ICES WGRP REPORT 2008

ICES OCEANOGRAPHY COMMITTEE

ICES CM 2008/OCC:04

REF. ACOM, HAWG

Report of the Working Group on Recruitment Processes (WGRP)

1 August 2008

By Correspondence

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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

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

Recommended format for purposes of citation:

ICES. 2008. Report of the Working Group on Recruitment Processes (WGRP), 1 August 2008, By Corresponde nce. ICES CM 2008/OCC:04. 22 pp.

Contents

1 Executive Summary

The Working Group on Recruitment Processes (WGRP) has continued to make progress against a three year work plan adopted in 2006. This workplan identified three areas of research: Contribution of coupled physical-biological models to understanding of recruitment, role of selective processes in recruitment determination and multistage models of recruitment. All work pertaining to the first theme has been completed, resulting in peer-reviewed publications and in collaboration with WGPBI, production of a manual of best practices. Similarly, work against the third theme is nearing completion, and it is anticipated that peer-reviewed manuscripts will be submitted in 2009. Finally, substantial progress has been made against the second theme. It is anticipated that this task will be completed in 2009, although products will likely not be available until 2010. Completion of these tasks provides the opportunity for WGRP to develop an initiate a new research plan. Options for reorganization of WGRP are provided.

2 Background

In 2005 at a WG meeting in Barcelona, WGRP adopted new, challenging terms of reference (ToRs). The new ToRs were designed to make specific contributions to advice provided by ICES to its clients. We identified three broad themes of endeavour: 1) a review of the contribution of coupled physical-biological models to understanding of recruitment, 2) an analysis of the patterns and consequences of sources of selective mortality on characteristics of exploited stocks and 3) an assessment of the utility of multistage descriptions of recruitment in understanding the affects of environmental changes on future patterns of recruitment. In slightly modified form these three research themes were adopted as ToRs for WGRP for 2006–2008. WGRP has continued to pursue the ToRs over the last three years. We have completed all work on the first objective and made substantial progress on the other two. It is anticipated that all work on these ToRs will be completed in the 2009–2010 period. This report provides a summary of work to date.

Completion of work against these ToRs represents both an opportunity and a challenge for WGRP. The completion of its current workplan in the near future presents WGRP an opportunity to redefine what it can contribute to ICES under its new structure. It also means that realignment of WGs that may be necessary under the new ICES structure could be achieved with little loss of productivity. However, the completion of the ToRs also represents a challenge as participation in recent WGRP activities has been low. Thus portion of this report also reflects on the future of WGRP.

2.1 Terms of reference

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

3 Progress against ToRs

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

This ToR stems from the WG planning exercise that was undertaken at the WGRP meeting in Barcelona in 2005. All products initially identified for this ToR have now been successfully completed. The last product arising from this TOR was the "Man-

ual of Best Practices for Modelling Physical-Biological Interactions during Fish Early Life History" which will be released as an ICES Cooperative Report in 2008. Currently, a draft of the Manual is available online at

http://northweb.hpl.umces.edu/wkamf/WKAMF-MRP_FinalDraft_24March08.pdf

This manual grew out of the highly successful Workshop on Advances in Modelling physical-biological interactions in Fish early life history (WKAMF), jointly sponsored by WG Phyiscal Biological Interactions (WGPBI) and WGRP that was held in Nantes in 2006. WKAMF has previously resulted in series of theme papers published in Marine Ecology Progress Series in 2007 (MEPS 347:121-306) by scientists from and outside of WGRP. The manual which has now been produced with input from WGPBI and WGRP members balances considerations of how best to represent the physical process in the environment with the biological processes of spawning, larval duration, growth, mortality and behaviour. The sections on behaviour and population connectivity are particularly noteworthy as they represent some of the first efforts to integrate information on these topics into coupled physical-biological models. Also included in the manual is a chapter evaluating the utility of coupled physical-biological models in forecasting recruitments. A central conclusion of this section is that quantitative, accurate and precise estimates of absolute recruitment will continue to be difficult to produce from coupled physical biological models. In contrast forecasts of how recruitment might qualitatively change in response to changes in the distribution and characteristics of the spawning stock, or to changes in climate regimes are possible and desirable.

3.2 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 review seeks to quantify sources and patterns in variability in three areas: the characteristics of spawners and their behaviour, early life stages and recruitment. Work on the first two areas seeks to document the processes that underlie the observed changes in patterns of recruitment. Subsequently, the objective is to determine whether the processes prior to or subsequent to spawning induce characteristic signals in recruitment variability. Progress continues on the first two components and is summarized below.

