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

22–26 June 2015

Seattle, USA



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Executive summary

The Working Group on Recruitment Forecasting in a Variable Environment (WGRFE) met at the School of Aquatic and Fisheries Science, University of Washington, Seattle (USA), on 22–26 June 2015, with fourteen participants and Dr. Liz Brooks (USA) and Dr. 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 2015 meeting included:

- a) Developing prototype, statistical recruitment tools for selected stocks, based on stage-structured models, which include environmental drivers and multi-species considerations

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

- 1) Progress in the development of forecast models that include environmental drivers, and also incorporate autocorrelation in the recruitment relationship.
- 2) Advancing work outlined in the SG 2011 report by reviewing methods that are being used for recruitment forecasting in fisheries settings for broadly different stocks and areas, and developing guidelines for applications to fisheries management and assessments.
- 3) The implementation of a procedure to evaluate ensemble forecasting methods, with focus on those that improve forecast accuracy or precision.
- 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)
2
Chair(s)
Samuel Subbey, Norway
Elizabeth Brooks, USA
Meeting venue
Seattle, USA
Meeting dates
22–26 June 2015

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 number of publications collaboratively written by the WGRFE is planned for 2015. See specific details in Section 5 (Progress report on ToRs and workplan)
- Methodological developments
 - We have evaluated the use of autocorrelation in recruitment as a simple, implicit approach to considering environmental influence in short-term forecasts.
 - We have explored whether it is possible to identify where in the early life history the “bottleneck” occurs by developing a statistical modelling framework of Paulik diagrams. Further simulations and a case study will be summarized in a manuscript to be submitted prior to the WGRFE 2016 meeting.
- Simulations
 - We have adopted a simulation framework to help identify approaches to ensemble methods that improve forecast accuracy or precision. It involves using a stochastic differential equation approach to generate recruitment based on a 2 and 3-parameter recruitment model with three Markov states. The simulations will cover a multidimensional grid of sets of model configurations or parameters.

5 Progress report on ToRs and workplan

The following summarizes progress made on ToRs for the 2nd year of WGRFE.

- Subgroup on forecasting recruitment.
 - The first activity is to review methods that are being used for recruitment forecasting in fisheries settings for broadly different stocks and areas. An outline with some general constraints (using age-structured assessments from the period 2005–2014) was developed.
 - The second activity and outline center on a survey of methods that perform well and might be considered as guidelines for applications to fisheries management and assessments. This will seek to advance work outlined in the SG 2011 report. The results envisioned include recommendations towards considering quantities of interest for management and also contrast methods with economic forecasting approaches.
 - Finally, the third topic considered approaches to ensemble methods focusing on those that improve forecast accuracy or precision. The group reviewed using a stochastic differential equation analysis to generate recruitment based on a 2 and 3-parameter model for three states of nature/regime with Markov

transition matrices. These will apply to the simulations over a multidimensional grid of sets of model configurations or parameters.

- Subgroup on BASSON—Unraveling the Recruitment Problem
 - Activities under this theme address WGRFE TOR (a): “Review approaches (modelling and methodologies) where stock recruitment models incorporate external drivers, along with all caveats.” A preliminary literature review identified 60+ papers that were divided among working group members. A spreadsheet with columns for summarizing different attributes of each study was created, and subgroup members will review each study and populate the appropriate fields in the spreadsheet. This review of studies and attributes will form the basis for a draft manuscript. The working group aims to have all papers reviewed by September/ October 2015 and to have a draft manuscript by January 2015. The target journal(s) for this manuscript are tentatively one of the following: Fish and Fisheries, CJFAS, or Reviews in Fish Biology.
- Subgroup on Paulik diagrams
 - This sub-group has preliminary simulation runs in a state-space framework for estimating a multi-stage stock recruitment model. The program is coded in R and RJAGS. The group prepared the outline of a manuscript that would address two main questions: (i) are recruitment predictions improved by estimating a multi-stage stock recruit function rather than the traditional single stage stock-recruit function; (ii) how well can a 3-parameter stock-recruit function identify stage-specific forms of density-dependence. An initial list of simulation scenarios was agreed to. Furthermore, the group identified datasets that were available for use as a case study in the manuscript (North Sea Autumn Spawning herring, and North Sea plaice), and noted the indices available for various life history stages as well as timing of those indices. Tasks were assigned for the simulation work and case study. Additionally, the group sketched out the topics that should be included in the introduction and discussion, and made preliminary assignments for who would be responsible for researching and summarizing that literature (e.g., review of Paulik diagrams, review of earlier state-space stock recruitment modelling, review of empirical studies of early life history stages).
- Subgroup on Autocorrelated recruitment
 - The working group tasked with investigating the forecast performance of Stock Synthesis with autocorrelated recruitment deviations met several times during the course of the WGRFE. A working simulation framework was presented by the primary author, Elizabeth Councill. Preliminary results showed that there may be significant bias in the estimate of autocorrelation produced by Stock Synthesis. However, these results have not yet been fully vetted. The subgroup identified both short and long term tasks for further

