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Report of the Working Group on Recruitment Processes (WGRP)

15 July 2005

Barcelona, Spain

International Council for the Exploration of the Sea
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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Contents

1 Executive Summary

The Working Group concentrated on the last Term of Reference and worked toward producing a clear set of guidelines and objectives for the future. The meeting was the day after the International Larval Fish Conference (sponsored by the American Fisheries Society), this year in Barcelona. Both regular members of the WGRP and invites who had attended the conference attended the meeting. The ToR was addressed with three presentations (R. D. M. Nash, IMR, Norway on the biological context in which the production of recruits occurs; T. J. Miller, CBL, USA reviewing the physical context in which recruitment occurs; and A. Folkvord, U. Bergen, Norway reviewing the early life processes that result in the final observed level of recruitment) (Section 3). These presentations once again highlighted the point that recruitment had to be considered in more than a single step, as undertaken in traditional stock and recruit relationships and that studies and understanding need to consider the adults (production of offspring) through to the juveniles (at recruitment) and not just the early pelagic phases of the life cycle. There are also new tools available (e.g., Individual Based Models, genetic techniques etc) that mean recruitment processes studied that were not possible previously can now be undertaken.

The presentations lead to formalisation of immediate and longer-term future goals and objectives for the Working Group (Section 4). The intention is for the work undertaken by the WG to result in both reports to ICES and manuscripts that can be submitted for publication in peer-reviewed scientific journals. The WG will review the contribution of coupled physical-biological models in regard to recruitment (4.1), examine selective processes that affect mortality in early life history (4.2), construct multi stage models of recruitment (4.3), examine the effects of stock structure, reproductive potential and recruitment on stock dynamics (4.4) and bring together experts in various fields of recruitment biology and ecology to debate the future directions for recruitment research (4.5).

Over the longer term it is the intention of the WG to approach other issues, namely environmental predictors of recruitment (4.6.1), synchronous and asynchronous recruitment in large marine ecosystems (4.6.2), the influence of recruitment events on community dynamics (4.6.3), and the effects of a changing global environment on recruitment processes (4.6.4).

The Working Group will co-sponsor (WGZE) a suggestion for a theme session (Predation on zooplankton and ichthyoplankton) at the 2006 ASC.

2 Background

The Working Group met in Barcelona, Spain, on 15 July 2005. A list of attendees is provided in Annex 1. The central objective of the meeting was to address a single term of reference adopted by the WG following the Oceanography Committee (OCC) meeting in Vigo, Spain, in September 2004. We were charged by OCC to critically review the work undertaken by the group to identify the specific contributions the workgroup could make to advice provided by ICES to its clients. Work on other terms of reference, and on matters arising was discussed only briefly.

2.1 Terms of reference

The terms of reference for the Working Group are provided in Annex 2. In the sections that follow we identify links to the individual Terms of Reference where appropriate.

2.2 Agenda

The agenda for the meeting is provided in Annex 3. The WGRP members adopted the agenda unanimously.

3 Presentations

Three short presentations were given at the beginning of the meeting to provide a common foundation on which discussions could follow. The presentations were invited specifically to review different sources of recruitment variability. The first presentation (R. D. M. Nash, IMR, Norway) considered the biological context in which the production of recruits occurs. The second presentation (T. J. Miller, CBL, USA) reviewed the physical context in which recruitment occurs. The final presentation (A. Folkvord, U. Bergen, Norway) reviewed the early life processes that result in the final observed level of recruitment.

3.1 The biological context: Role of population structure and life histories in recruitment

R. D. M. Nash (IMR, Norway)

The central assumption underlying Nash's presentation is that the high fecundity of fish necessitates a multistage understanding of population dynamics. In low fecundity taxa, it is possible to develop a simple renewal function in which the abundance of the population at two different periods can be represented by

$$N_{t+1} = (1 + R(N_t)) \cdot N_t$$

where N_i is the abundance at time i and R(N) is the population-dependent recruitment. In such populations, compensation (density-dependence) occurs in the adult stages. In contrast in highly fecund taxa, many processes interfere with the direct renewal function. For example, in fishes processes that relate stock size and characteristics to egg production, egg production to larval abundance and larval abundance to juvenile abundance must all be recognized. Compensation can occur at each stage identified above, thereby making the forecasting of recruitment from adult abundance challenging.

The traditional framework in which to understand the recruitment dynamics of highly fecund species is the stock-recruitment relationship. Nash suggested that the focus on the traditional stock-recruitment relationship does not provide a sufficiently complete framework in which to understand renewal processes. For example, Nash highlighted the traditional stock recruitment model (Figure 1) that has a single equilibrium point, defined by the intersection of the S-R curve and the 1:1 replacement line. He then presented more complicated models that could involve multiple equilibrium points, including a single Allee effect model (Figure 2). These models suggest the presence of a critical abundance level, below which the population would be attracted to a low, stable abundance level. The presence of such "pits" has been suggested to result from the effects of predators (biological control vectors) and reproductive behaviours (Lierman and Hilborn, 2001). More complicated models that involve multiple stable states have also been suggested. Solari *et al.* (1997) produced a non-linear model of recruitment in Baltic cod (*Gadus morhua*) that included multiple stable states (Figure 3) that resulted from the inclusion or local extirpation of distinct spawning stocks. These more complicated models offer the potential of multiple stable states, each one of which could be associated with distinct reproductive capacity at the population level.