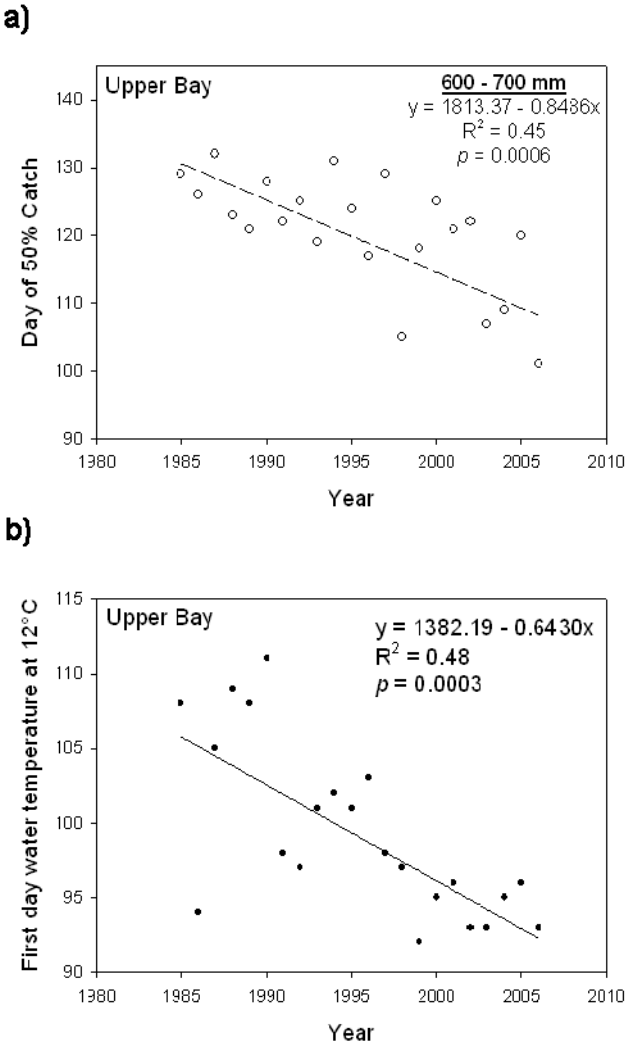

Figure 1. Spawning phenology of striped bass in the upper Chesapeake Bay, USA (Peer, in prep). A) Timing of arrival of mature females on spawning grounds estimated from a fishery-independent survey and B) Date when water temperature exceed 12°C, a critical threshold for spawning in this species.

Interest in changes in the phenology of spawning has increased as a result of interest in the affects of global climate change. There is a substantial body of literature on ecological responses to recent climate change (Walther *et al.,* 2002). Changes have been documented in the breeding ecology of birds, amphibians and insects (reviewed in Walter *et al.,*), but fewer examples are available for fishes. Carscadden *et al.* (1997) provide evidence of a earlier spawning times at higher temperatures in capelin (*Mallotus villosus*). Ware and Tansichuk (1989) provided similar evidence of Pacific herring. However, these studies considered the influence of interannual variability in temperature, rather than a specific climate trend. Sims *et al.* (2004) documented changes in the migration behaviour of flounder (*Platichthys flesus*) off Plymouth (UK) in response to a climate trend. Based on a high resolution, 13-year trawl survey, Sims *et al.* documented a that flounder migrated 1–2 months earlier in years that were up to 2°C cooler. The authors explain this somewhat counter-intuition result by suggesting that the migration was more synchronous at the population level in cooler years than in typical years. More recently, Peer (in prep) has conducted a similar analysis of spawning phenology of striped bass (*Morone saxatilis*) in Chesapeake Bay. The data for Peer's analysis come from on going striped bass spawning stock surveys in the

upper Chesapeake Bay, and routine water temperature monitoring conducted over the last 20–30 years. The spawning survey provides data on when ripe females arrived on the spawning grounds (Figure 1a). These data indicate that mature females arrived on the spawning grounds approximately 30 d earlier in 2005 than they did in 1995. Paralleling this earlier arrival on the spawning ground was a general warming of the waters of the upper bay over the same period. Striped bass spawning is tied to the 12°C isotherm. Surface waters in the upper Chesapeake Bay exceeded this critical threshold approximately 15 d earlier in 2005 than in 1985 (Figure 1b). The Other studies suggest One of the most detailed studies to date on this topic is that of Gillet and Quentin (2006) who studied the phenology of spawning in the fresh water roach, *Rutilus rutilus*. Gillet and Quentin document an increase in surface water temperature in Lake Geneva of 1°C over a 20-year period (Figure 2a). The authors also present data on the onset of spawning of roach in the lake based on egg surveys conducted three times a week from 1983. The survey data were used to estimate the first data of spawning and the duration of spawning. Survey data indicate a clear decline in the onset of roach spawning in the lake (Figure 2.b). Spawning occurred almost one month earlier in 2001 than it did in 1983. Additional analyses by Gillet and Quentin indicated that the earlier spawning resulted directly from an increase rate of accumulation of degree days between 1 October and the initiation of spawning.

