Report of the Working Group on Recruitment Processes (WGRP)

By correspondence

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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Recommended format for purposes of citation:

ICES. 2006. Report of the Working Group on Recruitment Processes (WGRP). By correspondence. ICES CM 2006/OCC:13. 8 pp.

Contents

Executive Summary

The WGRP has continued work, by correspondence, on three principal research themes identified following our 2005 meeting in Barcelona. Work on the first theme, the contribution of coupled physical-biological models to understanding recruitment, has been largely completed and has resulting in a manuscript submitted to Marine Ecology Progress Series. Additional work, in collaboration with WGPBI members to generate a Manual of Best Practices will be completed by 2007. Work on the second and third research themes is ongoing. The second research theme seeks to identify the sources, patterns and consequences of selective processes during fish early history. Work under this theme has focused on developing a database of studies that demonstrate the presence and outcomes of selective processes both in the field and in the laboratory. Work on this aspect of the project will continue into 2007. Following the completion of this component of the project, work will begin on understanding the implications of the documented selective processes on our ability to implement sustainable fishing practices and management. The final research seeks to explore the potential of multistage models of recruitment to identify regulatory processes that have remained latent in traditional analyses. As with work conducted for the second theme, this work is at the preliminary stages of compiling data that will be the foundation for subsequent analyses.

1   Background

As requested by the Oceanography Committee, WGRP met in Barcelona in 2005 to challenge ourselves to develop new Terms of Reference (ToRs) and a plan of work that identified the specific contributions the workgroup could make to advice provided by ICES to its clients. As a result of that meeting, we identified three general areas that we felt would represent specific examples of how WGRP could contribute to ICES advice. The first ToR developed recognized that coupled physical biological models of recruitment processes have developed rapidly over the last twenty years. However, these models have yet to see broad application in making forecasts of recruitment. We proposed that WGRP, in collaboration with the WGPBI, would undertake a critical review of the contribution that such coupled models have made to our understanding of recruitment and assess the prospect for such models to contribute to forecasts of recruitment. The second ToR developed recognized that recruitment is a highly selective process. Selection results from the non-random contribution of individuals to the formation of subsequent year class strength. For example, the fish that comprise the spawning stock are often not a random draw of potential spawners. This example of selection can arise from impacts of size-selectivity of fishing gear over multiple generations(Conover and Munch, 2002). Alternatively, survival during early life history is also non-random, with surviving larvae usually being a non-random subset of those that hatch (Meekan and Fortier, 1996). In recognizing the importance of these processes, WGRP proposed to critically review the sources, patterns and consequences of selectivity on recruitment in marine fishes. The third ToR developed for 2006 focused attention on assessing the benefits of recognizing multiple stages within the recruitment process itself. For example, recruitment often involves ontogenetic habitat shifts that expose survivors to different environments. Multistage approaches to recruitment were developed more than 30 years ago, but have not been systematically applied to understanding recruitment process. Here, we report on the progress made against each ToR

1.1   Terms of reference

The Terms of Reference for the Working Group are provided in Annex 1.

2   Progress against ToRs

In 2006, the WGRP addressed its ToRs by correspondence.

2.1   Review of the contribution of coupled physical-biological models to our understanding of recruitment

Several products have resulted, or are in the final stages of completion relative to this ToR.