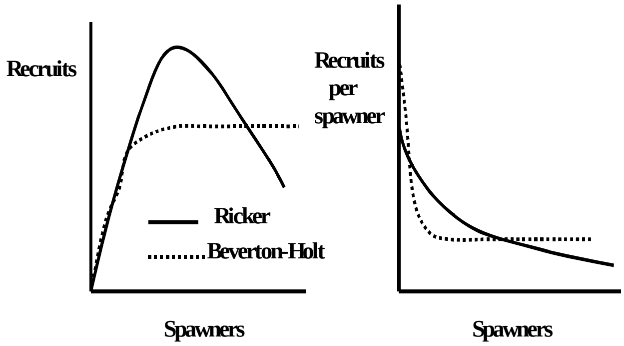

Figure 1: Traditional stock- recruitment models (redrawn from Lierman and Hilborn 2001).

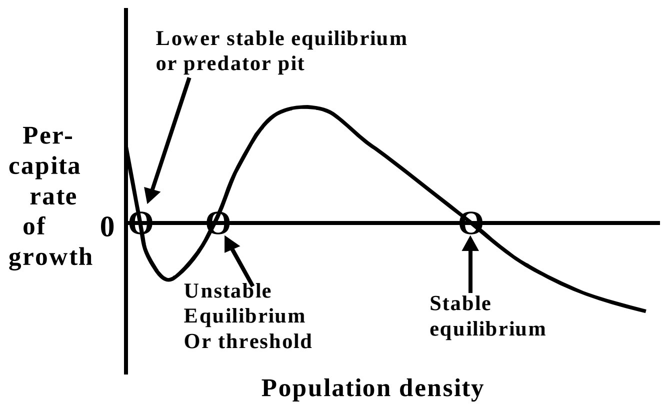

Figure 2: Stock recruitment relationship exhibiting an Allee effect (redrawn from Lierman and Hilborn, 2001).

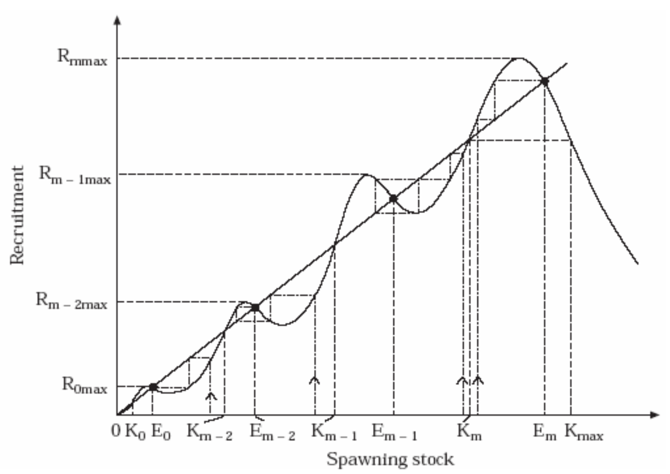

Figure 3: Stock and recruitment relationship for Baltic cod (redrawn from Solari *et al.* 1997). The figure clearly shows multiple stable states for the population.

The requirement for multistage recruitment models that is created by the high fecundity of fish lead to Paulik's extension of the stock-recruitment diagram (Paulik 1973). Paulik's approach allowed for the identification of functional relationships between successive life history stages. There is no requirement that the relationships for successive stages should be similar. Nash and Dickey-Collas (2005) used this approach to analyse year class strength in North Sea herring (Figure 4). This work showed a linear relationship between spawning stock and egg production, but strongly compensatory relationships between subsequent life history stages. Patterns in such Paulik diagrams can be useful both to determine where research effort should be invested to understand the mechanism controlling recruitment and to identify outlier events (year classes 1986–1990 and 1997, and more recently 2002-04 for North Sea herring) that may suggest changes in the mechanisms that have controlled population dynamics.

From this foundation, Nash then moved to consider the biological influences that might regulate the relationships between successive life history stages. Working from the assumption that you can not get a greater number of recruits than the number of viable eggs that the adults stock produces, Nash reviewed data on the stock reproductive potentials. Traditionally, this has always been measured by the spawning stock biomass. However, considerable evidence is available to indicate that the reproductive potential of a stock (Trippel, 1999) depends on the characteristics of the spawners, beyond simply biomass (Marshall *et al.*, 1999). Factors that have been shown to have an impact on the stock reproductive potential include the proportion mature at age, spawning frequency, spawning duration, size- and condition-dependent egg production, and egg viability. Most work has focused on attributes of the females, although work in other taxa, particularly crustaceans have shown a role for attributes of the male as well (Hines *et al.* 2003). Thus, we might expect to find both maternal and paternal influences on recruitment (Chambers and Waiwood, 1996; Heyer *et al.*, 2001). Nash pointed out that these influences likely vary spatially as well as temporally. He specifically cautioned about the need to recognize that stock dynamics represents a moving baseline. For example, Marshall *et al.* (pers. comm.) have documented substantial variability in the maturity ogive of North-east Arctic cod over the last 50 years. These changes should not be viewed simply as inter-annual variability, but may in some cases represent evolutionary responses to anthropogenic or environmental stresses (Barot *et al.*, 2005; Rijnsdorp *et al.*, 2005).