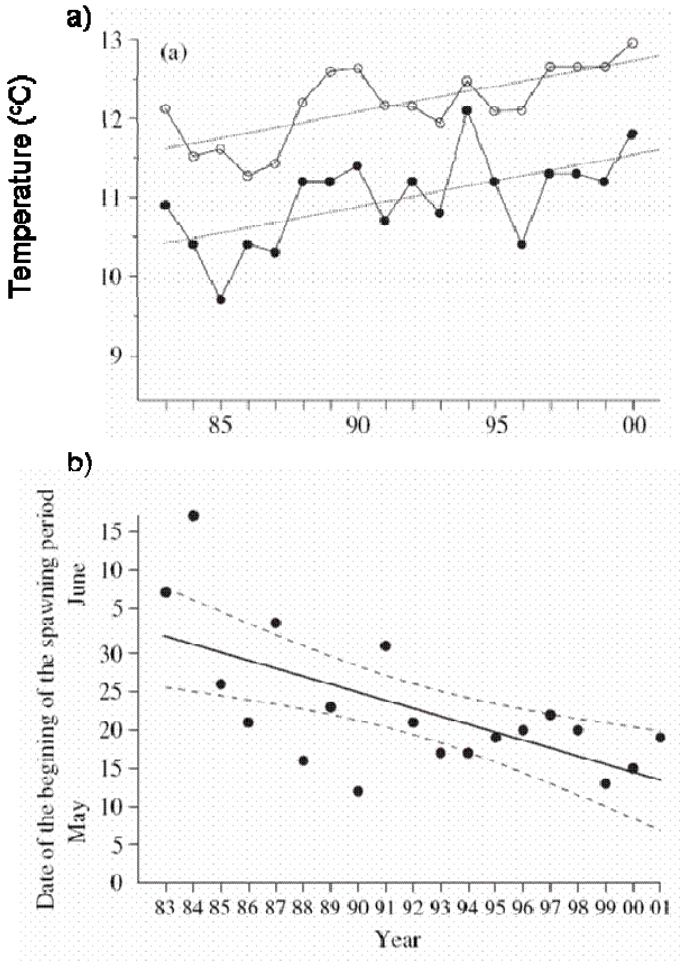

Figure 2. Effects of climate on spawning phenology of roach in Lake Geneva. A) Trends of surface (open symbols) and bottom (closed symbols) temperature and B) trends in first spawning in roach.

The documented changes in spawning phenology are likely to have cascading effects on the characteristics of the larvae produced. There is an extensive database on the effects of temperature on larval size, growth and performance (Houde 1989, Pepin 1991). Based on a literature review, Pepin indicated that temperature induced opposite but equal effects on egg and larval survival, so that temperature did not appear to have any net effect on early life survival. Both Pepin and Houde's analyses indicated a strong positive affect of temperature on larval growth-rates. Given the strongly size-dependent nature of mortality during fish early life history (Miller *et al.*, 1988), temperature may alter the characteristics of larvae who survive to recruit. However, Pepin and Houde's conclusions result from extrapolations from intraspecific comparisons to interspecific responses: such extensions may not be valid (Pepin and Miller, 1993). Moreover, even interspecific temperature-dependent responses, such as those documented by Chambers (Chambers, 1997) which are based on responses to variability in temperature, may not adequately represent how species may respond to a trend in temperature as a result of patterns of covariation among traits (Chambers 1993).

Review of relevant literature pertaining to selective processes in fish early life history is continuing. The analyses of climate influences are largely complete. Considerable

progress has been made on reviewing the literature on how the characteristics of spawners (e.g. size, condition and other phenotypic traits) affect the traits of offspring and subsequent recruitment patterns. It is anticipated that the results of this work will be available in time to be presented at upcoming ICES workshops (see Section 4.1).

3.3 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 goal of this task is to compile and evaluate the application of multistage models of recruitment for as wide a range of taxa as possible. We seek 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. groundfish vs. pelagics).

In the fisheries literature the concept of recruitment is often considered solely as the relationship between stock and recruitment with many relationships being used to describe the number of individuals that survive from an annual spawning through to being vulnerable to the fishery. A review of fisheries textbooks quickly reveals the highly variable nature of the relationship between stock and recruitment that typifies most species that have been studied (Pitcher and Hart 1982, Hilborn and Walters 1992, Jennings *et al.*, 2001, Walters and Martell, 2004). This research initiative recognizes that a strong assumption underlying the development of stock-recruit models is that recruitment is regulated at a single stage – most often the larval stage. Paulik (1973) was one of the first to recognize that recruitment might be regulated at multiple life history stages (or stanzas). The original Paulik (1973) model used salmonids with very distinct life history stanzas to produce a theoretical model which tracked a cohort from spawning through to recruitment and on to the new generation of spawning stock (see Figure 3). Rothschild (1986) further developed the theoretical framework with his conceptual model of the population dynamic process to consider a number of stanzas which are affected by the physical environment, food, predation, and feedbacks between density dampening and density-enhancing mechanisms..

