ICES WGRFE REPORT 2014

SCICOM STEERING GROUP ON THE SUSTAINABLE USE OF ECOSYSTEMS

ICES CM 2014/SSGSUE:01

SCICOM

First Interim Report of the Working Group on Recruitment Forecasting in a Variable Environment (WGRFE)

16–20 June 2014

ICES Headquarters, Copenhagen, Denmark

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. 2014. First Interim Report of the Working Group on Recruitment Forecasting in a Variable Environment (WGRFE), 16–20 June 2014, ICES Headquarters, Copenhagen, Denmark. ICES CM 2014/SSGSUE:01. 33 pp. https://doi.org/10.17895/ices.pub.9114

Contents

Executive summary 1

1 Administrative details 2

2 Terms of Reference a) – z) 2

3 Summary of Work plan 2

4 List of Outcomes and Achievements of the WG in this delivery period 2

5 Progress report on ToRs and workplan 4

6 Revisions to the work plan and justification 5

Annex 1: List of participants and group photo 6

Annex 2: Agenda..9

Annex 3: Recommendations 10

Annex 4: Presentations and Associated Discussion...11

Annex 5: Abstracts and Rapporteur Notes for WGRFE Meeting 12

Executive summary

The Working Group on Recruitment Forecasting in a Variable Environment (WGRFE) met at the ICES HQ, Copenhagen, Denmark, from June 16-20, 2014, with fourteen participants and Dr. Liz Brooks (USA) and Sam Subbey (Norway) as Chairs.

The formal mandate for this WG meeting was established in 2013/MA2/SSGSUE01. The overarching objective of the WG is to develop a framework for how to develop recruitment models with minimal prediction variance, based on incorporating both abundance indices and environmental drivers.

The ToRs for the 2014 meeting included:

a) Review (approaches modelling and methodologies) where stock recruitment models incorporate external drivers, along with all caveats.
b) Identify and collate relevant datasets for use testing the modeling framework to be determined.

This report summarizes discussions and proposed further work by the WG on the above ToRs. Specifically, this reports deals with:

1) Directions to pursue to develop a statistical framework for examining variance and existence of density dependence in the early life history.
2) The implementation of a procedure to evaluate ensemble forecasting algorithm (AFTER, which refers to the Aggregated Forecast Through Exponential Reweighting), which was originally proposed in the SGRF 2012 report
3) Comparison of the performance of forecast models that include environmental drivers, status quo methods, and the incorporation of autocorrelation.
4) Investigation of when environmental drivers make a difference in forecasts and the development of a simulation framework for further exploration.

1 Administrative details

Working Group on Recruitment Forecasting in a Variable Environment

Year of Appointment

2013

Reporting year within current cycle (1, 2 or 3)

1

Chair(s)

Samuel Subbey, Norway

Elizabeth Brooks, USA

Meeting venue

Copenhagen, Denmark

Meeting dates

16-20 June 2014

2 Terms of Reference a) – z)

a (Year 1)	Review approaches (modelling and methodologies) where stock recruitment models incorporate external drivers, along with all caveats. Identify and collate datasets for use in ToR (b).
b (Year 2)	Develop prototype, statistical recruitment tools for selected stocks, based on stage-structured models which include environmental drivers and multispecies considerations
c (Year 3)	Testing, validation and documentation of prototype models.

3 Summary of Work plan

Summary of the Work Plan

Year 1	Review state-of-the-art and caveats in developing recruitment forecasting models with environmental drivers
Year 2	Development of prototype, stage-structured models for recruitment forecasting for selected ices stocks
Year 3	Testing, validation and documentation of models and methodologies for peer review

4 List of Outcomes and Achievements of the WG in this delivery period

- Publications – a series of publications collaboratively written by WGRFE are planned for submission to a special issue in Canadian Journal of Fisheries and Aquatic Sciences (joining the Hjort Symposium manuscripts); in addition, several presentations made at this meeting will be submitted by the presenter either to the same special issue or individually to a separate journal

- Datasets – (list datasets from manuscripts)
- Methodological developments –
  - plenary discussions focused on directions to pursue to develop a statistical framework for examining variance and existence of density dependence in the early life history following Paulik diagrams;
  - ensemble forecasting will be implemented to evaluate the proposed methodology (AFTER, which refers to the Aggregated Forecast Through Exponential Reweighting, a product of SGRF) and to compare the performance of forecast models that include environmental drivers, status quo methods, and the incorporation of autocorrelation
  - it was suggested to explore when environmental drivers make a difference in forecasts and discussions focused on development of a simulation framework for further exploration
- Include list of URLs to access the different databases that already exist
  - CEFAS : http://www.cefas.defra.gov.uk/publications-and-data/fishdac.aspx
  - RAM legacy (Dr. Ransom A. Myers' original stock-recruitment database): http://ramlegacy.marinebiodiversity.ca/ram-legacy-stock-assessment-database
  - RAM current (Access to updated version of Dr. Ransom A. Myers' original database): http://ramlegacy.marinebiodiversity.ca/ram-legacy-stock-assessment-database
  - Global Population Database : http://www3.imperial.ac.uk/cpb/databases/gpdd (email directly for a full dump of database)
  - ICES Standard Graph Database : http://standardgraphs.ices.dk/
  - ERDAPP : http://coastwatch.pfeg.noaa.gov/erddap/index.html
- List of projection 'ingredients' to identify the pieces of information needed to make projections (assuming age structured approach)–
  - Biology (e.g., Numbers at age, Weight at age in catch, Weight at age for the stock, Maturity at age)
  - Fishery (Selectivity at age)
  - Recruitment function
  - Environment (external driver)

5 Progress report on ToRs and workplan

The following summarizes progress made on ToRs for the 1st year of WGRFE.

- Review approaches (modelling and methodologies) where stock recruitment models incorporate external drivers
  - Salmon (Brian Wells) – understanding spatial and temporal aspects determining bottom-up production of salmon recruitment to extend forecast horizon by a number of years
  - Sprat (Brian MacKenzie)-water temperature in 45–65m was significant influence on recruitment survival; impact on forecasts of SSB was only slight in short term due to age of maturity
  - (Jim Ianelli) evaluation of global climate models and their potential impacts on recruitment. In particular, how alternative control rules that lead to catch policies perform relative to the status quo.
  - (Jon Brodziak) develop r/s and recruitment predictors with environmental covariates
  - (Sam Subbey, NEA Cod)-Illustration of Ensemble projection using AFTER methodology
  - (Einar Svendsen) – using transport and productivity to get a time series of recruitment several years ahead
  - (Richard Nash) Use of Paulik diagrams to identify bottlenecks in recruitment (where in early life history the environment matters)
  - Implicit incorporation of 'unknown driver' when estimating reference points (Conservation Limits)
- Note caveats associated with identifying environmental drivers and relating them to recruitment
  - A method was introduced to test for causal link, potentially as a way to avoid using a correlation that will break down (Granger Causality Test and Brock, Dechert and Scheinkman (BDS) Nonlinearity test)
  - Quirky recruitment – need to be careful when developing driver relationships (and when testing them); results may be an artefact of the specific configuration and structure of the model that generated the output
  - Existence of retrospective bias in initial conditions is propagated through the projection horizon; forecasts only as good as your starting point
  - Non-stationarity of drivers – relationship between recruitment and an environmental driver may break down because the driver is non-stationary
  - Non-stationarity in expression of biological traits as a result of environmental driver—important to recognize that biological parameters in assessment or projection may not be constant;
  - Need to understand impact of thresholds, i.e. the point at which a driver becomes important (the 'tipping point');
  - Interactions between environmental drivers can be difficult to parse; a given driver may be important in some years while in other years a dif-

ferent driver(s) is(are) more important; similarly, there may be interactions between factors
  - need to account for nonlinearity of driver (e.g., nonlinearity may not become apparent until stock sizes increase)
  - Need to match spatial and temporal scale of driver to spatial scale of fish life stage and their prey
  - Consideration of the source of 'data' – is there a better way to organize and access stock assessment data at different levels of aggregation that would improve the ability to explore and understand SR relationships
- Identify and collate datasets for use in ToR
  - Baltic Cod (point of contact: R Nash)
  - Sprat (point of contact: R Nash)
  - Northeast Arctic Cod (point of contact: R Nash)
  - North Sea Autumn Spawning Herring (point of contact: R Nash)
  - North Sea Spring Spawning Herring (point of contact: R Nash)
  - Waleye Pollock (point of contact: J Ianelli)
- Future cooperation should be sought with WGIPEM (Working Group on Integrated, Physical-biological and Ecosystem Modelling) and WGMG (Working Group on Methods of Fish Stock Assessment)

6 Revisions to the work plan and justification

No revision necessary.