study. Short term tasks were focused on identifying and rectifying any potential model misspecification, and identifying sources of potential bias. These tasks include rerunning the simulations with a large volume of age composition data to test the model for consistency and identify if the bias is occurring because of insufficient age comp data or if the bias is due to model misspecification. Also included in the task list is to perform a power analysis to identify the volume of compositional data SS needs to estimate autocorrelation reasonably well and to produce an outline of a paper that will be used to structure the final reporting document(s). Longer term goals will compare forecast results for a range of autocorrelation values, and contrasting life histories, to evaluate whether forecasts of recruitment are improved by accounting for autocorrelation.

6 Revisions to the work plan and justification

No revision necessary.

Specific tasks for the third meeting (to be held in 2016) are listed below based on work progress during the second meeting.

- 1) Evaluate the performance of ensemble methods on case studies across different regions and species.
- 2) Evaluate when environmental drivers work, for which type of species and covariates, and whether a distinction can be made between quantitative versus qualitative 'improvement' in forecast.

7 Next meetings

WGRFE third meeting will take place on 13–17 June 2016, JRC-Ispira, Italy.

Host: Ernesto Jardim

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Annex 1: List of participants and group photo

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Participants at 2nd WGRFE meeting (Seattle, USA; 22–26 June 2015).

Ute Schaarschmidt; Jon Brodziak ; Liz Brooks (Co-Chair); Brian Wells; Nikolai Klibansky ; Anna Frank; Sam Subbey (Co-Chair); Eliza Council; Jim Ianelli; Richard Nash; Jim Thorson; Kelli Faye Johnson; Melissa Haltuch



Participants demonstrate the ensemble forecast approach at 2nd WGRFE meeting (Seattle, USA; 22–26 June 2015).



Participants demonstrate variability in recruitment forecasts at 2nd WGRFE meeting (Seattle, USA; 22–26 June 2015).



WGRFE Co-Chairs Sam Subbey (Norway) and Liz Brooks (USA) demonstrate how to dress for success at 2nd WGRFE meeting (Seattle, USA; 22–26 June 2015).

Annex 2: Agenda

				Talk		WGRFE 2016 Seattle Speakers - 30min talk + QA			
Wednesday 24 Jun		Thursday 25 Jun		Friday 26 Jun		Monday 22 Jun		Tuesday 23 Jun	
	General Intro to day 3 rapporteurs	General Intro to day 4 rapporteurs		General Intro to day 5 rapporteurs		1	Ensemble model Project	Sam	9:00 - 9:40 AM
						2	Combining Forecasts	Jon B	
						3	Paulik diagram Project	Liz	
						4	Multi-stage Pop. Dyn. model	Ute	
	SUBGROUPS MEET	SUBGROUPS MEET		PLENARY Review of Short Summaries				9:40 - 10:20 AM	
Health Break		Health Break		Health Break		Tuesday		10:30 - 10:45 AM	
	SUBGROUPS MEET	SUBGROUPS MEET		PLENARY Review draft report		5	Effect of recruitment/harvest pulses	Anna	Health Break
						6	Update on autocorr recruitment forecasting	Eliza	Talk 2
						7	Brief sketch of Basson	Liz	Talk 6
				Planning ahead				Talk 3	
								Talk 7	
				WGRFE 2016				11:25 - 12:05 PM	
	lunch	lunch						12:05 - 1:30 PM	lunch
FOR THE WEEK	PLENARY SUBGROUP REPORTS	PLENARY SUBGROUP REPORTS		no meeting				1:30 - 2:00 PM	Talk 4
	SUBGROUPS MEET	Report drafting * Title and abstract from speakers * Summary from subgroups						2:00 - 3:45 PM	SUBGROUPS MEET - PLAN FOR THE WEEK

Annex 3: Recommendations

RECOMMENDATION	ADDRESSED TO
1. Achieving the goals of the WGRFE require active participation of the contact persons (stock assessors/coordinators) to : *Address technical questions about assessments of stocks in key regions e.g. ICES Areas.	ICES Secretariat

Annex 4: Presentations and Associated Discussion

- | | |
|----------------------|--|
| 1. Sam Subbey | A comparative solution project for ensemble methods |
| 2. Jon Brodziak | Combining forecasts |
| 3. Jon Brodziak | Object-Oriented Design of MAS, A Metapopulation Assessment System |
| 4. Liz Brooks | Paulik diagrams |
| 5. Ute Schaarschmidt | Discrete-time Egg-Larva-Juvenile-Adult model |
| 6. Anna Frank | Effect of harvest and recruitment pulses on population dynamics |
| 7. Eliza Council | Autocorrelation in recruitment forecasting |
| 8. Liz Brooks | Revisiting the paper by Basson |
| 9. Brian Wells | Evaluating and using numerical ocean and biological model products to assess salmon dynamics along the coastal California Current system |

Annex 5: Abstracts and Rapporteur Notes for WGRFE Meeting

Sam Subbey: A comparative solution project for ensemble methods

Abstract: This presentation considers the use of synthetic data to evaluate the performance of methodologies for generating a representative recruitment forecast from an ensemble of different model forecast.