Thomas Miller (USA, Co-Chair WGRP) completed his review of the development, application and prospects for individual-based, coupled physical biological models (ICPBMs) to understanding recruitment in fishes. This analysis has resulted in a manuscript that has been submitted for consideration for publication to the journal Marine Ecology Progress Series. The manuscript reaches several key conclusions: (1) ICBPMs have the flexibility to include the principal mechanisms thought important in regulating recruitment, (2) ICPMs often focus on individual recruitment mechanisms, principally transport-related hypotheses, (3) only approximately 1/3 of ICPBMs included growth (Figure 2.1.1), (4) only approximately 1.3 of ICPBMs included predation mortality (Figure 2.1.1), and (5) ICPBMs have typically taken adopted an explanatory framework rather than a hypothesis-testing framework.
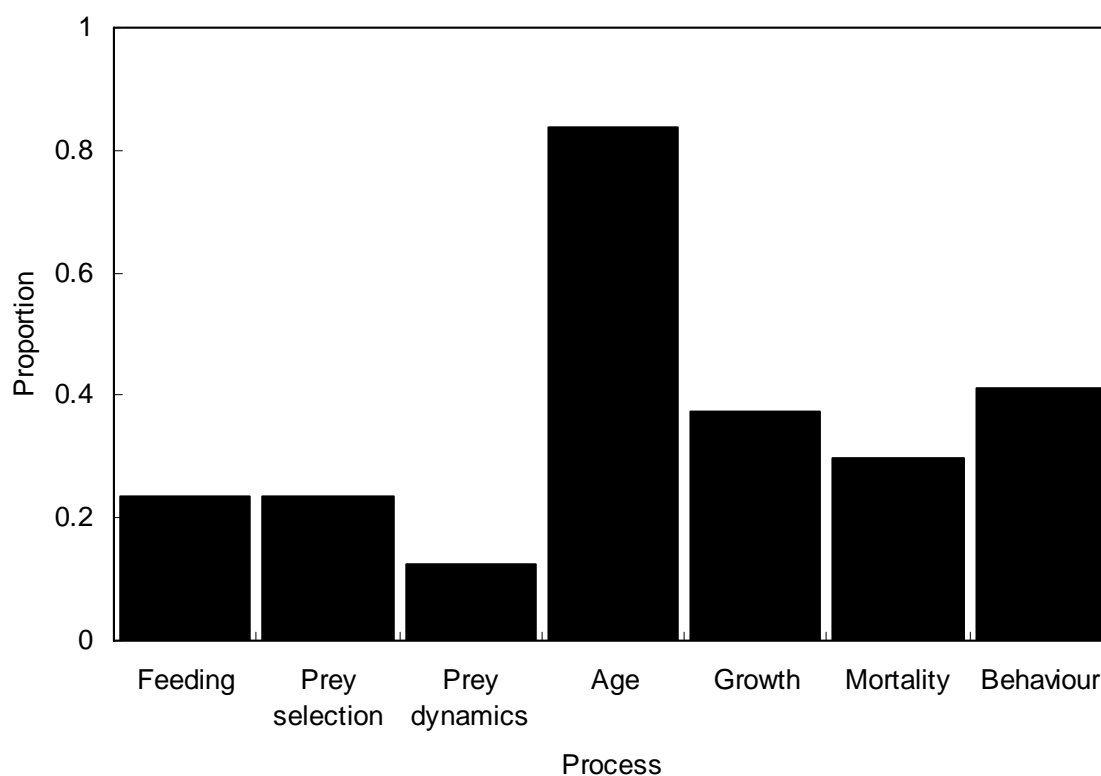
Figure 2.1.1. The frequency of representation of different biological processes thought to be important in recruitment in ICPBMs reviewed by Miller.

The review indicated that ICPBMs have focused on a restricted suite of taxa and systems, so that model of gadoid fishes in the North Sea and off the NE coast of the USA predominate. Thus, the generality of findings from ICPBMs is unknown. The review focused attention also on two alternative approaches to representing growth in ICPBMs. The first approach, exemplified by work by Heath and colleagues (Heath and Gallego, 1997; Gallego *et al.*, 1999), uses empirically-derived, temperature-dependent growth models to predict growth given the modelled temperature history of individual larvae within the model. The approach makes the implicit assumption that growth potential does not vary over the model domain, other than as regulated by temperature. Proponents of this approach suggest that concerns over the accuracy of sub-grid scale processes in the physical model impose the need to use the conservative nature of temperature as a foundation for growth models. This approach was found to be effective, but relies critically on the accuracy of the empirical growth model. If the underlying is biased, the growth trajectories predicted by the model will be similarly biased (Folkvord, 2005). The second approach to representing growth in ICPBMs employs a more mechanistic framework that seeks to predict growth based upon the outcome of individual foraging events and metabolic costs. This approach is exemplified by work by Werner and colleagues (Werner *et al.*, 1996). The approach has the advantage of introducing stochasticity into growth trajectories and can incorporate effects of prey availability and small-scale turbulence on ingestion rates, but relies critically on the accuracy of predictions of sub-grid scale velocity and prey distribution fields. Finally, the review identified three general approaches that have been adopting in applying ICPBMs to understanding recruitment. Most often ICPBMs have been used in an explanatory mode in which model results are used to explain observed patterns. This approach rarely involved any exploration of the sensitivity of the model results to underlying variability in parameter estimates or forcing functions. Less frequently, modelling teams adopted an inferential approach which explicitly sought to assess the importance of individual processes on the outcome of models. For example Brickman and

Frank (2000) compared the impact of two alternative representations of larval mortality on the distribution and characteristics of survivors. This approach was viewed as more powerful than the explanatory approach. Most powerful, but most rarely used were approaches that explicitly sought to test hypotheses regarding recruitment. As an example of this approach, Mullon *et al.* (2002) tested hypotheses regarding the timing and distribution of spawning locations for cape anchovy in the Benguela system off South Africa. In his review paper, Miller suggests that hypotheses-based approaches should be encouraged to improve the formulation of ICPBMs that will be necessary if they are to become forecasting tools.