Specific tasks for the second meeting (to be held in 2015) are listed below based on work progress during first meeting.

1) Evaluate performance of AFTER ensemble method on case studies; develop stand-alone package for use by assessment scientists; include manual and example.

2) Perform simulation study over different life histories to evaluate when environmental drivers work and whether a distinction can be made between quantitative versus qualitative 'improvement' in forecast.

3) Evaluate the use of autocorrelation in recruitment as a simple, implicit approach to considering environmental influence in short-term forecasts.

4) Explore whether it is possible to identify where in the early life history the "bottleneck" occurs; consider developing statistical modelling of Paulik diagrams.

Annex 1: List of participants and group photo

Jon Brodziak	National Marine Fisheries Services NOAA Inouye Regional Center 1845 Wasp Boulevard, Building 176 Honolulu, Hawaii 96818 HI United States	jon.brodziak@noaa.gov
Elizabeth Brooks (Co-Chair)	National Marine Fisheries Services Northeast Fisheries Science Centre 166 Water Street 02543 Woods Hole MA United States	liz.brooks@noaa.gov
Jennifer Devine	Institute of Marine Research Nordnes P.O. Box 1870 5817 Bergen Norway	jennifer.devine@imr.no
Anna-Simone Frank	Institute of Marine Research Nordnes P.O. Box 1870 5817 Bergen Norway	anna-simone.frank@imr.no
Jim Ianelli	National Marine Fisheries Services Alaska Fisheries Science Center, Bldg.4, 7600 Sand Point Way 98115 Seattle WA United States	jim.ianelli@noaa.gov
Brian R. MacKenzie	DTU Aqua - National Institute of Aquatic Resources Section for Ocean Ecology and Climate Jægersborg Allé 1 2920 Charlottenlund Denmark	brm@aqua.dtu.dk
Richard D. M. Nash	Institute of Marine Research Mob: +47 91845894 Nordnes P.O. Box 1 5817 Bergen Norway	Richard.Nash@imr.no

Mark Payne	DTU Aqua - National Institute of Aquatic Resources Section for Fisheries Advice Charlottenlund Slot Jægersborg Alle 1 2920 Charlottenlund Denmark	mpa@aqua.dtu.dk
Ute-Alexandra Schaarschmidt	Institute of Marine Research Nordnes P.O. Box 1870 5817 Bergen Norway	ute-alexandra.schaarschmidt@imr.no
Kyle Shertzer	National Marine Fisheries Services Beaufort Laboratory 101 Pivers Island Road 28516-9722 Beaufort NC United States	Kyle.Shertzer@NOAA.gov
Sam Subbey (Co-Chair)	Institute of Marine Research Nordnes P.O. Box 1870 5817 Bergen Norway	samuel.subbey@imr.no
Einar Svendsen	Institute of Marine Research Nordnes P.O. Box 1870 5817 Bergen Norway	einar.svendsen@imr.no
James Thorson	National Marine Fisheries Services Northwest Fisheries Science Center 2725 Montlake Boulevard East 98112-2097 Seattle WA United States	james.thorson@noaa.gov
Brian Wells	National Marine Fisheries Services Southwest Fisheries Science Center 110 Shaffer Road Santa Cruz, CA 95060 United States	brian.wells@noaa.gov
Jonathan White	Marine Institute Rinville Oranmore Co. Galway Ireland	jonathan.white@marine.ie

Participants at 1st WGRFE meeting (ICES Headquarters, Copenhagen, Denmark; 16-20 June 2014). First row (left to right): Brian Wells, Richard Nash, Anna Frank, Ute Schaarschmidt, Jim Thorson. Second row (left to right): Kyle Shertzer, Jon Brodziak, Jonathan White, Jennifer Devine, Sam Subbey, Jim Ianelli, Mark Payne, Einar Svendsen.

Annex 2: Agenda

	Monday 16-Jun	Tuesday 17-Jun	Wednesday 18-Jun	Thursday 19-Jun	Friday 20-Jun
9:00 - 9:40 AM	Welcome (housekeeping) Overview, Summarize SGRF Discussion of Goals / agenda / rapporteurs	General Intro to day 2 rapporteurs	General Intro to day 3 rapporteurs	**Mark Payne** Marine Science	General Intro to day 5
9:40 - 10:20 AM	**Talk 1** **Richard Nash** recruitment - Principles	**Talk 5** **Einar Svendsen** Recruitment	**Talk 9** **Jim Ianelli** Council's Recruitment Working Group	**Talk 13** **Nash/Payne** Quirky recruitment	**Plenary** manuscripts
10:30 - 10:45 AM	Health Break	Health Break	Health Break	Health Break	Health Break
10:45 - 11:25 AM	**Talk 2** **Jennifer Devine** life history variation	**Talk 6** **Brian MacKenzie** and potential applications to forecasting	**Talk 10** **Ute Schaarschmidt** slow-fast population dynamic model	**Talk 14** **Richard Nash** dynamics	**Review draft report**
11:25 - 12:05 PM	**Talk 3** **Jon Brodziak** The evolution of AGEPRO	**Talk 7** **Brian Wells** Chinook salmons	**Talk 11** **A. Frank** Differential Equation Model	**Plenary Session 4** Summary of case studies; are there common themes? What can we take from successes ...	**Planning ahead** **WGRFE 2015** * grants for support? next meeting
12:05 - 1:30 PM	**lunch**	**lunch**	**lunch**	**lunch**	no meeting
1:30 - 2:10 PM	**Talk 4** **Liz Brooks** performance of stock projections	**Talk 8** **Jonathan White** assessment: But what about environmental effects?	**Talk 12** **Jim Thorson** autocorrelated, sychronous, and spatial	**(Plenary 4 cont.)** ...and failures? Recommendations that might apply to other stocks; is anything 'off the table'?	
2:10 - 3:45 PM	**Plenary Session 1** Current methodologies, challenges, and management considerations; matching method to question asked and advice; reference points vs catch advice	**Plenary Session 2** Availability and predictability of climate/environmental conditions; how to determine level of detail needed; time for research vs timely advice	**Plenary Session 3** How to make progress towards existing challenges; new methods or refine the questions? Short term vs long term projections -- use need the same method?	**Report drafting** * title and abstract from speakers * summary of questions for each talk * summary of each plenary	
3:45 - 4:00 PM	Health Break	Health Break	Health Break	Health Break	
4:00 - 5:45 PM	**Frontier research/paper ideas**	**Frontier research/paper ideas**	**Frontier research/paper ideas**	**Subgroups** * themes for manuscripts * authorship for manuscripts * work plan/draft schedule	
5:45 - 6:00 PM	Prep for Tuesday 17th June	day summary / wrap up	day summary / wrap up	day summary / wrap up	
6:00:00 PM	close for day	close for day	close for day	close for day	
7:00 PM+		Group Dinner			

Annex 3: Recommendations

Recommendation	Adressed to
1. WGRFE recommends the inclusion of assessment metadata into the ICES stock-assessment database ("standard graphs") to allow the quick and easy integration of european stock assessments into global databases, such as the RAM legacy database. Specifically, the "scientific basis for the advice" already on the advice sheets to the database could be incorporated into this database, and updated each year, so that it is possible to track the changes in the development of the basis of the advice together with the history of the perception of the stock. Further information that could also be useful includes: * Contact person, for technical questions about the assessment (e.g. the stock assessor / coordinator) * The reference to the actual working group report, including the ICES CM number * Information about the spatial region where the stock is to be found e.g. ICES AreaIDs, LMEs, Spawning grounds	ICES Secretariat

