Gmacs Example Stock Assessment

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Introduction

Gmacs is a generalized size-structured stock assessment modelling framework for molting crustacean species. Gmacs can make use of a wide variety of data, including fishery- and survey-based size-composition data, and fishery-dependent and -independent indices of abundance. Gmacs is coded using AD Model Builder.

Crab stocks of Alaska are managed by the North Pacific Fisheries Management Council (NPFMC). Some stocks are assessed with integrated size-structured assessment models of the form described by Punt, Huang, and Maunder (2013). Currenlty, each stock is assessed using a stock-specific assessment model (e.g. Zheng and Siddeek (2014)). The Gmacs project aims to provide software that will allow each stock to be assessed inside a single modelling framework.

Gmacs is used here to develop an assessment model for the Bristol Bay Red King Crab (BBRKC) stock. This analysis serves as a test-case for the development of Gmacs: the example assessment is intended to match closely with a model scenario presented to the Spring 2014 BSAI Crab Plan Team Meeting by Zheng and Siddeek (2014).

Together, the Gmacs-BBRKC model and this report serve as the first example of what should follow for other crab stocks: that is, direct model comparisons to (1) test the efficacy of Gmacs, and (2) determine whether Gmacs can be used in practice to closely match the outputs of existing ADFG stock assessment models.

Summary of analytical approach

Information here on the model, the history, and specifications (current and old).

ADFG-BBRKC

To reduce annual measurement errors associated with abundance estimates derived from the area-swept method, the ADFG developed a length-based analysis (LBA) in 1994 that incorporates multiple years of data and multiple data sources in the estimation procedure (Zheng et al. 1995a). Annual abundance estimates of the BBRKC stock from the LBA have been used to manage the directed crab fishery and to set crab bycatch limits in the groundfish fisheries since 1995. An alternative LBA (research model) was developed in 2004 to include small size groups for federal overfishing limits. The crab abundance declined sharply during the early 1980s. The LBA estimated natural mortality for different periods of years, whereas the research model estimated additional mortality beyond a basic constant natural mortality during 1976-1993.

The original LBA model was described in detail by Zheng et al. (1995a, 1995b) and Zheng and Kruse (2002). The model combines multiple sources of survey, catch, and bycatch data using a maximum likelihood approach to estimate abundance, recruitment, catchabilities, catches, and bycatch of the commercial pot fisheries and groundfish trawl fisheries.

g. Critical assumptions of the model:

h. The base natural mortality is constant over shell condition and length and was estimated assuming a maximum age of 25 and applying the 1% rule (Zheng 2005).

ii. Survey and fisheries selectivities are a function of length and were constant over shell condition. Selectivities are a function of sex except for trawl bycatch selectivities, which are the same for both sexes. Two different survey selectivities were estimated: (1) 1975-1981 and (2) 1982-2013 based on modifications to the trawl gear used in the assessment survey.

iii. Growth is a function of length and did not change over time for males. For females, three growth increments per molt as a function of length were estimated based on sizes at maturity (1975-1982, 1983-1993, and 1994-2013). Once mature, female red king crabs grow with a much smaller growth increment per molt.

iv. Molting probabilities are an inverse logistic function of length for males. Females molt annually.

v. Annual fishing seasons for the directed fishery are short.

vi. Survey catchability (Q) was estimated to be 0.896, based on a trawl experiment by Weinberg et al. (2004) with a standard deviation of 0.025. Q was assumed to be constant over time. Some scenarios estimate Q in the model.

vii. Males mature at sizes =120 mm CL. For convenience, female abundance was summarized at sizes =90 mm CL as an index of mature females. viii. For summer trawl survey data, shell ages of newshell crabs were 12 months or less, and shell ages of oldshell and very oldshell crabs were more than 12 months.

viii. Measurement errors were assumed to be normally distributed for length compositions and were log-normally distributed for biomasses.

h. Changes to the above since previous assessment: see Section A.3. Changes to the assessment methodology.

i. Outline of methods used to validate the code used to implement the model and whether the code is available: The code is available.

3. Model Selection and Evaluation

a. Alternative model configurations: Several scenarios were compared for this report: Scenario 4: base scenario. Scenario 4 includes:

(1) Basic M = 0.18, and additional mortalities as one level (1980-1984) for males and two levels (1980-1984 and 76-79 & 85-93) for females.

(2) Including BSFRF survey data in 2007 and 2008.

(3) Assuming survey catchability to be 0.896 for all other years.

Gmacs-BBRK

How Gmacs deals with retention and selectivity: this is an important part to add, as there.

Comparison of Data and Model Specifications

ADFG

Survey Data

Catch Data

Weight and Fecundity

For the length-weight relationships, Jie's data file `rk7513s1.dat` has information on the weight-at-length parameters for BBRKC. He suggests we use the 'new' parameters listed (see line 339 onwards): these parameters were estimated by NMFS.