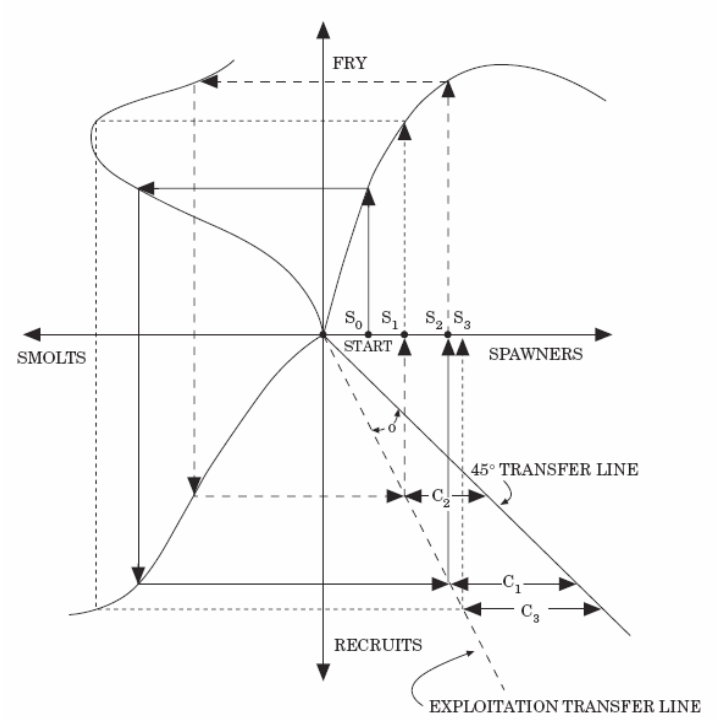

Figure 3. Conceptual multistage recruitment figure after Paulik (1973).

The first full illustration of a 'Paulik diagram', was developed by Nash (1998) for Irish Sea plaice using a combination of assessment results and model forecasts (Figure 4a). To examine the potential relationships (density-dependent or –independent) operating in each phase, functional relationships were fitted to the data (Figure 4b). Nash (1998) demonstrated a combination of density-dependent and independent relationships operating on different stages in the life cycle. These relationships were characterized in to a conceptual model (see Figure 4c) which allowed for shifts in 'productivity' in both the stock and the environment. Rothschild and Fogarty (1998) give a similar illustration but used a three-dimensional figure for environmental effects on the stock and recruitment relationship. This adds in a level of temporal instability into the population dynamics which is not readily apparent in a simple Paulik diagram as illustrated in Figure 3.

To develop Paulik diagrams based on fishery-independent and fishery-dependent data rather than simply on models requires a large effort in field sampling and a reasonably long time-series of censusing a number of life history stages. There are very few populations where this has been done; one major exception is North Sea herring (see Nash and Dickey-Collas, 2005). For this research theme, we sought to bring together a selection of data on multiple life history stages of commercially exploited fishes. In all cases the fish are classed as 'high fecundity', undertake external fertilization and do not undertake any form of parental care of eggs or larvae, and the larvae have a pelagic dispersal phase. The data are arranged into four panel sequential graphs (Paulik diagrams) to illustrate inter- and intra-annual variations in survivorship in the selected life history stanzas. The intention is to identify which time periods in the life history generate variable survivorship and hence have the potential of determining year-class strength. A series of simple polynomials are fitted to the data in each panel with the intention of highlighting any potential relationships between sequential life history stanzas. Comparisons are made between species and also between stocks, where this is possible. The problem of converting these data in to func-

tional Paulik models is explored along with potential ways to discern underlying relationships when the ecosystem and species productivity is not stationary.