Annex 4: Presentations and Associated Discussion

1.	Richard Nash	Multiple life-history underlying stock recruitment - Principles
2.	Jennifer Devine	Predictive Recruitment Models Incorporating Life-History Trait Variation
3.	Jon Brodziak	The evolution of AGEPRO
4.	Liz Brooks	Retrospective Forecasting - evaluating performance of stock projections
5.	Mark Payne	NACLIM and a perspective on prediction in Marine Science
6.	Brian MacKenzie	Environmental forcing of sprat recruitment in the Baltic Sea and potential applications to forecasting
7.	Brian Wells	A process study to evaluate environmental influences on recruitment of Chinook salmon
8.	Jonathan White	Incorporating variability and risk in Atlantic salmon stock assessment: But what about environmental effects?
9.	Jim Ianelli	Activities of the North Pacific Fishery Management Council's Recruitment Working Group
10.	Ute Schaarschmidt	A stock-recruitment relationship derived from a slow-fast population dynamic model
11.	A. Frank	Prediction of Stock Recruitment with a Delay Differential Equation Model
12.	Jim Thorson	Estimating recruitment variability including autocorrelated, sychronous, and spatial components
13.	Mark Payne/ R. Nash	Quirky recruitment
14.	Richard Nash	Contrasting herring vs Cod recruitment dynamics
15.	Einar Svendsen	An Ecosystem modelling approach to predicting cod recruitment

Annex 5: Abstracts and Rapporteur Notes for WGRFE Meeting

1. Richard Nash: Multiple life-history underlying stock recruitment - Principles

Abstract: Initially there is the question of what is a Stock-Recruitment Relationship (SRR) and what is it generally used for? In most cases the SRR is used for projecting forward in time the recruitment and the logical link is to the parent stock size. However, between the parent stock and recruitment there are a large number of processes which can be termed early life history dynamics. One way to follow the progression of numbers of individuals through each life history stanza and to identify where bottlenecks or 'step changes' in survival occur is to utilse Paulik diagrammes. The computational form of the diagrammes was illustrated by Paulik in his multi-life stage models whereby the resultant stock to recruitment relationship and subsequent stock size was a function of density dependent and independent relationships through the early life history. Paulik also showed how complex relationships in early life history can also result in multiple equilibrium points for stocks and their recruitment, an idea that was also raised for Baltic cod by other authors. In fact Norwegian Spring Spawning herring show something similar with distinct shifts in the stock size due to single large recruitments. The concepts in the multi-life stage models do not allow for non-stationarity or interannual variability in the drivers of mortality and thus survivors. This variability can be generated through modelling survival through the early life history e.g. in Irish Sea plaice or illustrated in the Paulik diagrammes. This therefore raises the question of how complicated should we make the 'prediction' of recruitment? The two alternatives are; should we stick with the simplistic stock-recruitment type relationship and live with the fact that it doesn't really reflect the real world, or should we consider complex relationships for the early life history? Two last points to consider are the use of other measures than SSB will involve the collection of more data and a general understanding of the ecology of the species of interest and the dynamics of a population are an integral part of a functional ecosystem and to predict responses probably will entail approaching the dynamics at the ecosystem level.

Rapporteur: Kyle Shertzer

Rapporteur Notes:

Irish Sea plaice—variation in recruitment appears to be temperature driven. The Paulik diagrams can be useful for identifying thresholds (e.g., in temperature) where there would be a shift to a new equilibrium recruitment.

What about variance in relationships? Paulik diagrams could be useful for decomposing variance, e.g., effects of density.

Modeling recruitment at age-0 vs older ages. Response: it depends on when the year class gets established. Also, it would be useful to define what recruitment means. Age-0, older age, recruitment to the fishery (rather than population).

Non-stationarity. Distinguish between functional response (e.g., more die during warmer temps) vs changes over time in relationship.

What is the goal of the management advice? Is the goal here to understand the mechanisms, where modelling might get very complex. Or, is it better to keep it simple? Might depend on the type of data you have available. Does the relationship actually exist? Are there data to support modelling the relationship?

Understanding mechanisms in recruitment may or may not help improve forecasts.

2. Jennifer Devine: Predictive Recruitment Models Incorporating Life-History Trait Variation

Abstract: Life history parameters, such as maturity at size or age, sex ratio, fecundity, and spatio-temporal extent of spawning, can vary throughout a species' geographical range or temporally due to environmental variability, climate change, or exploitation patterns. Stocks of the same species naturally have differences in traits throughout their range as they are adapted to the local environment, but increased environmental variability results in trait plasticity. Changes in growth and maturation will ultimately affect recruitment, which is a dynamic process integrated over several life stages, with different factors interacting at each stage and across scales. The state of a population in any given year is a function of the stock (e.g., reproduction, growth, biomass) and recruitment, which is itself a function of past events (e.g., state of the stock, environmental conditions). Therefore, recruitment is explicitly linked not only to the amount of spawning stock biomass (SSB), but also parental size and growth history. Recruitment must decline if there is insufficient spawning biomass, but recruitment will also decline with reduced body size, as fecundity, egg size, and spawning extent is inextricably linked to the fish's growth history and condition. Conventional S-R relationships treat all spawners as contributing equally to recruitment by assuming parameters (e.g., fecundity, maturation) are constant for fish of all ages and size and that the sex ratio remains fixed, but these assumptions have been recognized as being false. For several stocks, the recruitment relationship has been re-evaluated to incorporate alternative indices of reproductive potential, which include estimates of total egg production, spawner condition, and spawner age-diversity (i.e., parental effects), but these methods have rarely been incorporated into S-R models even though the methodology to do so exist. Nor has this methodology been expanded to include trait plasticity, including under climate change scenarios. Any factor changing the demography of the population will impact reproductive potential of the stock and have large management implications, both for sustainability and recovery.

Rapporteur: Jonathan White

Rapporteur Notes:

- Constant fecundity relationships are assumed in classic S/R models, of course this is not the real case.
- Differences in productivity of different stocks are shown
- Age plus the number of individuals, their age, size, maturity and fecundity etc. of different cohorts contribute.
- For many fish stocks, F1 generations do not contribute individually to an F2 individuals, multiple cohorts (all those which are mature) contribute to the following years progeny.
- Plactiticty is a driver of model/ parameter forecast variability if cohort contributions are not parsed out into their individual contributing components/variables.
- Age structure may therefore be important, with reference to the different biological parameters relating to fecundity, and the impact of biotic and abiotic environmental variables upon these.

- How should risk functions or variance be built into providing management advice?
- Should probabilities of target attainment, and cut offs (75%? 65%?) be incorporated and how would model uncertainty and complexity be included?
- More complex models will fit the data / information better, and while AIC and DIC measures and their like can account for this statistically, however by having the model structured in the way in which it is/ options set in the first place, something of the management structure has already been implemented (and assumedly agreed).
- Where should we instigate our environmental covariates? If spawning stock is little influenced by egg survival, it would not suggest it as a good indicator of future SSB. However the SSB may need to be incorporated if traits are important.
- Benchmarks which are S/R based clearly need to incorporate a measure of spawning stock.
- Where alternatives, SPR (*Spawning Potential Ratio*) proxies are used do S/R relationships matter? (While some parts of such an assessment are S/R based, alternative proxies may be used).
- Some degree of biomass at different points in the life cycle is important, however depending upon species and stocks there may be bottle necks in the life cycle. If a stock is below a threshold along the life cycle then following stages may be highly impacted. While if the level is exceeded, the following stage may then be more influential, eradicating the effect of the earlier stage on the following stages.
- The type of management target will also be important, considering if B_{lim}, B_0, MSY or other target is the focus, as a target or cut-off.

