP ToRs were dealt with by correspondence after the meeting.

WGLESP was set up as a continuation of a Study Group (SGRESP) and it was its first year as a Working Group. Nominated members declared interest in the group although could not contribute much this year. Prioritisation of activity has been a problem this year. The group is related to GLOBEC and has unique topics on fish spatial patterns in relation to environment.

2 Progress on the Terms of Reference

2.1 ToR a) Complete specific work emanating from past activity

The expansion of anchovy in the North Sea had been analysed in the past (SGRESP reports 2005, 2006) for understanding how a species colonises new habitats. This was further carried on. Results are reported under ToR (f) and are in the report of WGFE.

Catch at length was extracted over a larger period from 1965 to 2006 from North Sea IBTS and DATRAS data bases as well as CTD data from ICES hydrographic data base. An analysis of the expansion of anchovy in the North Sea was completed and compared to other short lived species such as red mullet and sprat. It was concluded that anchovy in the North Sea is present as residual populations and that expansion is due to good recruitments. Also, a potential spawning model for anchovy in Biscay applied to the North Sea hydrographic conditions showed that spawning was possible in the North Sea only in the coastal areas in summer. A small number of anchovy eggs were effectively present in the German GLOBEC ichthyoplankton surveys.

The collapse of anchovy as reported in the SGRESP 2006 report was an artefact. At that time, all countries had not reported/updated their survey results in the DATRAS data base. The collapse was not seen on the correct updated data used this year.

2.2 ToR b) Present and discuss new results on life cycle spatial patterns, environmental forcing on fish habitats and their modelling

No new results were reported. Because of the OSPAR request the meeting of WGLESP was changed from the original plan. This ToR originally applied to outcome from the WKTEST workshop which is planned later this year (June 2007). (See introduction for full details).

2.3 ToR c) Maintain overview of developments in the field and report to relevant ICES WGs

No work has been reported on this topic.

2.4 ToR d) Provide synthetic contributions from the ICES area to the SPACC program of GLOBEC, in particular review the outcome of the ICES ASC 2006 Theme Session on Large-scale change in the migration of small pelagic fish and the factors modulating such changes

Out comes from the ICES 2006 ASC Theme Session B on Large-scale change in the migration of small pelagic fish and the factors modulating such changes.

The report of the Theme session can be found on the ICES website (ASC page). A series of papers presented changes in the migration patterns and distributions for a wide range of stocks in the world: sardine in Japan, California current, Humbolt current, South Africa, herring and mackerel in North East Atlantic, and mackerel and sardinella in Western Africa. Changes in the distributions were related to large scale forcing environmental conditions. But density dependence, fish condition, population age structure and fish behaviour were also evidenced as drivers of change, meaning that changes in spatial distributions need to be considered as resulting from the interaction between external and internal factors to the populations. Mechanisms need be understood as similar changes can result from different interactions between environment, density-dependence, fish condition, population structure and behaviour. The theme session major contribution was to evidence those interactions. Environmental forcing alone cannot be expected to explain changes in distribution, unless it represents major events overwhelming all other biological parameters.

Results from the ICES/GLOBEC 2007 Workshop on Long Term Variability in SW Europe (WKLTVSWE)

The report of the Workshop can be found on the ICES website (<http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WKLTVSWE>). A summary report was published in the GLOBEC Newsletter of April 2007. Fish abundance, hydro-climate variables as well as plankton indices were collated and jointly analysed to describe combined large-scale temporal changes. The Atlantic area considered was from Cadiz (35°N) to Brest (49°N). The work compiled appropriate indices for the area since 1920–1940 and worked them with standard multivariate and temporal methods for regime shift detection. A variety of oceanographic features occur in this area, including upwelling, river discharge, poleward current, gyres, fronts. The area is under the influence of two situations: one boreal in which northern winds prevail with upwelling events and a sub-tropical one in which southern warm salty waters enter the Bay of Biscay. Sardine catches in Portugal have been related to upwelling strength, NAO and northerly winds. While sardine and anchovy showed synchrony in their abundance variations prior to 1978, the pattern has been asynchronous thereafter. The spatial distribution of anchovy has been reduced since the 1980s and confined to SE Biscay.

2.5 ToR e) Program new workshops

The WGLESP list of topics for workshops was:

- Connecting the fish to the ecosystem (oceanographic features, plankton production, top predators);
- Habitat modelling that combines environmental forcing and population memory.

WKLTVSWE evidenced long-term changes in clupeiform fish in SW Europe in relation to regimes in the ecosystem and climate indices. On the climate change topic, thematic cooperation with GLOBEC/SPACC would be desirable, based on the large experience that this group has worldwide. The OSPAR request on climate change impact on fish dynamics and distributions is thought to require more inter-disciplinary work as well as more work on the mechanisms driving changes in distributions.