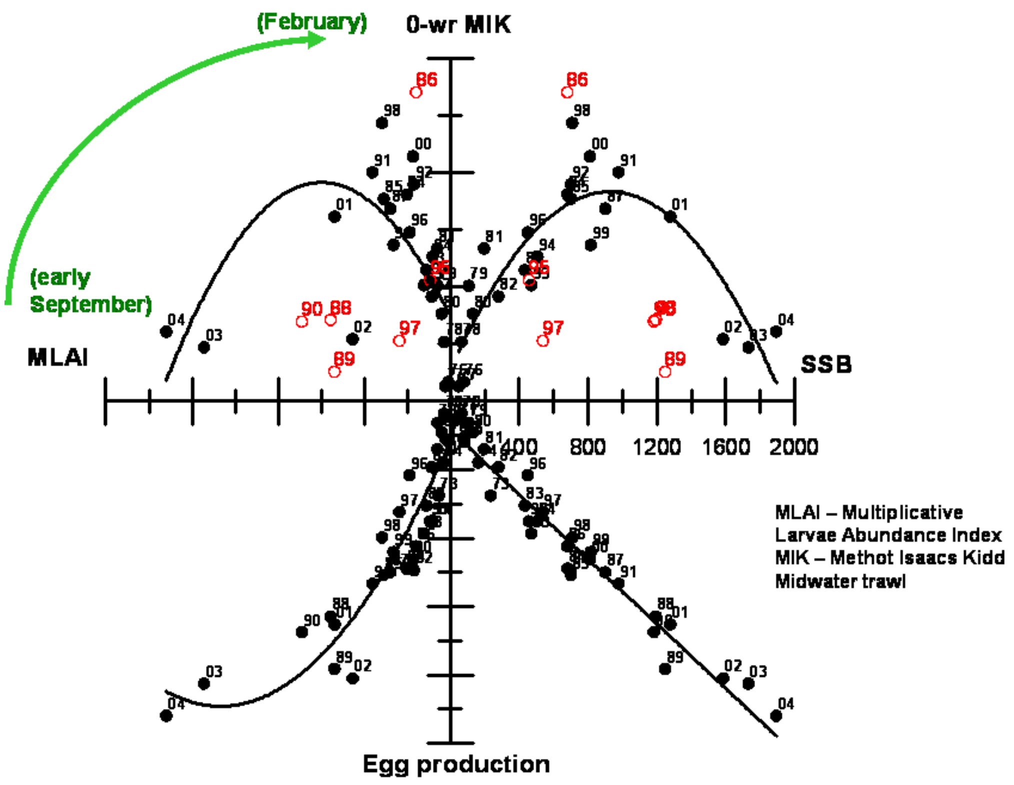

Figure 4: Paulik recruitment diagram for North Sea herring updated from Nash and Dickey-Collas (2005).

3.2 Physical controls on recruitment processes: A questions of scales

T. J. Miller (CBL, USA)

Physical processes occur over a wide range of spatial and temporal scales. In turn these physical processes than affect biological processes at specific spatial and temporal scales. The interaction between these two is perhaps best captured in the results of a thought experiment developed by Haury *et al.* (1978). Haury and colleagues imagined an infinite number of sensors that could measure variation in the biomass in plankton community over a broad range of spatial and temporal scales simultaneously. The plotted the hypothetical results of these sensors on a response surface (Figure 5). Evident on the response surface are areas of high biomass variability that occur over broad spatial scales but at limited temporal scales (e.g., diel variability) and other peaks in biomass variability associated with fixed spatial scales but more variable temporal scales. Miller overlaid this hypothetical response surface with scales of variability in the biomass of fish populations. He suggested that fish abundance varies on relatively short temporal scales, but over large spatial scales, whereas fish populations vary over more restricted spatial scales and longer time scales (Figure 5). Miller suggested that the disposition of the two levels of organization (individuals vs. population) has given rise to two different traditions to integrate the effects of physical processes on fisheries recruitment.