Rapporteur: Liz Brooks

Rapporteur Notes

The SGRFE 2012 and 2013 report showed that for the Northeast Arctic cod, recruitment forecasts required combining several model forecasts. Several methodologies for how to derive such a representative forecast were discussed, and included the FAST method. The aim here was to create synthetic data, to evaluate the performance of averaging methods. An initial proposal was for the presenter to generate data, make it available on a website, and invite scientists to fit and forecast and post their results to the website. Logistics of this initial proposal require further scoping.

The group appreciated the style of a “blind” test for forecast methods. However, the project needs modification so that the type of simulated data mimics that of a typical assessment working group setting. Questions about errors in the simulations were discussed. Process errors, and observation errors, must be considered. Also, one needs to distinguish between estimating the correct relationship versus forecast performance.

Jon Brodziak: Combining forecasts

Abstract: The talk reviewed motivations for considering multiple models in forecasting, and touched on existing methodology, some of which can be borrowed from the economics literature. Some general principles to consider when combining forecasts were also reviewed.

Rapporteur: Sam Subbey

Rapporteur Notes

- Ensemble evaluations must be based on two considerations namely, the central tendency, and dispersion.
- Forecasts must involve at least 5 independent models and/or data (principle from economics—must we have 5 for assessment?).
- Equal weighting must be considered, unless there is strong evidence to do otherwise.
- The central challenge is how to combine disparate models in a management setting.

Jon Brodziak: Object-Oriented Design of MAS, A Metapopulation Assessment System

Abstract: The talk discussed metapopulation assessment system vision MAS, Characterized by OO Design (Object Oriented). The system allows for spatially explicit construction, selection and forecasting, and design, with defined classes and class relationships.

Rapporteur: Sam Subbey

Rapporteur Notes

- The framework for structuring this model paradigm could be useful when considering the WGRFE modeling task.
- Structuring the program design into layers of analysis and classes is efficiently accomplished with object oriented programming.

Liz Brooks: The Paulik diagram

Abstract: The talk revisits the Paulik diagram, which recognizes that there are several life-stages from egg to recruitment. The talk discusses the estimation framework for generating data using specific recruitment functions (Shepherd, Generalized, BH, Ricker models) and involves operating, and estimation models. Within the estimation framework, N-stages result in N measurements and (N-1) process errors.

Rapporteur: Sam Subbey

Rapporteur Notes

The model framework was developed in R and analysis performed with JAGS (just another Gibbs sampler). Some of the issues to consider include

1. performance of stage specific vs. composite S-R functions
2. identifiability of density dependence form
3. the challenges with parameter estimation
4. stage-specific environmental drivers
5. stage-length vs process error variance

Summary:

- Stage 1 is more difficult to predict. More points outside the confidence interval than in the second stage.
- There is a challenge with parameter estimation: the fully saturated model not converging. The estimation process hits zero lower bounds and specifying parameters with negative lower bounds leads to node errors.
- Stage-specific environmental drivers are not modelled by a Markov switching model is being developed to address this.
- How precise must datasets have to be for any form of identifiability remains an issue to be addressed

Ute Schaarschmidt: Discrete-time Egg-Larva-Juvenile-Adult model

Abstract: This paper investigates the dynamics and emergent properties of a discrete-time, continuous-state, stage-structured (Egg-Larva-Juvenile-Adult) population dynamics model. The model adopts a parsimonious approach in incorporating elements of environmental and demographic stochasticity.

Population dynamic models often summarize the early life history dynamics in one equation, a so-called stock-recruitment relationship. We analyse the stock recruitment relationship emerging from the dynamical description of the early life history stages in the multi-stage model. Results are illustrated using numerical experiments.

Rapporteur: Jon Brodziak

Rapporteur Notes

Ute S. presented information on her research on a multistage population model with nonlinear dynamics. The model was denoted as DELJA, which stands for discrete eggs, larvae, juveniles, adults. The stages of individuals in the model can be thought of as stages in a Paulik diagram representing the transition and survival probabilities of each individual in each of four stages.

The first stage is egg production, in which the surviving mature females produce eggs. In the second stage, the egg survival rate determines the survival of eggs to the larval fish stage. For the third stage, the surviving larval fish transition to the juvenile stage. In the fourth stage, the surviving juvenile fish transition to the adult stage. This completes one cycle of stage dynamics specified in the Paulik diagram.