3. Jon Brodziak: The evolution of AGEPRO

Abstract: In this presentation, I describe the evolution of an age-structured projection model (AGEPRO) from the 1990s to the present. The AGEPRO model was designed to evaluate the likely population consequences of complex harvest scenarios under alternative hypotheses about the stock-recruitment relationship. Uncertainty in initial population size at age is incorporated into the projections through bootstrapped or Markov Chain Monte Carlo estimates of population size at age derived from any age-structured stock assessment model. AGEPRO uses Monte Carlo simulation to evaluate probabilities of achieving targets for fishing mortality or stock size and the expected age structure of landings and the population. The initial AGEPRO model included 5 stochastic recruitment models along with an option for stochastic natural mortality. The current version now includes twenty one models that can be used to make stochastic projections of future recruitment that are either dependent or independent of spawning biomass and are either uncorrelated or autocorrelated along with an option for stochastic variation in natural mortality at age. AGEPRO can employ ensembles of recruitment models with year-specific probabilities of occurrence to make projections that account for model selection uncertainty. In this context, it is important to emphasize the importance of using probabilistic reasoning to characterize future resource status, for which there can be no rational certainty. The AGEPRO model has been used extensively to make stock projections for fishery resources in the New England and Mid-Atlantic regions of the USA. The AGEPRO model is part of the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/AGEPRO.html). The cur-

rent version of AGEPRO allows the user to incorporate process uncertainty in weights at age, natural mortality, maturity, fishery selectivity, and discard fraction. Additional features include calculation of the probability of exceeding biological reference point thresholds and search for rebuilding strategies to achieve user specified outcomes. Future research on AGEPRO is planned to incorporate alternative process error distributions, e.g. lognormal, to include autocorrelation and covariance options for process errors as well as options to incorporate two-sex population structure or metapopulation structure.

Rapporteur: Jim Ianelli

Rapporteur Notes:

Jon Brodziak presented the background and evolution of the projection model AGEPRO used in NE and other places in the USA. He described a wide variety of features and the evolution of the software including some aspects on how it was used rebuilding analyses. The software is freely available at http://nft.nefsc.noaa.gov/AGEPRO.html and documentation can be found there as well.

Configuring projections using correlated recruitment is possible and a number of functional forms including non-parametric stochastic forms. The group commented as follows.

SS: Projections for applying autocorrelation parameter and it was noted that Thorson has a paper looking at autocorrelation among stocks (examining synchrony). Also discussion about autocorrelation as function of a changing environment and it was noted that this is for combined variation for all sources..

JT: The question of if rebuilding considerations should be evaluated midstream (e.g., on US west coast rebuilding plans are generally left alone). This gets at the utility of if future recruitments were appropriately estimated. Is the lack of checking on rebuilding resulting in bias? What policy could provide best practice?

SS: Question on model class structure. Writing documentation before the code. Question about what goes into the "environment class". Jon responded that this in draft form.

JW: Variety of topics being discussed and noted the need to figure out how to best plug in environmental effects for recruitment predictions.

JB: Haddock has been subject of oceanographic conditions, Friedland 2007 paper CJFAS on bottom-up forcing for haddock w/ positive relationship w/ primary production, calls it a prior piece of information. Spring survey less useful for pre-recruits (?) but fall survey can pick up age 0s quite well with a strong signal for the 2003 year class.

4. Liz Brooks: Retrospective Forecasting – evaluating performance of stock projections

Abstract: Stock assessments for groundfish stocks in the Northwest Atlantic Ocean were examined with respect to performance of stock projections. For a given stock, data were sequentially removed from the end of the time series for n=1, 2, …, 7 years to create "retrospective models." Next, each retrospective model was forecast for y=1, 2, …, 7 years. The forecasts were conducted multiple times, and in each iteration, a single assumption was changed in the projection model. For example, an initial null model was projected where all true values were used for future catch, recruitment, selectivity, maturity, and weights at age. Additional runs were made where all but one of those values was fixed at the true value, and the remaining value was calculated according to status quo assumptions (weight, selectivity, and maturity were the average of recent years, recruitment was resampled from a cumulative distribution of previous recruitment estimates, etc.). In this way, the influence of a given assumption in the projection could be estimated. Results indicated that the single most important reason for poor projection performance was not due to any of the assumptions in the projection horizon, rather it was due to the fact that the terminal year model estimates were unstable, causing the starting point for the projections to be very biased. Aside from this retrospective pattern of bias, the factor that was most important in the projections depended on the species and the time horizon examined. For many groundfish stocks, the recruitment assumption was more important than the assumed values for biological parameters or selectivity. However, for haddock, the assumed weights at age were more important due to the large changes realized during the 7 year period of projections. In conclusion, this talk emphasized that the estimate of where the stock is now is as important as projecting where the stock will be in the future. Also, the relative importance of inputs to the projection model are somewhat species specific and depend on the length of the projection.

Rapporteur: Jennifer Devine

Rapporteur Notes:

--Discussion on Georges Bank cod poor projection estimate (slide 26). Model still assumes large year class coming through.

-- Bias can be explained by suggesting catches used in the model were smaller than they should have been, M could have been larger, catchability in the surveys was different

-- Questions mainly revolved around explaining the results (e.g., why points are outside the CI, were all possible combinations of parameters tried? Yes.)

-- VPAs were tuned against several indices (depending on stock), availability of all age classes to survey was good.

-- Noted it was an extremely important point to do the retrospective because this is glossed over in many assessments.

-- Same approach will be tried with statistical catch-at-age models. Variation in selectivity over time can be modelled for the surveys within the statistical catch-at-age models. Can look at how selectivity varies over time instead of using the breakpoint strategy as used for the presentation/VPA models.

-- Pacific hake - see similar patterns in the retrospective analysis. This species is assessed every year because of this.

-- Similar components within each presentation. These common themes may be pulled into the 'recipe book' at the end.

-- Appearance that uncertainty not appreciated by managers: projected distribution of catches is given, but managers want a point estimate.

Only get 1 quota - is the TAC level evaluating risk in the appropriate way to meet the mgmt targets? These become the control rules (sep. procedural/control rule from assessment uncertainty). Managers should get a set of control rules, not a range. At the end of the day, if still in band of scientific uncertainty, control rules don't really matter. expected yield curve is asymmetric, so do not lose out. Can decrease the F, lose only a bit, but still be precautionary.

-- Consequences of adapting one TAC vs another (to managers) -- this is what is missing currently.

Allow the managers to then make the decision based on the risk.

-- Isn't this already given to managers - table of catch, F matching that, projected SSB? Can even put uncertainty estiamtes around these.

-- This is also a business and livelihood - so giving them 'risk' is not enough information. Maybe it should be in terms of $, not biomass. How do you translate into $ in the future??

-- BS cod stock example (price drop on cod)

-- Predict the environment and selecting most important driver: the question around this seemed to illustrate the difference between pure modellers vs. biologists working with models. Path analysis/hierarchical models - might be useful in teasing apart the mechanism, but also fitting the mechanism into the interactions. Requires working closely with oceanographers.

5. Mark Payne: NACLIM and a perspective on prediction in Marine Science

Abstract: A well-known truism holds that all models are wrong, but some are useful. However, models, in both the mathematical and conceptual meanings of the word, are the foundation of the modern scientific processes, and the conduit via which progress is made. Traditionally these models are used for knowledge acquisition: however, science and scientists are increasingly being asked questions that require application of the models in a predictive context. Given that all models, and therefore their predictions, are wrong, how do we identify the models that are useful for making forecasts, projections and predictions about marine systems? Put simply, what does a prediction have to do to be believed? In this manuscript we review a range of approaches applied across both marine science and other disciplines to validate models and their predictive capacity, and associated issues. We consider case studies from statistical modelling, earth system models, decadal prediction models, species distribution models and migration models to identify the criteria and tests employed in this diverse sample of disciplines. We then synthesise these approaches into a common framework against which a predictive model can be assessed. Specifically, we focus on questions regarding the model structure, explicit tests of predictive capacity, and the importance of scale. We propose that this framework can be used as a check-

list of items against which a forecast/prediction/prediction can be compared, and therefore the robustness, reliability and most importantly, the usefulness of its predictions assessed.

Rapporteur: Jonathan White

Rapporteur Notes:

A project to develop Predictions of a physical environment into predictions of a biological environment

Climate modelling, large scale, circulation project, with 2 interesting groups:

- WP on heat wave modelling
- WP on fisheries forecasting assessment

When do environment-recruit correlations work?

What goes wrong?

- System is very complex (chaotic?)
- Non-stationary controlling factors
- Data limitations (often <50 points)
- Knowledge is correlative

Physical forecasting is good, and improving. Biological forecasting is lagging (way) behind.

Presently El-Niño forecasts are strong

Trade off across Generality, Precision, Realism – relating to Mechanistic, Analytical and Empirical structures/assumptions, change in one will change at least one other.

Models cannot do everything.

So, what is a good prediction?

- Tests of predictive capacity are often made against data which are not independent.
- Does a model perform well against a simple persistence model?
- Are emergent properties of a system reproduced.
- How do predictions compare with common understanding, expert knowledge and expectations.