At the broadest scales correlative models of climate and oceanographic forcing on recruitment have been developed. As an example of this work, Miller reviewed work by Wood (2000) who analyzed the effect of climate on guilds of species that use estuarine nursery areas along the Atlantic coast of North America. One guild studied spawn in the coastal ocean, but rely on the estuaries as nursery areas. Examples of these species include Atlantic menhaden (*Brevoortia tyrannus*), Atlantic croaker (*Micropogonias undulates*) and spot (*Leiostomus xanthurus*). A second guild migrates into estuaries to spawn. Examples of this guild include striped bass (*Morone saxatilis*) and a number of river herrings and shad. Wood analyzed sea surface pressure maps over a 50-year period and using multivariate analysis, identified a limited number of distinct synoptic climatologies, associated with a relative pressure difference between the Ohio Valley and Azores during spring. These local climatologies were strongly correlated with recruitments observed in fishery-independent time series. Analysis of the correlation structure among and between members of the spawning guilds indicated that conditions that favoured one species of the guild, typically favoured all species in that guild. Moreover, and of perhaps greater importance, was that these same conditions that favoured one guild, were detrimental to recruitment success of the other guild. Thus conditions that favour recruitment of striped bass do not favour recruitment of Atlantic menhaden, one of their principal prey. Following on from Wood's initial work, Miller and colleagues have examined the consequences of the correlated nature of recruitment in simple population models. Using simple age-structured models, Miller *et al.* have shown that correlated recruitments can play an important role in regulating the dynamics of individual species. Importantly, their results show that failure to recognize the presence of correlated recruitments when present could lead to erroneous conclusions regarding the strength of predator-prey interactions. For example, strong negative correlations in recruitments (such as those found for striped bass and Atlantic menhaden) could lead to substantial under-estimation of the strength of predator prey interactions.

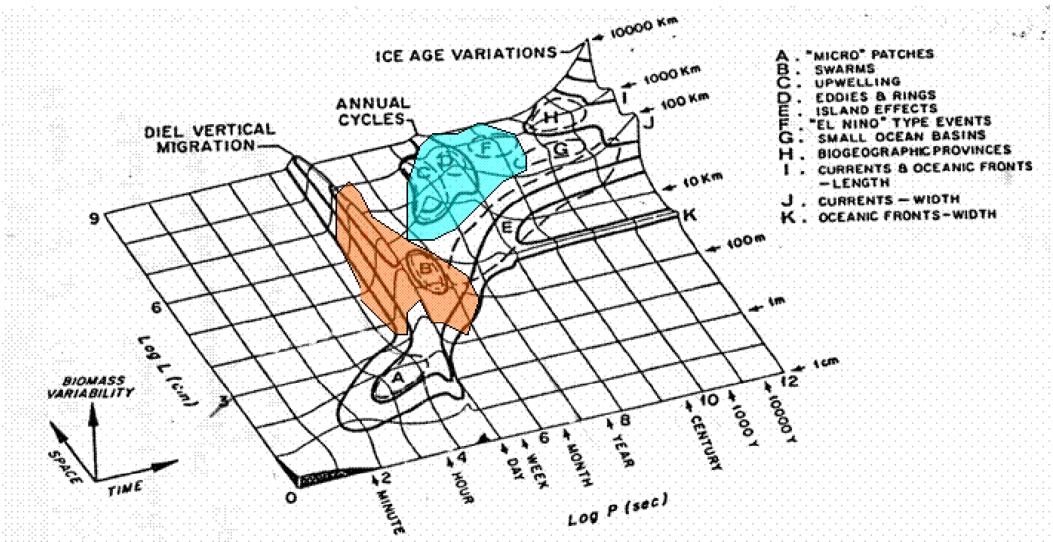

Figure 5: Haury diagram for variation in fish abundance (after Haury *et al.*, 1978). The orange area shows the time-space scales at which fish abundances likely vary, whereas the blue area shows the time-space scales at which fish populations likely vary.

Miller suggested that coupled physical-biological models have contributed substantially to our understanding of mesoscale processes. He highlighted results of an ongoing review of the contribution of such models to our understanding of recruitment processes (see 2004 WGRP report ICES 2004). For this meeting, he highlighted what in his view is the strongest application of such models – to develop specific testable hypotheses regarding population regulation. In the first example, Mullon *et al.* (2002) used a coupled physical-biological model to understand the temporal and spatial distribution of spawning of Cape anchovy (*Anchoa capensis*) off South Africa. Mullon and colleagues showed that only a restricted range of locations and spawning months reliably delivered recruits to known nursery areas. The results of the model relied strongly on "homing" of adults to their natal area – something that had not heretofore been hypothesized, and can now be tested. In a similar vein, coupled physical biological models were used to predict spawning locations of Atlantic menhaden off the Atlantic coast of

North America (Quinlan *et al.*, 1999). Quinlan *et al.* predicted spawning locations as a function of the age at entry of larvae into the nursery areas for three specific locations. Their work predicted specific time lags between ages at recruitment at different nursery areas for larvae that shared the same natal region, and predicted natal regions different to the conventional wisdom. These results now form the basis of a funded project to quantify recruitment dynamics in this species.