Fecundity-at-length is a little more complicated: This information was provided by Jie:

From Jie: Fecundity-at-length depends on clutch fullness, which changes from year to year. Right now, we do not use fecundity in the management, so no fecundity is used in the model. The "fecundity" used in Andre's simplified model looks like the male mean weight by length with the "old" parameters". If GMACS needs fecundity, maybe just input mean weight by length of mature females, or mature males (please use "new" parameters). As to the maturity by length, right now, it is 0 for lengths less than 90 mm and 1 for lengths 90 or larger for females and 0 for lengths less than 120mm and 1 for lengths greater than 119 mm for males. In the future, I plan to estimate maturity by length for females over time to improve estimation of growth.

Gmacs

The data and model specifications used in the Gmacs-BBRKC model are very similar to those used in the '4nb' scenario developed by Zheng and Siddeek (2014), herein referred to as the ADFG-BBRKC model.

Parameterization of the Bristol Bay red king crab.

Parameter Number of estimated parameters Value Natural mortality 1 Males (1980-84) 1 Females (1980-84) 1 Females (1976-79; 1984-1993) 0.18 yr-1 Other years

Growth Transition matrix Pre-specified Molt probability (slope and intercept) (1975-78) Females? 2 Molt probability (slope and intercept) (1979+) Females? 2 Molt probability (slope and intercept) Males? Pre-specified

Recruitment Gamma distribution parameters 4 Annual deviations ??

Fishing mortality Mean fishing mortality (directed fishery) 1 Annual fishery deviations (directed fishery) ?? Mean fishing mortality (groundfish fishery) 1 Annual fishery deviations (groundfish fishery) ?? Mean fishing mortality (Tanner fishery) 1 Annual fishery deviations (Tanner fishery) ??

Fishery selectivity Directed fishery slope and intercept (by sex) 4 Groundfishery slope and intercept (both sexes) 2 Tanner crab fishery slope and intercept (both sexes) 4 Retention Slope, inflection point, asymptote 3 Initial conditions ?? Survey catchability 1 Survey selectivity NMFS Slope and intercept (1975-81) by sex 4 NMFS Slope and intercept (1982+) by sex 4 BSFRF selectivity Pre-specified BSFRF CV 1

Population Dynamics

Comparison tables of two different model approaches could be done by

Specification	Parameter	ADFG Value	Gmacs Value	Comments
No. sexes	M	2	2	

Specification	Parameter	ADFG Value	Gmacs Value	Comments
No. shell condition	M	2	2	
No. maturity	M	2	1	
No. size-classes	M	20	20	

Life History Trait	Parameter	ADFG Value	Gmacs Value	Comments
Natural Mortality	M	Fixed	Fixed	M is fixed in both models

Fishery Dynamics

Specification	Parameter	ADFG Value	Gmacs Value	Comments
No. Fleets		5	2	
No. Fleets		5	5	

There are five separate fishing fleets accounted for in the ADFG model:

Comparison of Model Results

The results of the ADFG-BBRKC model are compared here to the results of the Gmacs-BBRKC model.

Model	FSPR	BSPR	FOFL	OFL	RSPR
Gmacs (one sex)	0.28	32995.95	0.28	3373.93	8160.40
Gmacs (two sex)	0.21	22205.54	0.21	3030.39	16959.09

The mean weight at length used in the two models differs little for males (Figure 1). However, the pattern is very different for females. This difference is due to…

The fit to the NMFS surveys also differ (Figure 2). The ADFG-BBRKC model provides as bad a fit to the female survey biomass as the Gmacs-BBRKC model. However, the ADFG-BBRKC model provides a much better fit to the male survey biomass.

In both the ADFG-BBRKC and Gmacs-BBRKC models, time-varying natural mortality (M_t) is freely estimated with four step changes through time. The years (t) that each of these steps cover are fixed a priori. The pattern in time-varying natural mortality is resonably similar between the two models (Figure 3), however the peak in natural mortality during the early 1980 is not as high in the Gmacs-BBRKC model.

Patterns in recruitment through time (R_t) estimated in the two models are similar, but differences in natural mortality schedules will affect these matches (Figure 4).

The number of crabs in each size class ($\mathbf{n}$) in the initial year ($t = 1$) and final year ($t = T$) in each model differ substantially (Figure 5).

The spawning stock biomass of mature males, termed the mature male biomass (MMB_t), also differs a lot bewteen the two models (Figure 6).