Are scales, applications and uses appropriate to a models structure and associated data.

Even so:

A drunken man and his dog, walking home may independently appear not to be following any predictable trajectory, however their relationship (their paths looked at together) can some idea of the most probable location of either when information of the other is provided.

So, are there any low hanging fruit?

And rather than trying to predict what our favourite fish does, should we be asking what would a predictable quantity look like? Should it be:

- Directly coupled to (observable) physics
- Drive by unique, simple mechanisms

- Data-rich (easy to validate)

This would appear to rule out:

- Recruitment (sorry guys)
- Growth and productivity
- Anything to do with catch (!)

But suggests spatial distributions of physical variables:

- Physically coupled (e.g. temperature)
- Are data-rich
- Established methods

Potentially useful e.g. survey design

6. Brian MacKenzie: Environmental forcing of sprat recruitment in the Baltic Sea and potential appli-cations to forecasting

Abstract: Sprat is a short-lived clupeid species which has important roles as zooplanktivore and forage fish in the Baltic Sea food web; the species is commercially important and supports large fisheries. Its recruitment (1-group) fluctuates widely among years with little influence of spawning biomass, and with little autocorrelation across years. This presentation will summarize attempts to model recruitment in relation to process-based knowledge of factors hypothesized to affect recruitment, and how such links could be used to improve short-term (1-3 years ahead) forecasts of recruitment and fishery yield. Prior to these investigations, no models involving spawner biomass or ecosystem variables were available to estimate recruitment, and forecasts in the ICES Baltic fisheries assessment working group used a time-period based average recruitment.

The main environmental forcing considered is temperature which is considered to represent impacts on egg survival rate, zooplankton abundance for larvae, juveniles and adults, and larval and juvenile growth rates. We identified significant effects of spring (May) temperature on recruitment for the 1973-1999 yearclasses. These temperature effects were strongly correlated with winter severity conditions (i. e., maximum ice coverage of the Baltic Sea, North Atlantic Oscillation). As the assessment working group meets in April, these links provide 2-4 months of additional leadtime and facilitate within-year recruitment forecasting by the working group. We have conducted sensitivity analyses of the impact of including winter-spring recruitment forecasts on short-term recruitment and fishery yields. These analyses showed that yield forecasts can differ by ca. 18%, due to the contribution of recruiting yearclasses to catch composition, and that the impact of including ecosystem forcing on recruitment and subsequent fishery advice depends on spawner biomass. At low spawner biomass levels (i.e., those close to or somewhat above B-lim), short-term fishery advice could benefit from knowledge of recruitment fluctuations.

We have validated and updated the original temperature-recruitment rleationships using both subsequent and historical recruitment yearclasses. The present relationship now covers yearclasses 1955-2009. May temperature explains significant variation (ca. 20%) for all time periods considered.

Fishery advice and simulations at longer time scales (e. g., 5–10 years; climate change impacts at multi-decadal-century scale) are less constrained by the annual stock assessment cycle and can therefore employ ecosystem variables at other periods of the year which may also explain variability in recruitment. Summer (i.e., August) tem-

peratures explain more variability in recruitment for the time period 1955-2009 than spring temperatures (61% vs. 21%), although summer temperatures are not presently predictable from winter conditions and, due to working group meeting timing (April), cannot be used operationally for within-year short-term forecasting. However inclusion of August temperature in a Ricker model now results in a relationship with a weak but significant spawner biomass influence on recruitment (13%, vs. 52% explained by both temperature and spawner biomass). Combined environment-spawner biomass-recruitment relationships could be useful for simulating climate and fishing impacts on stock development at longer time scales.

Overall, spring and summer temperatures have significant impacts on recruitment (ca. 25–60%, depending on season of year), whereas the relatively high level of spawner biomass has had a much lower influence on recruitment during the last 50 years.

References and main topics relevant to WGRFE:

MacKenzie, B. R., Köster, F. W. 2004. Fish production and climate: sprat in the Baltic Sea. Ecology 85: 784-794.

-contains original analysis of temperature impact on recruitment, with links to winter severity conditions and comparisons of recruitment forecasting methods.

MacKenzie, B. R., Horbowy, J., Köster, F. W. 2008. Incorporating environmental variability in stock assessment - predicting recruitment, spawner biomass and landings of sprat (*Sprattus sprattus*) in the Baltic Sea. Canadian Journal of Fisheries and Aquatic Sciences 65: 1334-1341.

-update of recruitment-temperature relationship with 5 new yearclasses and sensitivity analysis of effects of including ecosystem-based recruitment forecasts on short-term fishery advice.

MacKenzie, B. R., Meier, H. E. M., Lindegren, M., Neuenfeldt, S., Eero, M., Blenckner, T., Tomczak, M., Niiranen, S. 2012. Impact of climate change on fish population dynamics in the Baltic Sea – a dynamical downscaling investigation. Ambio 41: 626-646; doi: 10.1007/s13280-012-0325-y.

-updated recruitment, temperature and spawner bimoass relationships for years 1955-2009. Climate change scenario simulations of stock development for different climate and exploitation levels.

Rapporteur: Jim Ianelli

Rapporteur Notes:

Ecosystem not used very much

Temperature has increased (sprats survival lower at lower temperatures)

Relationship with temperature explains about 28% of total variance

Age 0 survey index used to effect 2006 age one estimates

May temperatures unavailable at the April working group meetings

On update, August surface temperatures seems to explain more of the recruitment variability than the May temperatures at depths. August is important month in upwelling systems. August variability has a greater signal than May (and they are autocorrelated).

There is some spawning in the summer and may be more in the upper water column than in spring.

Cannibalism may play a role but confusing with greater recruitment at higher August temperatures.

Cod may also play a role. Spatial aspects could play a role since there appears to have been some changes in the spatial distribution of spawning in recent years.

Oxygen concentrations may affect survival of sprat eggs if they get stuck in anoxic regions.

Black sea shows a decrease in recruitment as temperatures increase because it's much warmer.

The group discussed if reference points have been evaluated relative to different temperatures, especially since recruitment appears to have a strong relationship. Growth may also impacted and affect harvest rates (through SPR estimation).

7. Brian Wells: A process study to evaluate environmental influences on recruitment of Chi-nook salmon

Abstract: We reviewed work that has been completed toward understanding the ocean features determining variability in Central Valley Chinook salmon productivity. We examined the potential influence of wintertime basin features (North Pacific High strength and location) on preconditioning the central California coast for improved prey abundance for salmon in the spring as they move to the ocean. At a regional scale, we examined the spatial and temporal structure of the physical and biological features of the California central coast and how the ecosystem can influence condition and survival of newly emigrated Chinook salmon. At an even finer scale, we demonstrated how the mesoscale distribution and abundance of krill can influence survival and later adult abundance. With these mechanistic models in hand we extended the capacity to demonstrate the relationships between salmon and their ecosystem by using 4 dimensional biophysical models (ROMS-NEMURO). Together, the work demonstrates the temporal and spatial scales to which Central Valley Chinook salmon respond and provide ecosystem-level strategic and tactical tools for improving salmon management.

Rapporteur: Jim Thorson

Rapporteur Notes:

- Mark Payne: "what's spring transition?"
    - Brian: date when upwelling starts around March
- Liz Brooks: "why use a GAM to predict survival given a mechanistic assumption about dynamics?"
    - Brian: This is just intended descriptively
- Ute: "what do you say to fisheries biologists who distrust ROMs results?"

    - Brian: Points out that some ROMs models use data assimilation and are thus more trustworthy for hindcasting environmental conditions. This can then be used as an environmental variable.
- Mark Payne: Claimed that Brian showed a strong mechanistic argument for his forecast, and that this lends credibility to the forecast.
- Jon Brodziak: The model will break down if freshwater flow stops
    - Brian: agrees, and says that the preponderance of hatchery fish makes marine survival even more predictive about returns.
- Richard Nash: wants to return to Ute's point
    - Jim Thorson: Comments that MSE is necessary to show that any model is useful for fisheries management.
- MacKenzie: comments that the ICES system could use multiple assessments, while continuing to only provide harvest advice from the non-environmental model, and that stakeholders could get used to the environmental model in this way:
    - Liz Brooks: This is essentially an ensemble model with an initial ("prior") weight of 99% and 1%, where subsequent re-weighting may lead to the environmental model being used.