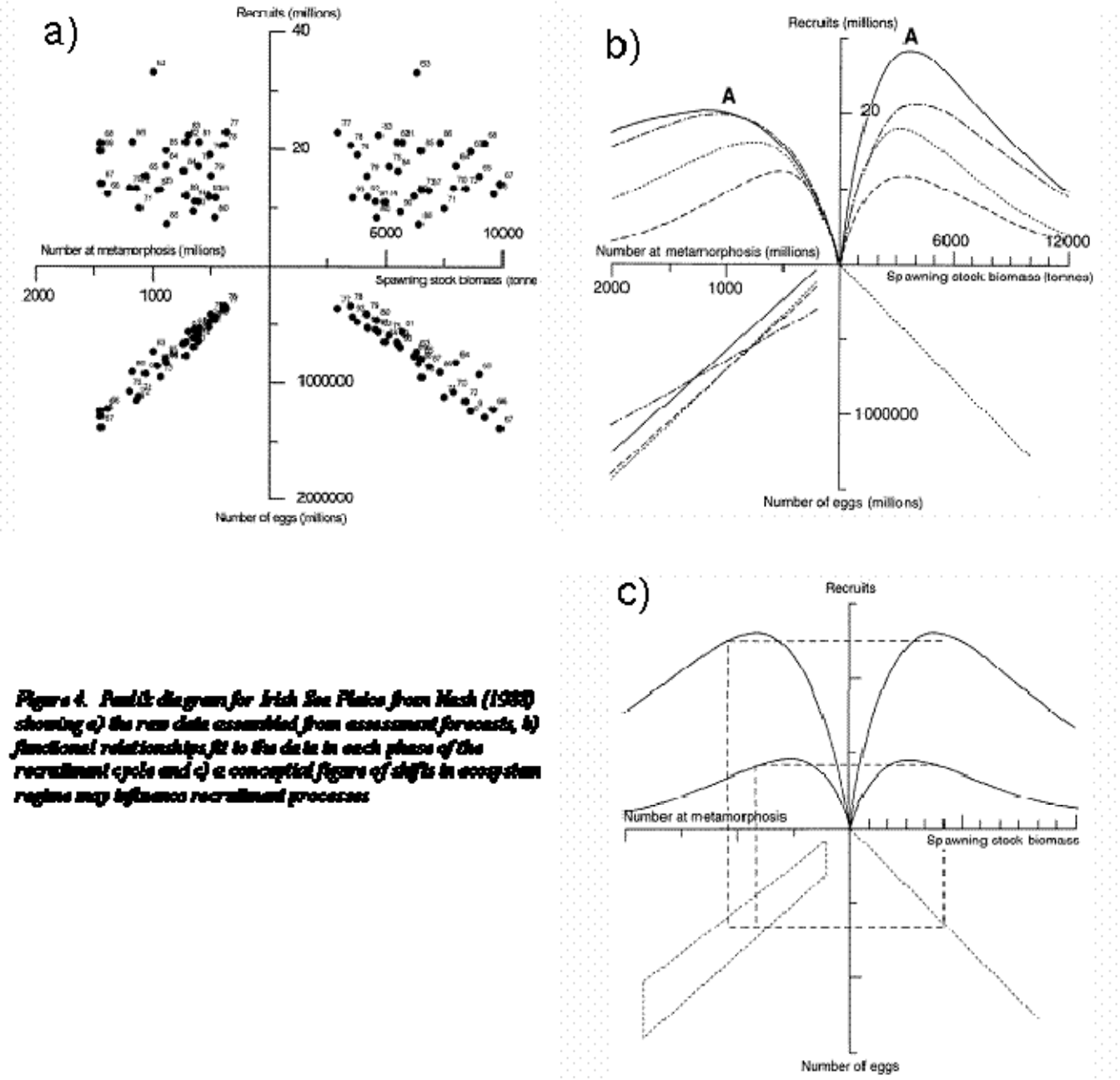

Figure 4. Paulik diagram for Irish Sea Plaice from Nash (1998) showing a) the raw data assembled from assessment forecasts, b) functional relationships fit to the data in each phase of the recruitment cycle and c) a conceptual figure of shifts in ecosystem regime may influence recruitment processes

To date data from the following stocks have been assembled: Irish Sea plaice, North Sea herring, Norwegian spring-spawning herring, Northeast arctic cod, North sea cod, Irish sea cod, Baltic Sea cod, Shelikof Strait walleye pollock, Northern walleye pollock. We are working to expand representation of species in the analyses to expand the inferences possible.

However, several preliminary conclusions are possible from the analyses. One of the most striking aspects of all the diagrams is the consistent, almost linear relationship between SSB and egg production. There is some variability generated in the transition from spawning-stock biomass to egg production, however, the variability generated in egg to larvae or later transitions is much greater.

Details of the analyses of individual species will follow in subsequent manuscripts. However, sufficient analyses have been completed to gain insight into the statistical aspects of fitting functional relationships to these data. Forcing single relationships through the data may not be ideal or even appropriate in some instances. The current focus is on using the diagram approach to identify where deviations from a linear or curvilinear relationship occur and indicate where further investigation in to processes should be targeted. One such approach is to use clustering techniques in each to the transitions e.g. Subbey and Nash (in preparation). Subbey and Nash analyzed data from North Sea herring using three clustering techniques (Partition coefficient, Xie and Benis Index and Separation index) to identify the number of valid clusters in the data. Examples of the SSB to egg production and MLAI to O-wr index along with the resultant stock and recruitment plot of SSB to O-wr index are given in Figure 5a. In this example it appears that there could be 'phases' in the egg production, however, there is generally a linear relationship between the two. In the transition between the larvae and O-wr there appear to be at least two levels with three relatively high O-wr clusters and two relatively low. In the stock and recruitment plot (SSB to O-wr) this appears as three clusters, one incorporating the increase in recruitment with increasing stock size then a set of high recruitments and a series of low. Here we have an objective way to 'group' the data and then to undertake further analyses. By using multiple stages in the life history the changes in mortality schedules can be tracked to or from the life history stage in which it occurred.