3.3 The ultimate context: Offspring to recruits

A. Folkvord (U. Bergen, Norway)

Folkvord built on the previous two presentations to make the point that stock and recruitment diagrams tell us principally what cannot occur and are not particularly good at telling us what can occur – i.e., high recruitments at low stock sizes are highly unlikely, but high recruitments at higher stock sizes do not occur reliably). He noted that efforts to seek the "time" at which year class is set are likely to be unsuccessful unless a clear definition of what "set" implies is made. Folkvord compared what he termed bottom up approaches (e.g., coupled physical-biological models) with top down approaches (e.g., characteristics of survivors). Folkvord suggested that the former approaches impose a mechanism on recruitment and seek to use deviations from expected results to infer the generality of the controlling mechanism, whereas the top down approaches seek to infer mechanism for the patterns of recruitments that are observed. Folkvord made a strong case for the application of growth standards to recruitment research, similar to human growth charts that provide information on the distribution of expected sizes of people at different ages. He suggested that combining knowledge of size at age and weight at size would provide a useful approach both to determining the role of selective sources of mortality in regulating recruitment and to determining when such processes have acted. He provided evidence from field studies, calibrated to indicate the proportion of maximum growth observed in mesocosms, that the majority of cod larvae that survive are growing at their physiological maximum rate (Folkvord, 2005).

4 Future Goals for WGRP

Following the three presentations summarized above, participants at the meeting had a full and frank discussion of the role of WGRP within the ICES framework. Discussions ranged widely, and can only be summarized here. In the section that follows we focus most on products of use to ICES clients that the WG feel it can produce over the short- to medium term (3–5 yrs) rather than ideas for projects that could not be completed in this time frame.

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

This review is currently underway and is scheduled for completion by year's end. It represents a joint project between WGRP and WGPBI. The idea for the review arose simultaneously within both WGs, and it has been decided that WGRP will take the lead in this area. The review does not seek to be an assessment of best modelling practices in the area of coupled physical-biological models, rather it seeks to identify the contribution such models have made and can make in the future to our understanding of recruitment. The review is based on an unbiased, but not fully comprehensive review of the literature since 1993. Journals that were believed to have published the majority of such work were selected prior to any papers being identified. The focus of the review was on fish early life history studies. Models were characterized to where they sought to provide explanation, or infer mechanisms or generate hypotheses. The review suggests that the field of coupled physical-biological modelling is maturing rapidly. There has been a marked shift from models that explain to ones that infer. More recently, a shift to models that develop testable hypotheses has been noted. If it suggested that progress to understanding the controls on recruitment success will be most rapid if these hypotheses are indeed tested empirically.

4.2 Selective processes in early life history

A common theme of all three presentations summarized above was that sources of mortality are likely not neutral: rather only a subset of the potential recruits survive. There was extensive discussion regarding the potential for progress on our understanding of the sources, patterns and consequences of selective processes during early life history. For example, otolith microstructural analysis has indicated that recruits often are not drawn randomly from the entire spawning period (Rice *et al.*, 1987). Selection for faster growing individuals has also been documented (Meekan and Fortier, 1996). Overwinter mortality often selectively removes small individuals, so that there appears to be a size threshold for overwinter survival (Hurst and Conover, 1998). While all three of these studies are indeed examples of the impact of selective mortality, the nature of the selection differs in each case. In the birth-date frequency example, the selective mortality agent is acting to stabilize the distribution of potential birth-dates, whereas the two other cases are examples of directional selection (Miller, 1997). All three cases provided above are examples of phenotypic selection without any apparent evolutionary consequences. However, Conover and colleagues have recently shown the potential for evolutionary changes in fish populations following selective harvesting of fish from only a limited number generations. Thus the potential for phenotypic selection to have genetic, long term consequences is clear.

It is important that we understand the sources and patterns of selective mortality if we are to assess the long term consequences of selective mortality on recruitment processes and ultimately our understanding of stock dynamics. Accordingly, the WGRP will sponsor an effort to assess the sources, patterns and consequences of selective mortality during early life history. The goals of the project will be to document the evidence for selective mortality during fish early life history, define and catalogue the patterns of selective mortality, and review the techniques available to detect the action of selective mortality sources. Although, the WG believe that this is an essential first step in an effort to understand the impact of selective mortality during early life history, it is clearly not sufficient by itself. Thus, the WG proposes to sponsor a theme session at the 2007 Larval Fish Conference to be held in St. Johns, Newfoundland, Canada. The goals of the theme session are two fold. First, the WG's selective mortality review project will be presented for the first time at the session. Second, we will invite a range of internationally recognized experts to contribute papers. Together these presentations will help guide the second stage of the proposed project which will be to understand the consequences of selective mortality in population-level models. To date, the majority of attempts to include selective mortality sources have not been whole life cycle models. We propose to explore the consequences of selective mortality across generations. It is anticipated that the selective mortality project will be completed within five year. The initial phases of the project will be lead by Chris Chambers (USA) and Arild Folkvord (Norway), but other scientists will be invited to participate as appropriate.

4.3 Multistage models of recruitment

Nash's presentation clearly identified the advantages of considering recruitment as a multistage process rather than a single event. Discussions at the WG meeting focused on the opportunities that arise if comparative analyses of multistage recruitment models could be conducted. Meta-analyses of simple stock-recruitment models have yielded considerable insights into the regulation of recruitment at the species and ecosystem levels (Myers and Barrowman, 1996). However, to date no similar database of multistage recruitment models has been developed.