8. Jonathan White: Incorporating variability and risk in Atlantic salmon stock assessment: But what about environmental effects?

Abstract: In this presentation Atlantic salmon stock assessments at two spatial scales were presented. To forecast Total Allowable Catch (TAC) two pieces of information are required: a biological reference point, the size of the returning adult population needed to produce a sustainable following population, and an estimate of the size of the spawning adult population, to be compared against the reference point.

At the scale of individual rivers the current approach of salmon stock assessment and setting of TACs (conservation limits) in Ireland was presented. In this case biological reference points are set at the level of Maximum Sustainable Yield (MSY) for each river based upon hierarchical Bayesian S/R analyses of reference rivers and transferred to other rivers based upon covariates of latitude and wetted area. S/R analyses are calculated as adult to adult returns, converted to egg numbers by lagging years, and relative to fecundity, two sea age classes and three smolt ages into egg numbers per m^2. These are then raised by the wetted are of each river and river specific sea age ratios and fecundities applied, to give 1SW, 2SW and total conservation limits (CL) per river. Variability about egg depositions, sea age structure and associated fecundities are incorporated into CL assessments through Monte Carlo simulations to give variability in the form of 90^{th} percentiles about CLs. This process is undertaken every 5 years to give stable CLs, while allowing for changes in populations over time. Estimates of returns are made through Monte Carlo simulations, recorded annual angling catches are raised by exploitation rates or fish counter values where available, as seen over the proceeding five years. Any other recorded catch is also incorporated. Estimated returns and CLs, and their ranged, are compared in Monte Carlo simulations and resulting ranges are presented as a risk framework of catch options with given probabilities of CLs being attained. The catch option given a 75^{th} percen-

tile of the CL be attained is recommended, and taken, as being the approved catch option.

In this process there no explicit inclusion of environmental variables, however, in estimating CLs the variability seen across the temporal and spatial ranges of the reference rivers is incorporated in from their S/R functions weights, fecundities, sea and smolt ages, and this is translated to other rivers through latitude and wetted area and variability in fecundity and sea ages, taken from catch weights observed in a 6 year data set. Through these, the effect of their experienced environments, in both marine and freshwater mêlées, are incorporated implicitly.

At the regional scale, ICES WG on North Atlantic salmon undertake assessments of North American and Western European salmon stock complexes. The European assessments are subdivided into Northern and Southern stock complexes. For these a "run reconstruction" assessment is undertaken to calculate expected retuning numbers for the forthcoming year. These are calculated through Monte Carlo simulations with ranges around exploitation rates and reporting rates for 1SW and 2SW age groups, for national and high-seas catches, and lagged and broken down by sea age ratios and smolt age compositions. The results, in the form of a 20 to 30 year time series of returns, lagged eggs and pre-fisheries abundance (the estimated abundance of salmon each year prior to any fisheries exploitation) are exported to a hierarchical Bayesian forecast model, which develops a productivity parameter that is then cast forwards in a random walk and upon which forecasts of returns and lagged eggs are made for a further five year period. While no explicit environmental variables are incorporated in this process, the variability seen in the time series do reflect the effect of the environment on abundances. Output is both at the complex level and disaggregated to the country level, however the multi-stock nature of these should be recognised. These models are being developed into a Bayesian hierarchical life cycle structure, with the intent that environmental covariates may be incorporated at specific life cycle stages, giving temporal and freshwater / marine points.

As general points concerning mathematical modelling and forecasting of fisheries stocks status, it was noted that:

~ **No model** can be a perfect representation of nature (Dickey-Collas *et al.*, 2014)
~ **Uncertainties are pervasive** in biology, human and management components of fisheries systems: arise from variability within and among component and complex interactions (Peterman, 2004; Holt *et al.*, 2008).
~ Useable forecasts are ones in which **uncertainty can be reduced** to where **useful information is reported** (Clark *et al.* 2001).
~ The wide range of distributions of CLs illustrates the **uncertainty that managers face** (Ó Maoiléidigh *et al.*, 2004).
~ By **acknowledging the natural variability**, while **ensuring useful information** is produced, we can predict the **most probable** situation, with **uncertainties**.

It is the role of the **framework** in which they are applied **and expertise** of ecologists to interpret the situation at large, and advise – especially in relation to **extremes**, which by nature have low probabilities, but do occur.

Rapporteur: Jennifer Devine

Rapporteur Notes:

-- Salmon at Sea project - sample size was too small to add any information

-- Most of the discussion revolved around the presentation; didn't really go into more general discussion (very focused)

-- No index of what mechanism between survival rates within 1st 2 months of going to sea, but this is a variable that seems to be very important

-- Later return to rivers. Merging together of rivers and timing (multireturn in same runs)

-- Majority of issues are when the fish are at sea; problems/issues pertaining to rivers has been thoroughly investigated/resolved

-- Information collection from drones - good data on migration patterns within next few months

Synchrony - look at which years have +ve residuals across different streams

If have 1-yr olds returning to all rivers, track those individuals (in residuals)

Model doesn't always fit - where does it not fit. Look across populations and spatial scales. Is the northern population doing one thing and southern another? If so, might provide indication of mechanistic link. Allows honing in on variables that matter.

Hopefully don't have a case where all populations are doing their own thing.

9. Jim Ianelli: Activities of the North Pacific Fishery Management Council's Recruitment Working Group

Abstract: North Pacific groundfish: shows how projections can be used to evaluate the potential impact of climate change as predicted from GCMs on eastern Bering Sea pollock recruitment. In particular, a set of alternative control rules and catch policies were developed to provide strategic insight on management issues.

In 2011 the Council requested that scientists form a working group to evaluate a number of issues on the treatment of recruitment for reference points and other aspects of management. Namely, the topics considered included:

A. Identification of regime shifts, either for an ecosystem or some subunit thereof;

B. Estimation of parameters (average recruitment, stock-recruitment relationships, sR, etc.), and

C. Forecasting environmental variability

The activities within each of these broad categories involved an iterative approach with the Council's scientific committees. This included the current policy on identification and treatment of "regime shifts" and how policy, might more explicitly include risk considerations. The implication of using "proxies" for MSY related quantities was evaluated in an inverse way to "condition" stock-recruitment relationships (e.g., FMSY=F35%, BMSY=B35%). Finally the group evaluated the question of incorporating environmental forcing in stock assessments and how they might affect reference points.

Rapporteur: Kyle Shertzer

Rapporteur Notes:

Flat fish recruitment stanzas. Different curves and different MSY values for different time stanzas. Potential different productivity under different regimes.

Time variation in weight at age would lead to different implications of steepness and SPR. Look at how uncertainty in weight at age propagates into the PDF of MSY

Pollock forage potential. High forage potential later in the year appears to correlate highly with large year classes. Perhaps has to do with energy content in the overwintering recruits. Investigated, but inconsistencies in the collection of field samples weren't ideal for evaluating this hypothesis.

How do you handle environmental covariates of recruitment in projections? Work in progress. The investigation so far hasn't been for prediction as much as for evaluating effects on reference points.

Long term projections. Are they useful, given that multiple stock assessments will occur before the end of the projection time horizon? Useful in the sense of evaluating control rules.

10. Ute Schaarschmidt: A stock-recruitment relationship derived from a slow-fast population dynamic model

Abstract: The Beverton-Holt and Ricker functions are two distinct ecological descriptions of the link between a parental population size and subsequent offspring that may survive to become part of the fish stock.

This paper presents a model consisting of a system of ordinary differential equations (ODEs), which couples a pre-recruit stage with several adult stages. Elements of slow-fast dynamics capture the different time-scales of the population dynamics and lead to a singular perturbation problem.

The novelty of the model presented here is its capability to replicate a broad spectrum of the stock-recruitment relationship, including the Beverton-Holt and Ricker dynamics. The results are explained using geometric singular perturbation theory and illustrated by numerical simulations.

Rapporteur: Sam Subbey

Rapporteur Notes:

The main aim of the talk was to present a methodology for predicting time series data based on causal models. The talk highlighted the challenging characteristics of modelling stock recruitment data like jumps and spikes, cyclic behaviour and history dependencies. It demonstrated how these can be captured using a bivariate form of the Mackey-Glass (MG) model. The MG model belongs to a class of delay differential equations (DDEs).