In April 2006, WGRP collaborated with WGPBI to host a Workshop on Advancements in Modelling Physical-Biological Interactions in fish Early-Life History: Recommended Practices and Future Directions. WGPBI took the lead on this workshop, and undertook the organisation and execution of the workshop. Elizabeth North (WGPBI), Alejandro Gallego (WGPBI and WGRP) and Pierre Pettigas (WGPBI) convened the workshop. A summary of the workshop is included in the WGPBI 2006 report (http://www.ices.dk/reports/OCC/2006/WGPBI06.pdf). Several papers resulting from the meeting (including the Miller review discussed above) were submitted to Marine Ecology Progress Series for publication.

As a result of the workshop, it was agreed that WKPBI and WGRP would continue their collaboration to develop a "Manual of Recommended Practices for Modelling Physical-Biological Interactions in Fish Early-Life History." Development of the manual is underway with a draft of the first draft of the manual due to be completed by the end of 2006.

2.2 Selective Processes in Early Life History

This research initiative was proposed as a five year project at the WGRP meeting in Barcelona in April 2005. The objective of the project is to understand the sources and patterns of selective mortality to assess the long term consequences of selective mortality on recruitment processes and ultimately our understanding of stock dynamics. The initial phases of the project are being lead by Chris Chambers (USA) and Arild Folkvord (Norway). The first objective of the project has been to assemble a database of studies documenting selective processes in fish early life history. When completed, the database will contain both field and experimental studies to ensure that the full diversity of possible responses is represented in the database. Work on this aspect of the project is ongoing. We are also working to sponsor a theme session at the 2007 Larval Fish Conference. The goals of the theme session will be to review the impact and importance of selective mortality process in early life history. The arrangements for the workshop are well in hand. The 2007 Larval Fish Conference will be held 9-12 July 2007 in St. Johns, Newfoundland, Canada.

2.3 Multistage Models of Recruitment

This research initiative was also proposed at the WGRP meeting in Barcelona in April 2005, but as a three year project. The WGRP is undertaking a project to compile and analyse multistage recruitment models. The objectives of the project are to compare Paulik-style diagrams at three levels of resolutions: (1) different stocks of the same species, (2) different species in the same ecosystem and (3) different species within the same functional guild (i.e., ground fish vs. pelagics). The project is being lead by Richard Nash (Norway) and Tom Miller (USA). Currently, data are being compiled for several species and systems including Atlantic herring (*Clupea harengus*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and striped bass (*Morone saxatilis*) and Alaska/walleye pollack (*Theragra chalcogramma*). The Paulik diagrams will initially be presented in the form given by Nash and Dickey-Collas (2005) for North Sea herring. An updated version is given in ICES (2006).

3   Future Plans for WGRP

The WGRP will meet in St Johns, Newfoundland, Canada immediately following the 31st Annual Larval Fish Conference on 13–15 July 2007. We propose that the first day of the meeting will be dedicated to the two research projects that we identified during our 2005 meeting: (1) selective processes in recruitment and (2) multistage models of recruitment. We anticipate that work on the former will lead to an ICES Cooperative Research Report, and peer-reviewed journal articles. In contrast it is expected that work on the later will result in peer-reviewed journal articles only.