The WGRP proposed to initiate a project to compile and analyse multistage recruitment models. The objective of the project would be 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). Once compiled, recruitment patterns would be compared statistically. There are a large number of statistical tools that have been developed in the ecological field (e.g., K-factor analysis) which can be applied to quantify similarities and differences in the assembled database. The project will culminate in a special session at a future Larval Fish Conference or ICES ASC meeting. However, currently no commitment has been made as to which meeting will be selected. It is anticipated that the project would be completed within three years. The project will be lead by Richard Nash (Norway) and Tom Miller (USA).

4.4 Stock characteristics and recruitment

A principal theme of the discussions was that we must expand our exploration of recruitment processes to consider events that occur prior to spawning. There is clear evidence of heritability of traits important to early life survival and hence recruitment (Conover and Schultz, 1997). Moreover, there is extensive evidence from empirical studies of the importance of maternal effects on recruitment potential (Chambers and Leggett, 1996). Thus the WGRP believe that a greater understanding of the relationship between stock structure, spawning potential and recruitment success is vital to improving our understanding of stock dynamics. Accordingly, WGRP plan to invite the Cod and Climate Change working group to co-sponsor with us a theme session at the 2007 ASC on Stock Structure and Recruitment. It was suggested that NAFO may also be interested in co-sponsoring such a workshop.

4.5 MEPS theme session

Marine Ecology Progress Series publishes occasional theme session articles. These articles are a collection of short essays or viewpoints on topical themes. Recent theme sessions have included articles on small-scale turbulence and ecosystem-based fishery management. There have been several reviews of recruitment studies in recent years (Leggett and Deblois, 1994, Govoni 2005). However, these reviews presented a singular viewpoint on the development of the study of recruitment processes. Few of the reviews have provided a prognosis for the future contribution of studies of recruitment to our understanding of the sustainability of fish stocks. The WG discussed the potential of developing a theme session for MEPS that included a range of viewpoints on the future of recruitment research. Examples of people discussed as potential contributors include Pierre Pepin (Canada), Mike St. John (Germany), Carl Walters (Canada), Tom Miller (USA), and Brian MacKenzie (Denmark). These authors represent a range of approaches to understanding recruitment from empirical to theoretical and from strong proponent to sceptical critic. It is hoped that by carefully selecting authors to contribute the finished theme session would provide a balanced view of the principal challenges facing the field and the likelihood of our success in meeting these challenges. It was proposed that Tom Miller (USA) contact the new editor of MEPS to gage the journal’s interest in publishing such a theme session

4.6 Other projects

A range of other projects were discussed, but no one at the meeting stood forward to lead the project. The following ideas were briefly discussed

4.6.1 Environmental predictors of recruitment

The WG discussed initiating a project on environmental predictors of recruitment. Issues that could be addressed include determining the spatial scale of the responses, analyses of when and why the models fail, a comparison of the performance of simple versus composite environmental predictors. It was noted that a new SG has been formed, sponsored by the herring assessment working group to consider recruitment variability in North Sea planktivorous fish, and that perhaps this represented a potential outlet for this work. No-one from WGRP has as yet been appointed to the study group. Miller (USA) pledged to contact Mark Dickey-Collas (The Netherlands) to explore whether WGRP members could participate in the new SGRECVAP.

4.6.2 Recruitment correlations in large marine ecosystems

Miller's presentation included a novel analysis of the patterns of correlation in the recruitments of a suite of species that spawn along the mid-Atlantic coast of North America. This work identified spawning guilds, the members of which exhibited positive correlations in recruitment. In contrast species in different guilds exhibited negative correlations. The WG discussed the potential of expanding the existing analysis to new areas to determine the pattern of covariation among different species in a range of large marine ecosystem. The WG felt that this project, while meritorious, was beyond the scope of a project that could be undertaken by a single working group. WG co-chairs will explore potential collaborations that may make this project more feasible.

4.6.3 Recruitment dynamics as drivers of community shifts

The WG discussed the position of studies of recruitment processes in an ecosystem context. Participants indicated that there were several examples where changes in the recruitment dynamics of sentinel species were indicators of wholesale regime change (Gargett, 1997). However, it was difficult for the WG to identify specific meta-analyses that could be conducted within the framework of a WG project.

4.6.4 Recruitment in a changing global environment

Meeting participants felt that this was an important topic. However, it was not clear to participants exactly what kinds of reviews or analyses could be conducted that would shed specific light on the likely responses of fish populations to changes in the global climate. It was suggested that coupled physical-biological models would be an appropriate tool to use in this instance.

5 Other Matters

The WG has received a request from WGZE to co-sponsor a workshop at the 2006 ASC on "Predation on ichthyoplankton and zooplankton". Proposals would be due prior to the 2005 ASC in Aberdeen. There was general agreement that such a theme session would be appropriate, but no one volunteered to represent the WG in hosting the session. Miller (USA) agreed to contact the chair of WGZE to discuss participation.