It is thus recommended to convene an ICES/GLOBEC workshop in 2008 on 'Climate impact and regime changes of clupeiform pelagic fish in European and NW African waters'. The workshop activity would encompass topics such as (i) changes in distribution, population abundance and condition of pelagic fish in relation to changes in hydrodynamics and sea temperature, (ii) connecting the fish to the ecosystem.

2.6 OSPAR request – ToR f) and ToR g)

ToR f): Assess and report on changes in the distribution, population abundance and condition of pelagic fish in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature, taking account of work conducted in the fish stock assessment working groups

ToR g): Assess and report on the extent to which the changes reported in (f) can reliably be attributed to changes in hydrodynamics and sea temperature

The two WGLESP members worked in close collaboration together with the WGFE group and concentrated on the following items:

- characterise the colonisation of North Sea habitats since the late 1990s by southern-like short-lived species, anchovy and red mullet, and compare their distributions and recruitment dynamics to that of sprat, which is a resident species;

- apply to the North Sea a new version of a potential spawning model for anchovy in Biscay;
- identify periods in the ICES hydrography data base to characterise warming since 1960s;
- apply the quotient plot method to all considered species by WGFE to quantitatively characterise the temperature range of the species and summarise the interaction in the fish and temperature distributions;
- report on the mechanisms which drive changes in the spatial distributions of fish.

The outcomes of that work can be summarised as follows. Different factors will affect life cycle spatial organisation which can be grouped into two categories. External factors such like hydro-climate will act as forcing conditions on the suitability of the habitats. Internal factors to the population such as demography and behaviour will determine the capability of the population to effectively occupy all its potential habitats. Finally the actual distribution in a given year will result from the interaction between external and internal factors. Change in spatial distributions can then occur because the distribution of potential habitats changed under climate change and or because of the population's internal behaviour changed under demographic change.

Changes in spatial distributions can be analysed, modelled and predicted with a variety of approaches, data and tools. Potential habitats as well as population behaviour were here addressed using long-term series of fisheries survey data.

Potentiality in habitat suitability for a given species life stage was estimated by statistically analysing in a large number of realised yearly distributions the range of hydro-climate characteristics that recurrently correlated with zero as well as high abundance.

Population's behaviours when colonising novel habitats were tentatively analysed. During the past decade southern-like species have colonised North Sea habitats. The analysis was performed on short lived species: anchovy and red mullet for the pelagic and demersal domains. Being resident in the North Sea, sprat was considered as a reference short lived species for the area.

North Sea sprat showed no change in its spatial distribution but additional recruitment windows were observed with two waves of recruitment in certain years. In both the anchovy and red mullet cases the first colonisers observed were small fish. But the two species showed differences. North Sea colonisation by the red mullet was progressive while it was immediately complete for anchovy. Also all length classes were tracked seasonally for anchovy while they could not be for red mullet. The expansion of anchovy in the North Sea was therefore understood as recruitment pulses of low abundant resident populations. In contrast, the red mullet in the North Sea was thought to come from English Channel populations and keep connections with them via movements of the larger fish.

In the North East Atlantic, the analysis of the ICES hydrographic data base since 1960 showed three periods, 1960–1988, 1989–1998, and 1999–2005 in which warming was evident. The last period is a warmer period than the others while the second period is more variable as if it was a transitory period.

Pelagic fish showed a consistent seasonal difference in their temperature range between the first and third quarter of the year, which was greater than 5°C. It was thought that species can adapt to change in temperature, depending on other factors being in their correct range of values. To explicit the direct impact of temperature on changes in spatial distributions, an appropriate methodological approach could be that of limiting factors.

The report of WGFE contains the common work of both groups (see WGFE report).

Annex 1: List of participants

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Annex 2: WGLESP Terms of Reference for 2008

The ICES/GLOBEC Working Group on Life Cycle and Ecology of Small Pelagic Fish [WGLESP] (Chair: P. Petitgas, France) will meet by correspondence to:

- a) Prepare a document compiling the knowledge assembled by SGRESP on life cycle patterns and meso-scale oceanographic features for small pelagic fish in the North East Atlantic, to be proposed for publication as a Cooperative Research Report;
- b) Summarise outcomes from past activity (e.g. SGRESP, OSPAR request, 2006 Theme Session B, 2007 Theme Session G, WKLTVSWE, WKTEST) to document the mechanisms and controls of changes in spatial distributions and migration patterns;
- c) Report new results and methods for modelling habitat occupation;
- d) Liaise with other ICES groups of the Oceanography Committee and suggest ways to collaborate to address hydro-climate forcing on spatial distributions of pelagic fish.

WGLESP will report by *** to the attention of the Living Resources Committee, the Oceanographic Committee and GLOBEC/SPACC.