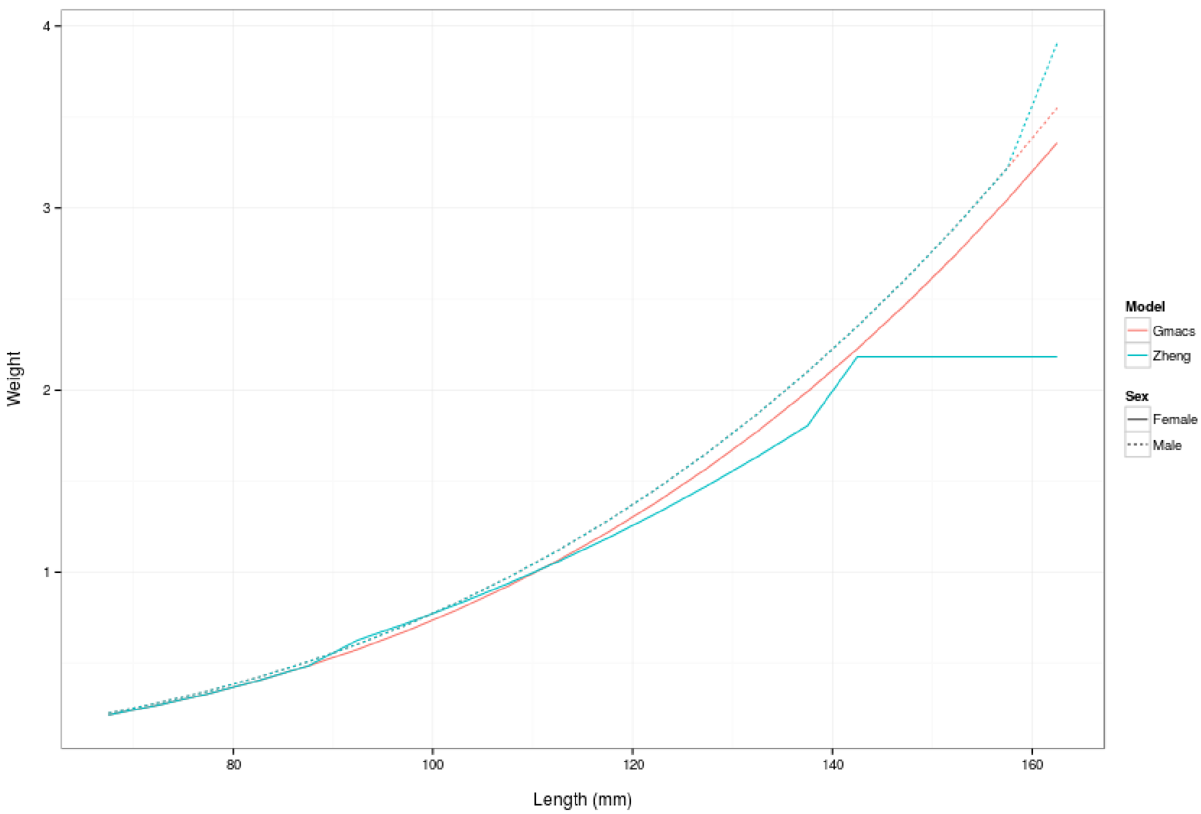

Figure 1: Relationship between carapace length (mm) and weight (kg) by sex.