3.1   Selective Processes in Early Life History

By July 2007, the WGRP will have completed its review of the literature relating to selective processes in early life history, and present its preliminary results at the Larval Fish Conference which precedes the WGRP meeting. Following the meeting, we will convene a small working team to begin work developing an ICES Cooperative Research report that will formally present the results of the project. We envisage the report focusing on the several key areas. The report will document the sources of selective mortality including selection on the parental spawning stock as well as on early life history stages. Selective processes need not be taken to refer just to mortality, they may relate to distribution of individual sizes, or spawning dates within the stock, or even to metapopulation structure within the species. The report will then discuss the long term evolutionary consequences of this selection on the population. Selective processes do not necessarily lead to changes in the population: evolutionary change only occurs when the selection is acting in a directional fashion. Alternatively, if the selective processes are acting in a stabilizing fashion, no change will be expected. To the extent possible, the report will document specific examples of selective processes during early life history and the consequences of these processes on the population. Finally, the report will explore the consequences of selective processes for the biological reference points employed in fisheries management. For example, size-selective mortality on the parental brooding stock may lead to reduced ages at reproduction, which may in turn lead to reduced recruitment success (Secor, 2000), despite minimal effect on total spawning stock biomass.

3.2   Multistage Models of Recruitment

By July 2007, the WGRP will have completed the compilation of data on North Sea herring, North-east Arctic cod, striped bass and walleye pollock. The preliminary multistage recruitment models in the form of Paulik style diagrams will be presented to the WGRP at the annual meeting. During this meeting refinements to the modelling processes will be discussed, agreement on proceeding with the other previously identified species and stocks sought and any other stocks and/or species with sufficient data identified.

4   Future Meetings

2007   St. Johns, Newfoundland (jointly with LFC)

2008   Copenhagen, Denmark

We have not planned WGRP beyond 2008, when we plan to meet at ICES headquarters. By 2008, WGRP anticipates that the bulk of the work on the two research project initiated in 2005 will have been completed. Thus, 2008 becomes a planning year to discuss, identify and initiate new research projects that reflect the interest of WGRP members, and the needs of ICES. Several ideas were suggested at the Barcelona meeting including "Recruitment correlations in large marine ecosystems" and 'Recruitment in a changing global environment" that were not taken up by WGRP. We will revisit these ideas and others in 2008 to determine the future direction of the WGRP.

5   Proposed Terms of Reference for 2007

The Terms of Reference developed for 2007 are based on the continuation of the two research projects initiated in 2005 following the Barcelona meeting. The proposed Terms of Reference are:

The **Working Group on Recruitment Processes** [WGRP] (Co-Chairs: R. D. M. Nash, Norway, and T. Miller, USA) will meet in St. Johns, Newfoundland from **date–date** July 2007 to:

a) conduct a synthesis and review of the evidence for sources, patterns and consequences of selective processes in fish early life history and its relevance to our understanding of forecasts of year class strength. *(carried over from 2006)*;

b) Based on the results of the review of selective processes in early life history, prepare an ICES Cooperative Research Report that identifies the challenges presented to sustainable fisheries management (capture and aquaculture) of selective processes in early life history;

c) summarize and analyse data relevant to multi-stage models of recruitment to determine whether patterns exist either within species or within ecosystems that may lead to generalisations regarding the nature of population regulation *(carried over from 2006)*.

WGRP will report by **date month year** for the attention of the Oceanography Committee.

Supporting Information

Priority:	Because the relationship between spawning stock and recruitment is fundamental to the scientific approach to fisheries management, the work of this group should be considered of high priority to ICES.
Scientific Justification and relation to Action Plan:	Action plan 1

ToR a and b) Action plan 1.2, 1.3, 1.6
At present there is a general lack of information on the causes of mortality in young stages of fish. In particular predation mortality. It is only recently that new analytical tools are being developed (specifically genetics based) that will allow the levels and sources of predation to be identified. This information is fundamental to our understanding of the processes that affect recruitment levels.
ToR b) Action plan 1.2, 1.3
The identification of where in the pre-recruit life history year class strength is determined is important for determining useful recruitment indices and forecast models for recruitment. There are a number of species that have been sampled regularly, both multiple sampling of a cohort over if young stages and over a number of years. A collation of these data will provide insight in to variability with a species across different environments and between species within an environment. |
Resource Requirements:	The WG requires active participation from the members assigned by the Delegates. A complement of 15-20 active members is required to accomplish the work identified in the resolution.
Participants:	In addition to regular members, the WG feels there would be benefit from greater participation by individuals with quantitative skills in the area of biometry and population dynamics.
Secretariat Facilities:	The Working Group will meet in conjunction with the 31st Annual Larval Fish Confernece in 2007 and so will only need secretarial assistance for an annual report.
Financial:	No financial implications
Linkages To Advisory Committees:	The activities of the WG are developing to provide more accurate medium-term forecasts of stock projections
Linkages To other Committees or Groups:	The activities of the WG are designed to provide input of knowledge to various Assessment WGs. There is no potential overlap in activities because the latter do not have the resources to consider the nature of this new knowledge outside the scope of their current activities. WGZE has close ties with the work of the Group. WGPBI also has close ties with WGRP – several people sit on both WGs.
Linkages to other Organisations:	GOOS, GLOBEC and NAFO through its Working Group on Reproductive Potential.