The talk focused primarily on the detection of external and internal influences expressed in the form of (nonlinear) Granger-Causalities. The Brock, Dechert and Scheinkman (BDS) Nonlinearity test was introduced to detect nonlinearity in time series, followed by the nonlinear Granger-Causality test to identify directions of nonlinear causal influences between the time series. The talk demonstrated the weakness with deriving time series models based on correlations, and the unsuitability of such models to detect causal dependencies.

In conclusion, model predictions of stock recruitment can be improved by considering causality relationships among covariates. The use of DDEs allows for capturing high amounts of data variability as well as the dependency of the predictions on past values of the time series.

The after-talk discussion focused on application of the methodology to real-world problems. A concern was raised about the ability of the methodology to deal with hidden (implicit) driving influences, and called for this to be investigated.

11. A. Frank: Prediction of Stock Recruitment with a Delay Differential Equation Model

Abstract: This paper investigates the use of Delay differential Equations (DDEs) to model stock recruitment. The modelling approach, which goes beyond correlations, investigates the causal links between recruitment and other covariates.
We evaluate the ability of the model to predict recruitment dynamics with minimum variance by applying it first to artificial data, and to fisheries data from the Barents Sea.

Rapporteur: Sam Subbey

Rapporteur Notes:

The talk discussed how process change occurring at different time scales can be modelled using differential equations and singular perturbation theory. An example of such a framework was presented in which fish at the pre-recruit stage where coupled to several adult stages. An assumption of the model was that spawning and natural mortality of pre-recruits change at a faster rate than ageing and natural mortality of adults. The talk demonstrated how, (geometric) singular perturbation theory, the dynamics between the slow and fast varying components can be understood.

Then model presented is capable of replicating a broad spectrum of the stock-recruitment relationship, including the Beverton-Holt and Ricker dynamics. The talk suggested a further application of the slow-fast differential equations methodology to stage-structured modelling of early life dynamics.

The plenary discussion centered on whether the continuous population dynamic model investigated could be further improved by introducing a time-lag between spawning stock size and subsequent recruitment. This is to be investigated by the presenter.

12. Jim Thorson: Estimating recruitment variability including autocorrelated, sychronous, and spatial components

Abstract: Variability in population dynamics for marine fishes arises in large part due to variable survival rates for larvae and early juveniles, causing variation in cohort strength. Statistical analysis of population variability (e.g., recruitment) requires an understanding of how variation occurs in time, space, and among species. I therefore review recent research regarding recruitment variation in marine fishes. This

includes synchrony among species subject to shared environmental drivers, where multispecies models have shown that including a synchronous trend in cohort strength can improve precision of recruitment estimates for data-poor species, and where common synchrony measures (e.g., pairwise correlation) can be derived from hyperparameters representing the ratio of shared and individual variation. I also review a recent study estimating the magnitude of recruitment variation and autocorrelation from the 1995 Myers database of stock and recruitment estimates from sequential population analysis models. This analysis estimated the marginal standard deviation of recruitment at approx. 0.75, and autocorrelation at approx. 0.45 on average, with small differences among taxonomic groups. Finally, I review recent efforts to develop state-space random field models, which can estimate spatial variation in population dynamics including recruitment. This has been applied to estimate spatial variation in recruitment for rex sole in the Gulf of Alaska, where the model estimates considerable variation in the center of gravity for recruitment production among years. I conclude by explaining prospects for semi-parametric models for the stock-recruit relationship, and recent attempts to explore the implications of 3-parameter stock-recruit curves on estimates of biomass targets for marine fishes.

Rapporteur: Liz Brooks

Rapporteur Notes:

Multispecies used in analysis require some thought as to species groupings; looked at PC to group species that had + relationship

Lines on slide 10: each coloured line is expected recruitment; used random effects by stock, by year, and by stock and year; variance partitioning exercise

Red shifted – the frequency is lower than white noise (sort of maps onto AR lags); slow pattern

A: do environmental drivers have to be redshifted (mark's comment this morning—the indices are not stationary)

Autocorrelation exercise was applied to RAM database with only VPA outputs

In fits of BH or Ricker on recruitment devs, what about a non parametric functional fit (or deriving function so that it is convex and monotonic, then invert it and end up with informative model)? What is empirical autocorrelation? Not done because it will include variation in SSB and in Recruitment. Vert-Pre work (from Hilborn)—not much information in typical SR curve … looking now at Markov Switching models as a better framework for estimating autocorrelation

Gaussian random field: Restriction on where points can be relative to boundary? A: boundary is implied to be reflective; does GRV include advection? A: no not yet

Can you derive shepherd from first principle?

Gaussian process instead of using a GAM

Diagnostics for model misspecification (identifying whether you are soaking up misspecification with random parameters)? A: need to develop those tools

With the spatial aspect, is that starting point or ending point for recruitment? A: it is the estimate of recruitment to fishing backed up to spawn date

Spatial approach only works if you have stability in movement patterns; units on map slide: numbers per sq km = density of adults, then back calculated to recruits; this will be messed up by pelagics that move

similar problem with sandeel and it would be useful for that application

Spatial dynamics (how far adults move to spawn, how far nursery grounds are relative to spawning site, and return from nursery ground); movement can be hundreds of thousands of km for NS herring; could this all just be the spatial variation of adults because you are assuming no movement as juveniles? If you don't have any data on movement, then you have to make assumptions; Tom Carruthers has shown that you can infer movement give how catch rates vary between years so you can get by even without tagging data

13. Mark Payne/R. Nash: Quirky recruitment

Abstract: The accessibility of databases of global or regional stock assessment outputs is leading to an increase in meta-analysis of the dynamics of fish stocks. In most of these analyses, each of the time-series is generally assumed to be directly comparable. However, the approach to stock assessment employed, and the associated modelling assumptions, can have an important influence on the characteristics of each time-series. We explore this idea by investigating recruitment time-series with three different recruitment parameterizations: a stock– recruitment model, a random-walk time-series model, and non-parametric "free" estimation of recruitment. We show that the recruitment time-series is sensitive to model assumptions and this can impact reference points in management, the perception of variability in recruitment and thus undermine meta-analyses. The assumption of the direct comparability of recruitment time-series in databases is therefore not consistent across or within species and stocks. Caution is therefore required as perhaps the characteristics of the time-series of stock dynamics may be determined by the model used to generate them, rather than underlying ecological phenomena. This is especially true when information about cohort abundance is noisy or lacking.

Rapporteur: Jonathan White

Rapporteur Notes:

Strange results occurring in recruitment time series, as it was smooth.

Three ways to calculate R:

1. Direct estimate
2. Random walk
3. S/R relationship

Three stocks investigated

- North sea herring: 3 R estimates agree
- Western Baltic herring: 3 R estimates do not agree
- Irish Sea herring: 3 R estimates do not agree

But, are these, all three estimators, all smoothing out signals which we are trying to pin environmental variables on.

Autocorrelation within each method (with a lag of 1)

The issue may be synthesised, in relation to trying to find useful environmental co-variables, to how fisheries assessment scientists summaries information, S/R data are given per year for an entire stock and its spatial range. Such synthesised data do not lend themselves well to finding correlations with environmental variables, as these tend to be more explicit in their **temporal and spatial ranges.**

Satellite community several levels of their products:

- Monthly gridded average values,
- Raw data prior to any spatial extrapolation/averaging/gridding/krigging

Do we need to start looking at S/R data in the same way, either through estimating S and R spatially and temporally, or the data used in their calculation/ estimation? This would include the survey data, both fisheries, catches and acoustics. Potential issues here are, of course, that raw data have not necessarily been applied in assessments without adapting/ raising/ down weighting/ removing parts.

The RAM database (RAM Legacy Stock Assessment Database) may be a starting point for this,

The accompanying metadata needs to be reliable.

Recommendations from this should be put into the WG report. These need to be realistic and attainable

- Stock assessment methods working group on board in improving openness and transparencies

The temporal and spatial scales of indices of stock status and temporal and spatial ranges of potential environmental covariates need to be similar, if relationships of any truth (and strength) are to be found.

The Data Collection Framework (DCF) and DCMAP are instigating regulations on documenting data collection and archiving. The historic processing steps from raw data to S-R estimates are more complex and somewhat labyrinthic in their nature and investigation may not yield short term, useful information.