Supporting Information

PRIORITY:	The work of the Group is essential if ICES is to progress the understanding of environmental forcing on life history, spatial and population dynamics of pelagic fish to provide alternative basis to management on stocks recognised to fluctuate under environmental forcing. There is no other group within ICES on this thematics that is also key for recovery plans of depleted stocks.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	<p>The purpose of the WG is i) to integrate various survey data together as well as with meteo, satellite, fishery and/or ecosystem model outputs and ii) develop understanding of how the spatial dynamics of the biological cycle and the stock dynamics are related to the ecosystem thus increasing ICES ability to use ecological information in assessment and prediction of small pelagics. The WG will work on different case studies in the ICES waters.</p> <p>This WG addresses Goal 1 Understand the physical, chemical, and biological functioning of marine ecosystems, in particular action numbers 1.2.2 Changes in spatio-temporal distributions in relation with environmental change, 1.6 assess and predict impact of climate variability and 1.7 play an active role in collaborations between ICES and other international research such as GLOBEC. This WG is also related to Goal 4 Advise on the sustainable use of living marine resources, in particular action number 4.11 Develop the scientific basis for an ecosystem approach to management.</p>
RESOURCE REQUIREMENTS:	No specific resource requirements beyond the need for members to prepare for and participate in the meeting.
PARTICIPANTS:	The Group is normally attended by some 15 members and guests. These would include scientists working on survey data, population modelling, environmental change and scientists participating to GLOBEC/SPACC.
SECRETARIAT FACILITIES:	None specific
FINANCIAL:	None specific
LINKAGES TO ADVISORY COMMITTEES:	Link with ACFM through WGMHSA and WGRES (advise on recruitment scenarios as deduced from environment & spawning habitat selection); Link with ACE through particular ToRs (e.g. Ospar request)
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Link with WGPBI and WGRP of the Oceanography Committee (link fish populations to meso-scale physical structures, use of hydrodynamics model outputs). Link with groups dealing with environmental and fisheries survey data.
LINKAGES TO OTHER ORGANIZATIONS:	This group is acknowledged to be of relevance to the GLOBEC/SPACC programme by its executive committee.

Annex 3: WKCLISP Terms of Reference for 2008

The ICES/GLOBEC Workshop on Climate impact and regime changes of clupeiform pelagic fish in European and NW African waters [WKCLISP] (Chair: J. Alheit*, Germany) will meet in Warnemünde, Germany xxxxx June 2008 to:

- a) Document changes in distribution, population abundance and condition of pelagic fish;
- b) Explain these changes in relation to changes in hydrodynamics and sea temperature;
- c) Explain these changes in relation with changes in the plankton ecosystem.

WKCLIM will report by *** to the attention of the Living Resources Committee, the Oceanographic Committee and GLOBEC/SPACC.

Supporting Information

PRIORITY:	The work of the Group is essential if ICES is to progress the understanding of the mechanisms driving changes in pelagic fish populations by connecting fish to the environmental and the ecosystem.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	<p>The WK addresses Goal 1 Understand the physical, chemical, and biological functioning of marine ecosystems, in particular action numbers 1.2.2 Changes in spatio-temporal distributions in relation with environmental change, 1.6 assess and predict impact of climate variability and 1.7 play an active role in collaborations between ICES and GLOBEC. This WG is also related to Goal 4 Advise on the sustainable use of living marine resources, in particular action number 4.11 Develop the scientific basis for an ecosystem approach to management.</p> <p>The WK will further allow ICES to answer the OSPAR request on the impact of climate change on fish population dynamics and distributions</p>
RESOURCE REQUIREMENTS:	No specific resource requirements beyond the need for members to prepare for and participate in the meeting.
PARTICIPANTS:	Participants would include scientists from WG of the LRC and OCC as well as from GLOBEC/SPACC.
SECRETARIAT FACILITIES:	None specific
FINANCIAL:	None specific
LINKAGES TO ADVISORY COMMITTEES:	Link with ACE through particular ToRs related to the Ospar request
LINKAGES TO OTHER COMMITTEES OR GROUPS:	Link with WGPBI and WGRP of the Oceanography Committee (link fish populations to meso-scale physical structures, use of hydrodynamics model outputs). Link with groups dealing with environmental and fisheries survey data.
LINKAGES TO OTHER ORGANIZATIONS:	This group will be proposed for approval by GLOBEC/SPACC steering committee

Annex 4: Table of Recommendations for 2008

RECOMMENDATION	ACTION
1. Publish as an ICES Cooperative Research Report the compilation of knowledge assembled by SGRESP on life cycle patterns and meso-scale oceanographic features for small pelagic fish in the North East Atlantic	WGLESP
2. Convene WKCLISP in 2008 to increase ability to address Oskar request on climate impact on pelagic fish	LRC
3. Review progress in the development of tools for the identification and characterisation of mesoscale physical structures in the ocean and of indices of mesoscale oceanographic features; evaluate the reliability of the indices for their use in explaining spatial temporal variability in fish populations	OCC
4. To answer the OSPAR request, understanding the mechanisms driving changes in the spatial distributions is necessary. It is recommended to convene trans-committee scientific work either as a workshop, theme session, symposium, or study group	ICES - WGPBI, WGZE, WGOH