6 Future Meetings

A range of options for future meetings were discussed. One option was to couple the WG meeting with scientific conferences such as happened for this meeting. The Larval Fish Conference is an attractive option as it is held regularly in both North America and in Europe. However, some WG members felt that tying the WG meetings specifically to a conference on larval fish may reduce participation by people interested in other early life history stages including pre and post spawning events. Alternative conferences including the Fishery Society of the British Isles and the EU-funded UNCOVER project were also discussed. In general it was felt that the WG benefits from meeting occasionally in conjunction with conferences, but that there was equally a need for separate WG meetings. The Working Group agreed to following time-table of future meetings to be presented to ICES.

2006	By Correspondence
2007	St. Johns, Newfoundland (jointly with LFC)
2008	Copenhagen, DK

7 Proposed Terms of Reference for 2006

This report has focused exclusively on a single ToR adopted in 2004. However, work is ongoing on at least two of the other ToRs adopted that year. Accordingly, these previous ToRs were carried forward for 2006. In addition, WGRP adopted two new ToR for the upcoming year. 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 work by correspondence during 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

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.
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.
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.
Secretariat Marginal Cost Share:	100%

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Annex 1: List of participants

WGRP members are shown in bold face

NAME	ADDRESS	EMAIL
Paula Alvaret	Azti- Tecnalia Foundation, Spain	palvaret@par.azti.es
Elisabeth Broughton	NOAA, NMFS, Massachusetts, USA	elisabeth.broughton@noaa.gov
Chris Chambers	NOAA, NMFS, New Jersey, USA	chris.chambers@noaa.gov
Unai Cotano	Azti- Tecnalia Foundation, Spain	ucotnao@par.azti.es
Darius Fey	SFI, Gdynia, Poland	dfey@mir.gdynia.pl
Arild Folkvord	Univ, Bergen, Norway	arild.folkvord@bio.uib.no
Monica Gagliano	James Cook University, Townsville, Australia	Monica.gagliano@jcu.edu.au
Alejandro Gallego	FRS Marine Lab, Aberdeen, UK	a.gallego@marlab.ac.uk
Bridget Geeen	NOAA, NMFS, New Jersey, USA	bridget.green@noaa.gov
Jeff Govoni	NOAA, NOS, North Carolina	Jeff.govoni@noaa.gov
Bastian Huwer	Leibnitz – Institute of Marine Science, Germany	bhuwer@ifm.geomar.de
Francis Juanes	U. Mass, USA	juanes@forwild.umass.edu
Jodie Kemp	U. Melbourne, Australia	j.kemp@pgrad.unimelb.edu.au
Tomasz Linkowski	Morski Instytut Rybacki, Gdynia, Poland	Linkwoski@mir.gdynia.pl
Greg Lough	NOAA, NMFS, Massachusetts, USA	greg.lough@noaa.gov
Brian MacKenzie	DIFRES, Copenhagen, Denmark	brm@dfu.min.dk
Thomas Miller (co-chair)	Chesapeake Biological Laboratory, USA	Miller@cbl.umces.edu
Erlend Moksness	IMR, Norway	Moksness@imr.no
Richard Nash (co-chair)	IMR, Bergen, Norway	richard.nash@imr.no
Myron Peck	IHF, Hamburg, Germany	myron.peck@uni-hamburg.de
Alfred Sandstrom	Swedish Board of Fisheries, Stockhold, Sweden	alfred.sandstrom@fiskervesket.se

Annex 2: 2004 Terms of References

The **Working Group on Recruitment Process** [WGRP] (Co-Chairs: R. D. M. Nash (Norway) and T. J. Miller (USA) will meet in Barcelona [1]on 15 July 2005 to:

a. Prepare a synthesis of multidisciplinary projects relevant to our understanding of recruitment processes and highlight unresolved issues, which deserve further consideration;

b. report on recent meetings that concern recruitment in fish populations (e.g., Climate Change – Bergen) so that information or progress relevant to the status or assessment of stocks in the ICES area can be highlighted;

c. 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;

d. review the development of new approaches or techniques used in the study of factors and processes that influence the development and survival of fish eggs and larvae in relation to recruitment and the formation of year class strength;

e. critically review the work undertaken by WGRP and prepare a clear set of guidelines for the future direction of this working group in relation to other current WGs.

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 1.2, 1.6 There are many meetings that occur each year with relevance to mandate to advise ICES on recruitment processes and understanding the underlying mechanisms of recruitment in fish populations. There is a need to go through each of the meetings and collate all the relevant information into one location. ToR c) 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 d) Action plan 1.2 The survival of early life history stages, e.g., eggs and larvae are fundamental to recruitment. In the past studies have been hampered by a lack of good innovative tools to study these early life history stages. New tools are being developed, however, there is a need to determine which are useful and promising for providing information which will enhance the study of recruitment processes and provide reliable data for input to models of recruitment. ToR e) Action plan 7, 8 The Working Group needs to undertake a periodic review of what it is currently doing in relation to the ICES Acton plans and where it needs to focus it's work in the future.
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.