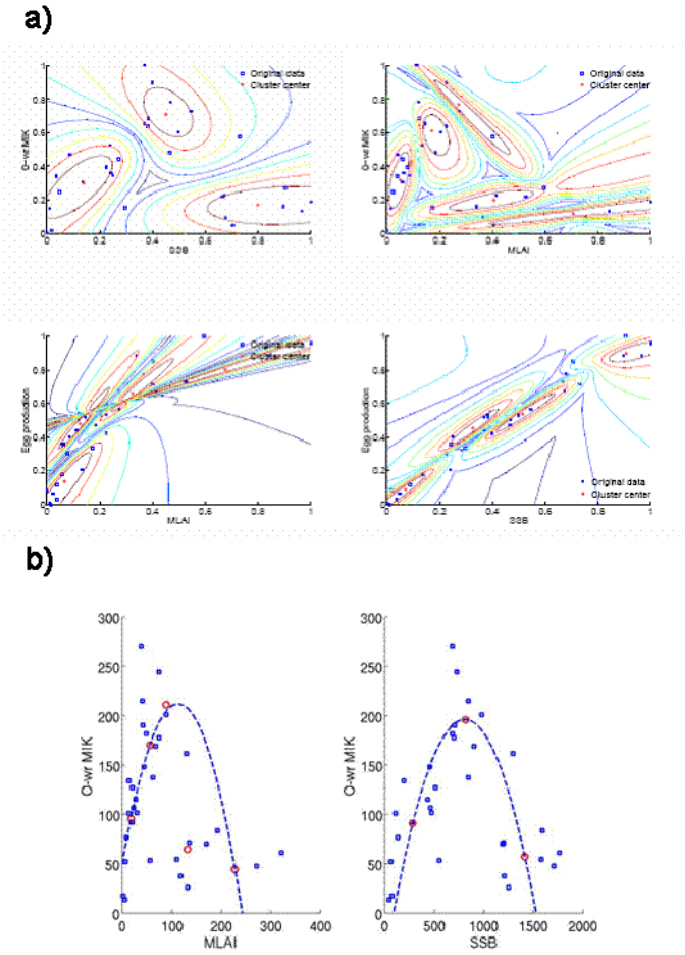

Figure 5. Analysis of North Sea herring data from Subbey and Nash (in prep) showing a) valid time-series clusters of stock and recruitment data indicated by red circles and b) resulting trend lines fitted to weighted cluster centres.

An additional usage of the clusters is to fit trend lines using the cluster centres (Figure 5b). In the case of the larvae to O-wr transition the fitted relationship appears as over compensation, however, one cluster is well below the fitted relationship. An examination of Figure 3a suggests that a more complex relationship is probably warranted or even there has been a shift in the mortality schedule between the two life history stages. The stock and recruitment panel appears as a classical over-compensation.

In general, the four panel approach to Paulik diagrams should be considered as a way of visually illustrating where variability is being generated between life history stanzas and which transitions should be focused upon. To do this, ideally the raw data should be plotted so as to demonstrate the extent of the variability between life history stages. It is accepted that, in general, external factors will influence the survival rates through a stanza; as such each transition will encompass an envelope of responses. Thus the most likely form will be a three-dimensional response surface in each quadrant or panel of the diagram. However, the four panel approach given by Nash (1998) and reproduced in Figure 2c remains the simplest presentation technique.

4 Future Plans for WGRP

4.1 Proposal for a joint workshop with WGPBI

WGRP proposes to collaborate with WGPBI to host a workshop entitled **Workshop on Understanding and quantifying mortality in fish early-life stages: experiments, observations and models [WKUM]** with Co-Chairs: Gallego, North, Petitgas and Houde will be held on 29–31 March 2010 in Aberdeen, Scotland [dates and venue to be confirmed], to:

a) review current and emerging laboratory, mesocosm, field and modelling methodology aimed at understanding the underlying mechanisms that control mortality during fish early-life stages;

b) summarize the state of our understanding of the mechanisms that control mortality of fish eggs, larvae and juveniles, identify information gaps, and list future research directions as proceedings from the workshop;

c) develop recommended techniques to quantify mortality in the field and model its affect on subsequent recruitment.

The workshop will report by 15 May 2010 for the attention of the Oceanography Committee. This workshop is highly relevant to the WGRP research theme "Selective Processes in Early Life History" discussed above. By the time the workshop convenes work on this research theme should have been completed, and its results will be available to be presented within the WKUM framework.

4.2 Selective Processes in Early Life History

By July 2009, 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 33rd Annual Larval Fish Conference in Portland, USA. 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.

4.3 Multistage Models of Recruitment

By July 2009, 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.

5 Other Matters

5.1 Future Status of WGRP

WGRP was scheduled to meet from 31 March – 1 April 2008. Notification of the meeting agenda and time and place were sent to all WGRP members on 31 January 2008. Contacts with individual workgroup members followed in an effort to ensure a well-attended meeting. A second notification of the meeting was sent out on 28 February, 2008. We received notification of regret from 17 WG members indicating that they could not attend the WG meeting. However, only two other WG members indicated that they would attend the meeting. With the attendance of the WG Co-Chairs, total attendance at the meeting would have been limited to four people. In light of the poor response to the announcement of the WG meeting, the Co-Chairs reviewed the progress that was likely at the meeting, and decided that cancelling the meeting was the prudent course. We note that this is the second year running that the WG meeting has been cancelled. In 2007, the primary cause was ill-health of one of the Co-Chairs: this year a perception of lack of interest was the primary cause. Given the recent history of participation in WG group activities, we believe it is necessary to critically asses the future of WGRP within the new ICES structure. It is appropriate that we ask hard questions regarding the relevance of a WG focused on recruitment. Further, if such a group is deemed necessary, we should review and assess its mandate, its relationship with other WGs and its membership.