6   References

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Annex 1: 2006 Terms of References

2005/2/OCC13   The **Working Group on Recruitment Processes** [WGRP] (Co-Chairs: R. D. M. Nash, Norway, and T. Miller, USA) will work by correspondence in 2006 to:

     a)   prepare a synthesis of multidisciplinary projects relevant to our understanding of recruitment processes and highlight unresolved issues which deserve further consideration *(carried over from 2005)*;

     b)   assess the role of spatial and temporal variability in the distribution and abundance of organisms together with the implications of these sources of variability on the design of sampling programmes and inferences drawn from them *(carried over from 2005)*;

     c)   conduct a synthesis and review of the evidence for sources, patterns and consequences of selective mortality in fish early life history and its relevance to our understanding of forecasts of year class strength;

     d)   summarize and analyse data relevant to multi-stage models of recruitment to determine whether patterns exist either within species or within ecosystems that may lead to generalisations regarding the nature of population regulation;

     e)   explore the potential of preparing a theme session article for Marine Ecology Progress Series on the Utility of Recruitment Research to Fisheries';

     f)   collaborate with WGPBI to enhance the use of physical-biological models for prediction of fisheries recruitment.

WGRP will report by 1 June 2006 for the attention of the Oceanography Committee.

Supporting Information

Priority:	Because the relationship between spawning stock and recruitment is fundamental to the scientific approach to fisheries management, the work of this group should be considered of high priority to ICES.
Scientific Justification and relation to Action Plan:	Action plan 1 ToR a) Action plan 1.3 Many countries have research programs on recruitment processes, many of which are also multidisciplinary. There is a need to determine which studies are currently underway and to determine which studies need to be undertaken to provide relevant information for the assessment and management of stocks in the ICES area. ToR b) Action plan 1.7, 1.11, 1.13.4 Survey data and sampling young stages of fish are fundamental to recruitment studies. Often these studies do not take in to account spatial heterogeneity in the distribution of the target organism and can thus present biased information on e.g. recruitment for input to stock assessment or population models. ToR c) Action plan 1.2, 1.3, 1.6 At present there is a general lack of information on the causes of mortality in young stages of fish. In particular predation mortality. It is only recently that new analytical tools are being developed (specifically genetics based) that will allow the levels and sources of predation to be identified. This information is fundamental to our understanding of the processes that affect recruitment levels. ToR d) Action plan 1.2, 1.3 The identification of where in the pre-recruit life history year class strength is determined is important for determining useful recruitment indices and forecast models for recruitment. There are a number of species that have been sampled regularly, both multiple sampling of a cohort over if young stages and over a number of years. A collation of these data will provide insight in to variability with a species across different environments and between species within an environment. ToR e) Action plan 1.2, 1.3, 1.6 There is a need to critically review the studies and concepts within research on recruitment. These articles will provide insight, controversy and future direction for recruitment research. f) Members of WGPBI and WGRP (Working Group on Recruitment Processes) share the common goal of enhancing, guiding, and promoting use of coupled physical-biological models for prediction of fisheries recruitment. Close coordination between

	Working Groups is required to prevent duplication of efforts. WGPBI members will invite WGRP involvement in 2005–2007 WGPBI activities, including joint sponsorship of the Theme Session (2005) and Workshop (2006). We will also work to develop a joint task between WGPBI and WGRP in 2007–2009. For example, WG members may focus efforts on building a community approach for using coupled physical-biological models in recruitment prediction.
Resource Requirements:	The WG requires active participation from the members assigned by the Delegates. A complement of 15–20 active members is required to accomplish the work identified in the resolution.
Participants:	In addition to regular members, the WG feels there would be benefit from greater participation by individuals with quantitative skills in the area of biometry and population dynamics.
Secretariat Facilities:	The Working Group will meet by correspondence in 2006 so will only need secretarial assistance for an annual report.
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Linkages to other Organisations:	GOOS, GLOBEC and NAFO through its Working Group on Reproductive Potential.
Secretariat Marginal Cost Share:	100%