14. Richard Nash: Contrasting herring vs Cod recruitment dynamics

Abstract: The presentation covers two contrasting herring stocks (North Sea Autumn Spawners, NSAS and Norwegian Spring Spawners, NSS) and two cod stocks (North-east Arctic, NEA and Baltic). NSAS herring can be considered as a group of sub-stocks with spawning starting in the north (September/October) and concluding in the south (December/early February). The principal juvenile nurseries are coastal, mainly in the German Bight. Adults over-winter in the north-east northern North Sea, at the 'shelf' edge and the adult feeding area is in the northern North Sea. Year class strength in herring occurs in the early life-history stages, generally during the larval phase and close to 'first-feeding'. A Paulik diagramme illustrates this and also shows a 'step' change in survival both in the 1988-1990 and 2002 onward periods. There is still a large amount of debate as the causes including a reduction in the available prey, reduction in the available suitable prey, parasitism and cannibalism. One caveat to the survey data on O-wr herring is that the estimates do not account for the Downs component of the stock and the contribution of this component has changed over time. The NSS herring stock is much larger than the NSAS stock and has a much longer migratory routes. The stock spawn along the west coast of Norway and larvae drift northwards. The nurseries are in the fjords and the Barents Sea, the larger year

classes generally emanating from the Barents Sea. The juveniles generally spend 3-4 years in the nurseries and then migrate out in to the Norwegian Sea to the feeding grounds. Currently the summer feeding ground boundary is to the west of Iceland. The overwintering grounds for the adult stock are currently to the west of Lofoten. The Paulik diagramme for NSS suggests that year class strength is apparent by the over-wintering stage, however with the distribution of individuals across the various nurseries the survey data are not as conclusive as for NSAS. In addition very large year classes appear to make a very large contribution to the stock in the Norwegian Sea, even at a very young age. NEA cod are generally found in the Barents Sea and migrate southward to spawn off Lofoten, occasionally further south. The eggs and larvae drift northward in into the Barents Sea where the juveniles settle. The distribution varies annually based on the drift patterns. A large amount of variability in abundance is seen by the O-group settling phase, however, due to variability in settlement time estimations of abundance are a challenge. Here the differences between survey data and VPA output illustrate the differences in perception of mortality schedules based on the data source. In the case of cod cannibalism on the young means that the eventual year class strength is often determined at an older age than e.g. in herring. In the Barents Sea the level of cannibalism is not only a function of the adult stock size but also the stock size of capelin, the preferred prey. Baltic cod contrast with NEA cod in that the environment has a much more profound effect on survival of young stages. In the Baltic anoxic conditions effectively change the available habitat and along with changes in the prey field affect mortality rates. These environmental effects are clearly seen in the Paulik diagrammes. In addition to the physical effects there are also species interactions such that predator prey interactions make the system quite complex. The underlying processes in early life history dynamics of Baltic cod are reasonably will understood.

Rapporteur: Jim Ianelli

Rapporteur Notes:

Richard Nash presented a number of datasets for NE Arctic cod and herring. In the northern part of the North Sea spring spawners can mix with the autumn spawning and in general there may be some straying. However, it’s generally thought that once participate in spawning in one mode, will stay in that mode.

Survey data used for lower left quadrant. Three sets of surveys used to produce the figure.

The group discussed the Paulik diagrams presented for cod and herring, and noted that there were a rich data set but additional work is needed to arrive at variances from these survey data. The group considered that it would be desirable develop quadrant-specific functional forms and test through simulation what precision would be needed to recover unbiased stock recruitment parameter estimates.

It was clarified that the multi-stage diagrams are called “Paulick diagrams” rather than “Peach diagrams.”

15. Einar Svendsen: An Ecosystem modelling approach to predicting cod recruitment

Abstract: The NORWECOM biophysical model system implemented with the ROMS ocean circulation model has been run to simulate conditions over 25 years for the North Atlantic. Modelled time series of water volume fluxes, primary production and drift of cod larvae through their modelled ambient temperature fields have been analysed in conjunction with VPA estimated time series of 3-year old cod recruits in the Barents Sea. Individual time series account for less than 50% of the recruitment variability, however a combination of simulated flow of Atlantic water into the Barents Sea and local primary production accounts for 70% of the variability with a 3-year lead.

Rapporteur: Brian Wells

Rapporteur Notes:

The main forces of the ecosystem are climate and fishing. However, in coastal areas you may have pollution and such. The key is to select the most important forces.

Why modelling? -Models can create information on what you forgot to measure as well as fill in the temporal spatial gaps.

Why observations? – Observations give you the knowledge of the ecosystem state, esp. at higher trophic levels. Observations help you know what to model for the critters and environment. They also inform models and provide initial conditions.

His group is working to hindcast 60 yrs. For physics, phytoplankton (eulerian), zooplankton (IBM and eulerian), fish larvae (IBM and eulerian), fish migration and overlap between species. At this time, phytoplankton is becoming operational. As an aside, the closer we get to mechanism the better it should be.

He argues, for this modelling to be useful we have to provide advice at the spatial and temporal scale relevant to management.

He then demonstrates how they model the system starting with transport to demonstrate how they can *move* zooplankton into the right regions, as a starting point. It didn't work to well. The connection to recruitment was, in fact negative, and strongly so ($r2 = 0.5$). Hypothesis as to why: If inflow to the region where juvenile fish are is too great the juveniles get pushed east and north and go to too cold water and die.

They then modelled primary production 1993–2004 for the whole region. They looked to see if there was a relationship between primary production and recruitment. They did a spatial temporal correlation of cod recruitment to the primary production. Cod recruitment was increased relative to phytoplankton. So, April primary production in the greater region where the larvae are was important.

JI asks should we be worried that we have searched to WHOLE Ocean and may be finding spurious results.

ES: Says we looked intelligently not as a blind shot.

They took an average of the area and then related it to recruitment. They suggest that the production of food in the region is important. Ultimately they look at transport AND primary production as a regression for fish production. It is about making food and then providing it to the fish. $R2 = \sim.70$

When they looked back to determine their capacity to match the true recruitment, the fit was sporadic. The fit to retrospective data is better and worse for different stanzas of time.

Future work: They want to look at the whole 60-year period. They want to make the model operational. They have on the shelf now 15 yrs of runs. They also will run IBM migration models to examine mortality. Unfortunately, at this time, they have to predetermine, to a degree, the migration pattern. Finally, they want to examine the possible effects of climate change.

Predicting a few years ahead is very difficult given the weather constraints. However, in a climate-change scenario it may be easier to provide strategic advice about far future conditions.

Discussion period:

MP: There is a concern of scale. MP does not believe we can predict specific locations at specific times. He wants to know if there is a 'sweet spot' where we get as close to mechanism as a possible without losing ourselves in the noise.

ES: We are not modelling the fine-scale overlap between individual larvae and zooplankton. Rather, we are modelling super-individuals. The model would let us know if there is good overlap between the masses of plankton and fish. And, lets us test whether greater overlap leads to the overall success of the fish. So, it is about measuring the relative overlap between years as a measure of recruitment strength: It is all probability.

MP: So, paraphrase, the models works because he is averaging?

JB: It is an integral. How small of an area do you need to go to be accurate relative your needs?

MP: At what scale does the model 'break down?'

JI: Seems like we need the most sharp tool but still don't know exactly what the need is.

RN: Points out that the model may have broken down recently because the stock is much larger and therefore out of range.

JT: Discusses movement processes and why is an IBM needed when ES doesn't have a detailed idea of what should be guiding the movement. There are other options in other fields.

ES: The point is that the zooplankton and the fish larvae do not have horizontal migration (they have vertical only). Rather, it is ocean circulation that determines horizontal motion.

MP: Suggests that IBM may be the simpler approach.

JT: Suggests it too slow.

MP: Time is not the issue. Knowledge of the true migration is.

RN: The models are probably good to get us to settlement. At that point, different models are needed (Gadget?). Using IBM for 1, 2, and 3 is interesting but not needed?

ES: When they do the modelling, the zooplankton and growth of fish larvae and link that to recruitment they end up with a statistic. But, what do we take out from all this? Perhaps, the biomass of juveniles?