Should ICES support a workgroup focusing on recruitment? We believe that there is a clear scientific justification for ICES maintaining an interest in recruitment processes. Understanding the sources of recruitment variability, the magnitude of that variability and its consequences to fish stocks remains a central challenge to society's ability to manage, sustain and restore marine fishery ecosystems. Improvements in our understanding of such issues have direct benefits to our ability to exploit sustainably individual stocks while ensuring the integrity of the ecosystems from which they are taken. The sole question is not whether ICES has a vested interest in recruitment studies, but rather how that interest should be marshalled. To date several groups, both formal and informal have explored recruitment issues. When recruitment is viewed as a species-specific, location-specific, context-specific problem, there has been a tradition of forming individual EGs, such as the Study Group on Recruitment Variability in North Sea Planktivorous Fish (SGRECVAP). These EGs are often promoted by concerns arising from stock assessment activities and may lack breadth to view recruitment processes in their wider context. The strong historical connection between the development of oceanography and studies of fish early life stages has lead to the development of both formal and informal groups under the Oceanography Committee. Indeed, reflective of this history, WGRP currently sits within OCC. However, this has lead to a heavy focus on planktonic processes, in part to the detriment of consideration of ecological and population dynamic processes. Also reflective of this history are informal groups within other WGs. The most recent example of this is the highly successful and active "larval fish group" within WGPBI, several of whom are also members of WGRP. This group focuses their efforts on representing recruitment processes in coupled physical biological models. This work also tends to be species- and location-specific. We consider these groups to be too focused to be able to provide the synthetic overview of recruitment that ecosystem-based ap-

proaches to fisheries will demand. We believe that there is a great deal to be learned from comparative analyses that consider recruitment more broadly to help identify patterns and processes that driven the evolution of the reproductive strategies we observe in support of ecosystem-based approaches. Indeed, we suggest that it is only by a holistic consideration of recruitment that includes dynamics of the spawning stock, egg, larval and juvenile stages that we can hope to understand how reproductive strategies might change in response to climate change, shifts in exploitation patterns, regime shifts etc. We further believe that because of the central importance of recruitment processes to the dynamics of marine ecosystems, this group should be at the hub of recruitment studies within ICES. It should coordinate with other WGs in supporting studies of recruitment that may cross traditional boundaries of stock assessment, oceanography and ecological studies.

What should be the mandate of a recruitment WG? We believe that the mandate of a recruitment WG should be to evaluate, analyze and synthesize research on reproductive and recruitment processes. We argue that this mandate should be defined quite broadly to include stock dynamics and characteristics that influence reproductive investments, the sources, patterns and consequences of variability in growth and survival of eggs and larvae, and the characteristics and fate of juvenile stages. This is a broadening of the current mandate which is more narrowly focused on eggs and larvae. However, we believe that such an expansion is warranted to allow consideration of a range of issues that directly influence or will likely induce changes in recruitment variability. Given the central role of recruitment in a large number of important fish stocks, we believe that such a broad mandate is not only desirable but is in fact necessary. We believe that the recruitment WG should serve as a centre of excellence, providing expertise to both assessment and other working groups. For example, the recruitment WG should collaborate with assessment WG to help understand and characterize whether and how ecosystem-level changes in productivity would likely directly affect the recruitment time-series of individual species. These activities would require collaboration with scientists from diverse backgrounds including statisticians, assessment experts, oceanographers and ecologists with expertise in early life history. As a second example, a recruitment WG could also collaborate with other WGs to assess questions related to the affect of climate change on fishery ecosystems. It is clear that broad patterns of ecosystem change will have cascading effects on the ecology of individual species within the ecosystem, including affect recruitment levels and variability. The extent to which we can understand and predict the likely scale of these affects is currently unknown. The are numerous other examples of broad questions that require a more holistic view of recruitment processes.

Who should participate in a recruitment WG? A broadly defined recruitment WG would require participation by scientists with a wide range of backgrounds and interests. Currently, WGRP is dominated by researchers with an active research program on the ecology of fish early life stages. Clearly, maintaining this foundation is important. But it is equally critical that other disciplines are well represented. It would be important to have participation from scientists with a strong quantitative background such as population dynamicists or statisticians who would provide the quantitative aspects to understanding recruitment processes. It would also be important to have representation from oceanographers would could provide the environmental context in which recruitment processes play out. A central challenge of broadening of the mandate of the recruitment WG is to ensure active, full participation of all members. Over the last few years, WGRP Co-Chairs have tried two approaches to encouraging participation. Originally, we used a rapporteur approach in

which individuals reported on research activity, which was then synthesized in annual reports. However, it was felt that this did not provide the holistic view of recruitment that we desired. Accordingly, WGRP Co-Chairs tried to focus activities on two or three broad themes that would result in publishable products in the hope of encouraging participation – the idea being that if there was something to which you could attach your name, there would be more motivation to attend. This has not been as successful as was hoped as participation has been limited to only a few. But, it is clear from other WGs (e.g. WGFE) that this product-based approach to workgroup activities can be successful if there is sufficient and broad participation from WG members. The only conclusions we can draw is that the current focus of WGRP activities is not of sufficiently broad interest to current WGRP members to attract their attention given the numerous competing calls on the time of researchers in this area. Thus, a central recommendation is that the recruitment WG be re-invigorated, and an initial WG meeting be held in late 2009 in a central location to identify, plan and commit to a specific work program. We recommend that the meeting be held late in 2009 to provide sufficient time to plan for the meeting and to ensure as broader participation as possible. It is also clear that this needs to be conducted under new leadership. The current WGRP Co-Chairs (R. Nash, Norway and T. Miller USA) have served since 2002. The current Co-Chairs are eager and willing to continue working as a part of a recruitment WG, but believe that the fresh start proposed here, also requires fresh leadership if it is to have the highest likelihood of success.