The WGRFE thanked Ute S. for her presentation and offered the following comments and questions. The WGRFE noted that this was a general modelling approach that could be used to examine the effects of nonlinear transition probabilities between stages. The WGRFE discussed the question of “Under what conditions do environmental conditions dominate the survival terms” and “When does a functional form (1-stage model or standard stock-recruitment relationship) provide an adequate representation of the stock-recruitment dynamics?”. That is, when can the multistage representation be simplified to a single functional form of recruitment strength as a function of parental stock size with observation error? Overall, the WGRFE concluded that multiple causal mechanisms could affect prediction of recruitment strength and that the Paulik diagram provided a useful modelling structure for accounting for differences in the functional form and parameters of life stage survival probabilities.

Brian Wells: Evaluating and using numerical ocean and biological model products to assess salmon dynamics along the coastal California Current system

Abstract: I overview our work that uses output from numerical ocean and biological models to assess influences of environmental conditions on variability in population and community dynamics along the coastal California Current System (CCS). Evaluation of

the models demonstrates that physical (CCS reanalysis from ROMS data-assimilative system) and biological (CoSiNE) outputs are coherent with empirical data at appropriate spatial and temporal scales and are suitable for quantifying ecosystem dynamics on central California shelf waters. I address a variety of ecological hypotheses by confronting model output with biophysical observations. I use data-assimilative ROMS reanalysis output to elucidate mechanisms connecting spatial and temporal upwelling dynamics to observed krill and forage fish abundances. In addition, we use ROMS-NEMURO output to predict interannual variability of biophysical habitat and forage base of juvenile Chinook salmon collected from shipboard surveys along CCS. I then use these results to elucidate the mechanisms influencing the region-specific survival of Chinook salmon populations along CCS by reconstructing the oceanic conditions experienced by salmon when they first entered the ocean and attach those conditions to an individual based modelling approach.

Rapporteur: Liz Brooks

Rapporteur Notes

- The IBM driven by the ROMs conditions showed consistency with hypotheses on success of recruits
- ROMs model predictions shows good correspondence with actual observations
- 2007 failure of salmon due to lack of zooplankton for out-migrants
- L1 vs L2 loss functions – the management objective should be matched to this, i.e., can it be boiled down to a single dimension or are multiple dimensions required?

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

Abstract: The talk presented a model for the numerical study of a system of delay differential equations with recruitment and harvest impulses. The aim was to study how impulses dictate the dynamics of the system, and under what impulse circumstances the stability of the system may be maintained.

Rapporteur: Liz Brooks

Rapporteur Notes

- There was some discussion about the function, $z(t)$, and what it encompasses. The function is “growth” and α is the efficiency of conversion.
- While the function is quite generic, one could choose to illustrate based on known relationships, e.g.
- The final plot of the talk generated interest and also comments about alternative ways to visualize the same information. The plot appeared to be showing cyclical behaviour around a stable point. It was suggested that one could also look at the same information as a time-series path, which would allow one to follow the path.

Eliza Council: Estimating recruitment variability including autocorrelation

Abstract: Simulation Study to Improve Forecasts of Stock Rebuilding and Estimated Probability of Exceeding Target/Limit Reference Points in the Presence of Autocorrelation and Environmentally-Driven Recruitment

Rapporteur: Nikolai Klibansky and Sam Subbey

Rapporteur Notes

Background

- Rebuilding forecasts assume pseudorandom distribution of errors and that random variation is independent of time.
- Regime shifts: periodicity in production patterns of stock productivity over time
- can be irregular or regular
- assumed to be independent of stock abundance or size: environmental, trophic interactions, climate change, survivorship
- some debate about how influential pseudorandom regime shifts are
- regime shifts showing up as autocorrelation?
- we might be able to model this as autocorrelation of recruitment deviations

Goals

- Quantify how well SS3 performs autocorrelated recruitment (AR) data
- How well does SS estimate autocorrelations of S-R data?
- How does forecast performance vary when estimating autocorrelated recruitment patterns?

Performance measures

- accuracy and precision for estimating auto-correlation in S-R relationship is assumed to be a fixed time-invariant parameter

Testing framework

- produce a set of first order autocorrelated recruitment deviations
- pass generated recruitment deviations to SS using ss3sim R package
- run ~50 simulations together with 5 bias correction runs
- 100 age/length comps with CV = 0.1
- run from years 1-100

- non-forecast runs labelled as

Results

- SS estimates autocorrelation well when there is no autocorrelation
- when there is negative autocorrelation, estimates from SS are biased

Summary

- SS maybe not so great at estimating AR when AR is nonzero

Discussion

Richard Nash: There is debate over what defines a regime shift (i.e. how long the time period has to be to define a regime shift).