1 WGRP originally intended to work by correspondence.

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 2005 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
Secretariat Marginal Cost Share:	100%

Annex 3: Agenda

Identifying the Challenges and Opportunities for Recruitment Studies in the 21st Century.

Hosted by ICES Recruitment Processes Working Group

at the

Institut de Ciències del Mar
Barcelona
15 July2005

Agenda

09:30 Welcome Statement *Tom Miller (CBL, USA)*

09.40.1 Briefing papers

The biological context: Role of population structure and life histories in recruitment. *Richard Nash (IMR, Norway)*

The physical context for recruitment: A story of scales
Tom Miller (CBL, USA)

The ultimate context: Offspring to recruits.

Arild Folkvord (University of Bergen, Norway)

11:00 Defining the role of WGRP within ICES

Assigning study groups

12:00 – 13:30 Lunch

13:30 Identification and discussion of key challenges

Study groups

15:30 Consensus building

17:00 Closing remarks

Annex 4: Action Plan Progress Review

Year	Committee Acronym	Committee name	Expert Group	Reference to other committees	Expert Group report (ICES Code)	Resolution No.		
2004/2005	**OCC**	**Oceanography**	**WGRP**		2005:\C:XX	XCXX		
Action Plan	**Action Required**	**ToR's**	**ToR**	**Satisfactory Progress**	**No Progress**	**Unsatisfactory Progress**	**Output (link to relevant report)**	**Comments** **(e.g., delays, problems, other types of progress, needs, etc.**
No.	**Text**	**Text**	**Ref. (a, b, c)**	**S**	**0**	**U**	**Report code and section**	**Text**
1.3	Please see Action Plan items below	Prepare a synthesis of multidisciplinary projects relevant to the understanding of recruitment processes and highlight unresolved issues which deserve further consideration;	a)	S				Work has been undertaken on this ToR but due to the 2005 meeting concentrating on ToR e finalisation of this ToR and reporting has been defered to a the 2006 report.
1.2, 1.6	Please see Action Plan items below	Report on recent meetings that concern recruitment in fish populations (e.g., Climate Change – Bergen) so that information or progress relevant to the status or assessment of stocks in the ICES area can be highlighted;	b)		0			The 2005 meeting of the WG concentrated on ToR e and as such this was not addressed. Papers from the Climate Change meeting are being published in the ICES Journalof Marine Science.
1.7, 1.11, 1.13.4	Please see Action Plan items below	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;	c)	S				Progress is still being made on this ToR and will be repoted on in the next meeting of the WG (2006).
1.2	Please see Action Plan items below	Review the development of new approaches or techniques used in the study of factors and processes that influence the development and survival of fish eggs and larvae in relation to recruitment of the formation of year-class strength.	d)	S				This ToR formed the basis of the WG meeting in 2005 to address ToR e.

Year	Committee Acronym	Committee name	Expert Group	Reference to other committees	Expert Group report (ICES Code)	Resolution No.		
2004/2005	**OCC**	**Oceanography**	**WGRP**		2005:\C:XX	XCXX		
Action Plan	**Action Required**	**ToR's**	**ToR**	**Satisfac-tory Pro-gress**	**No Pro-gress**	**Unsatisfa-tory Pro-gress**	**Output (link to relevant report)**	**Comments** (e.g., delays, problems, other types of progress, needs, etc.
No.	**Text**	**Text**	**Ref. (a, b, c)**	**S**	**0**	**U**	**Report code and section**	**Text**
7 and 8	Please see Action Plan items below	Critically review the work undertaken by WGRP and prepare a clear set of guidelines for the future direction of this Working Group in relation to the other current WGs.	e)	S			The whole report	This was the principal objective of the 2005 WG meeting and resulted in a clear set of objectives for the WG in the future.

1.2	Increase knowledge with respect to the functioning of marine ecosystems. This will be achieved through continued basic research on the biological, chemical, and physical processes of marine ecosystems and specific activities directed at improved understanding of observed and potential variability in the marine environment due to physical forcing and biological interactions. [MHC/OCC/LRC/RMC/BCC/DFC].* Particular planned activities include the following:
1.3	Increase knowledge of the effects of physical forcing, including climate variability, and biological interactions, on recruitment processes of important commercial species. [MHC/OCC/RMC/LRC/MARC/BCC/DFC]
1.6	Assess and predict impacts of climate variability and climate change, on scales from populations to marine ecosystems, including impacts on commercially important fish stocks. [OCC/LRC/BCC/DFC]
1.7	Play an active role in the design, implementation, and execution of global and regional research and monitoring programmes, in collaborations between the ICES and other international oceanographic research or monitoring programmes such as GOOS and GLOBEC. [OCC/LRC/MHC/BCC/DFC]
1.11	Continue to improve the coordination, conduct, and analysis of oceanographic and biological surveys to assure their accuracy and precision. [LRC/RMC/OCC/MHC/DFC]
1.13.4	Promote the development and use of new survey designs, data analysis methods, acoustic instrumentation and survey gears.
7	Keep abreast of the needs and expectations of ICES Member Countries.
8	Broaden the diversity of the scientists who participate in ICES activities.