6 Future Meetings

2009 See above

We have not planned WGRP beyond 2009.

7 Proposed Terms of Reference for 2009

The Terms of Reference developed for 2008 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 by correspondence in 2008/2009 to complete and produce products that involve:

a) co-convene with WGPBI a workshop entitled "Understanding and quantifying mortality in fish early-life stages: experiments, observations and models" (WKUM) with Co-Chairs Gallego, North, Petitgas and Houde will be held on 29–31 March 2010 in Aberdeen, Scotland [dates and venue to be confirmed];

b) complete the synthesis and review of the evidence of 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 2008;)*

c) 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;

d) summarize and analyse data relevant to multistage models of recruitment to determine whether patterns exist either within species or within ecosys-

tems that may lead to generalizations regarding the nature of population regulation *(carried over from 2008).*

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 c) 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 at ICES headquarters in 31 March – 2 April 2008, and will need meeting facilities for that meeting. Additional secretarial assistance will be required 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.

8 References

Carscadden, J., B. S. Nakashima, and K. T. Frank. 1997. Effects of fish length and temperature on the timing of peak spawning in capelin (Mallotus villosus). Canadian Journal of Fisheries and Aquatic Sciences 54:781–787.

Chambers, R. 1997. Environmental influences on egg and propagule sizes in marine fishes. Pages 63–102 *in* R. Chambers and E. Trippel, editors. Early life history and recruitment in fish populations. Chapman and Hall Ltd., London.

Chambers, R. C. 1993. Phenotypic variability in fish populations and its representation in individual-based models. Transactions of the American Fisheries Society 122:404–414.

Gillet, C., and P. Quetin. 2006. Effect of temperature changes on the reproductive cycle of roach in Lake Geneva from 1983 to 2001. Journal of Fish Biology 69:518–534.

Hilborn, R., and C. J. Walters. 1992. Quantitative Fisheries Stock Assessment. Chapman and Hall, New York.

Houde, E. 1989. Comparative growth, mortality, and energetics of marine fish larvae: temperature and latitudinal effects. Fishery Bulletin U.S. 87:471–495.

Jennings, S., M. Kaiser, and J. Reynolds. 2001. Marine fisheries ecology. *in*. Blackwell Science, Oxford.

Miller, T. J., L. B. Crowder, J. A. Rice, and E. A. Marschall. 1988. Larval size and recruitment mechanisms in fishes: toward a conceptual framework. Canadian Journal of Fisheries and Aquatic Science 45:1657–1670.

Nash, R. D. M. 1998. Exploring the population dynamics of Irish Sea plaice, *Pleuronectes platessa* L., through the use of Paulik diagrams. Journal of Sea Research 40:1–18.

Paulik, G. J. 1973. Studies of the possible form of the stock recruitment curve. Rapports et Procès-verbaux des Réunions du Conseil international pour l'Exploration de la Mer 164:302–315.

Pepin, P. 1991. Effect of temperature and size on development, mortality, and survival rates of the pelagic early life history stages of marine fish. Canadian Journal of Fisheries and Aquatic Sciences 48:503–518.

Pepin, P., and T. J. Miller. 1993. Potential use and abuse of general empirical models of early life history processes in fish. Canadian Journal of Fisheries and Aquatic Science 50:1343–1345.

Pitcher, T., and P. Hart. 1982. Fisheries ecology. *in*. Croom Helm, London.

Rothschild, B. J. 1986. Dynamics of Marine Fish Populations. Harvard University Press, Cambridge, MA.

Sims, D. W., V. J. Wearmouth, M. J. Genner, A. J. Southward, and S. J. Hawkins. 2004. Low-temperature-driven early spawning migration of a temperate marine fish. Journal of Animal Ecology 73:333–341.

Walters, C. J., and S. J. D. Martell. 2004. Fisheries Ecology and Management. Princeton University Press, Princeton, NJ.

Walther, G. R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J. M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389–395.

Ware, D. M., and R. W. Tanasichuk. 1989. Biological basis of maturation and spawning waves in Pacific herring (*Clupea harenus pallasi*). Canadian Journal of Fisheries and Aquatic Science 46:1776–1784.

Annex 1: 2008 Terms of References

The Terms of Reference developed for 2008 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 between 31 March and 2 April 2008 (at ICES Headquarters in Copenhagen) to complete and produce products that involve:

a) completing the synthesis and review of the evidence of 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 2007*);

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 multistage models of recruitment to determine whether patterns exist either within species or within ecosystems that may lead to generalizations regarding the nature of population regulation *(carried over from 2007)*;

d) evaluate the findings of SGRECVAP (2006 and 2007 meetings) and undertake work on the causes and dynamics of the serial poor recruitment in North Sea herring, and provide a report of the WGRP deliberations to the HAWG in 2008.

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 sam-

	pled 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.