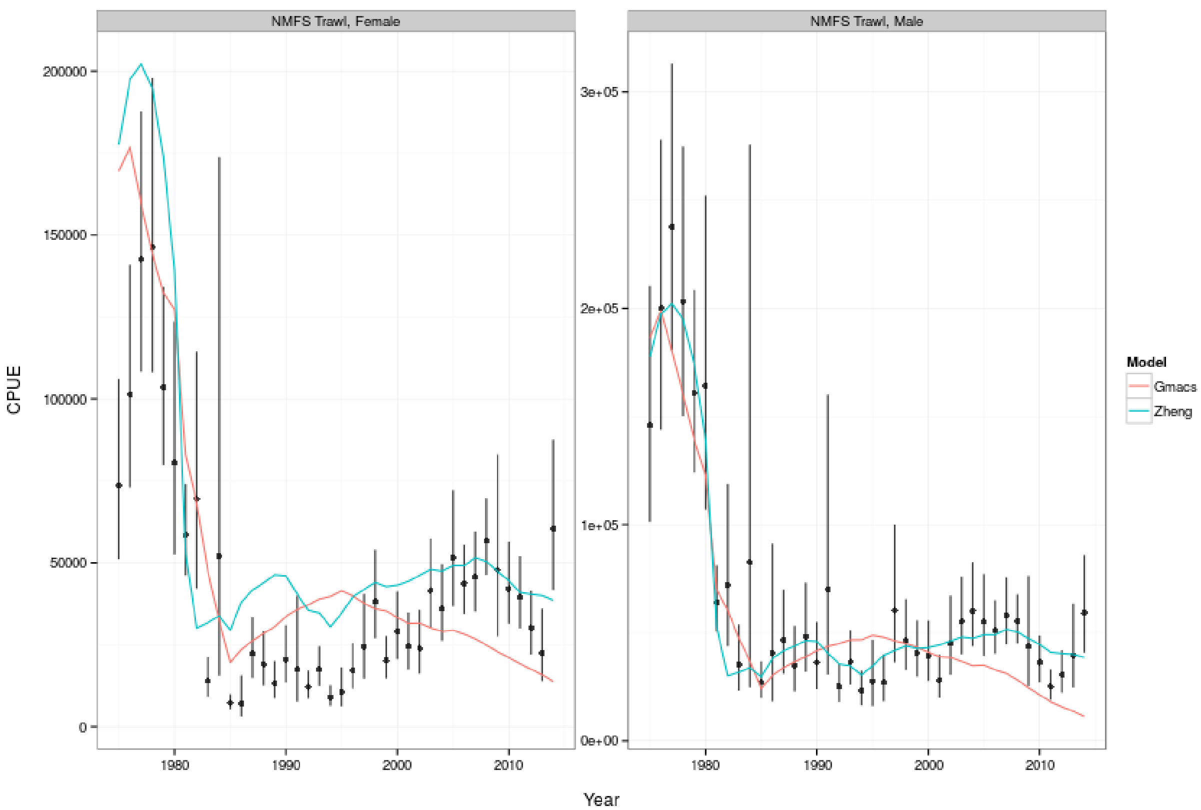

Figure 2: Survey biomass.

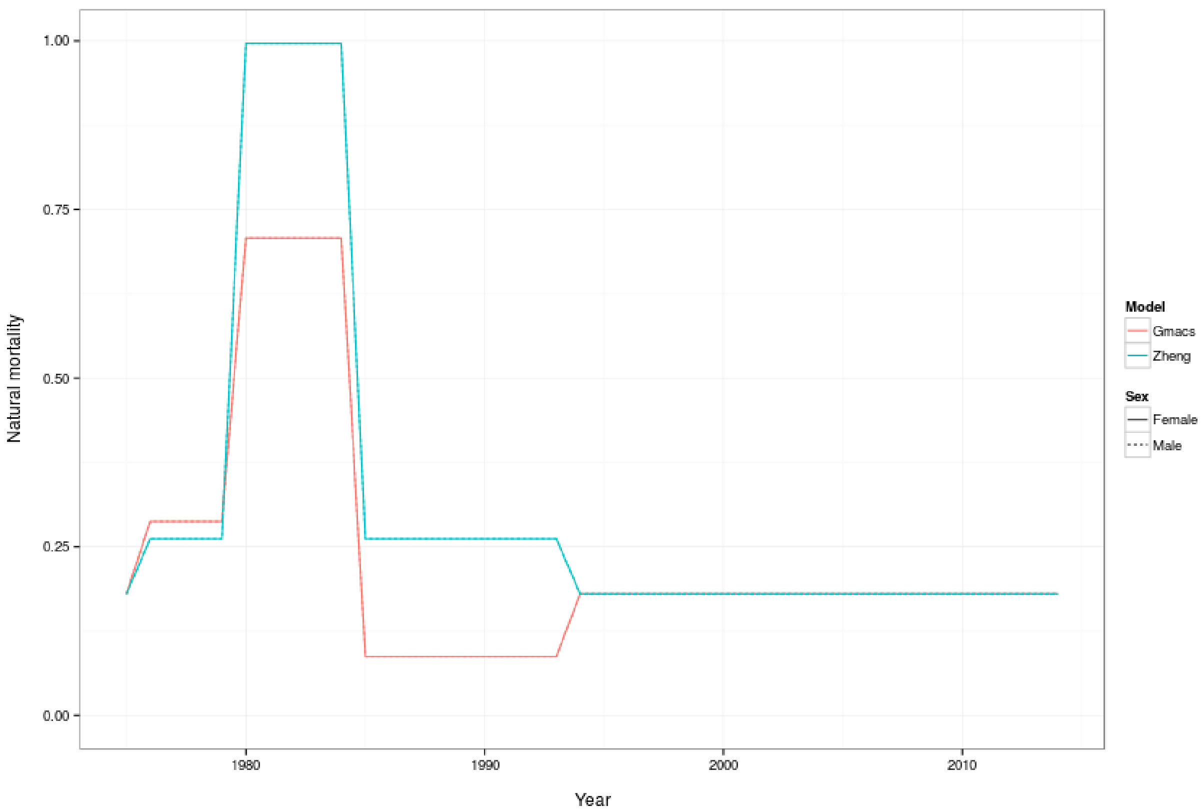

Figure 3: Time-varying natural mortality (M_t).

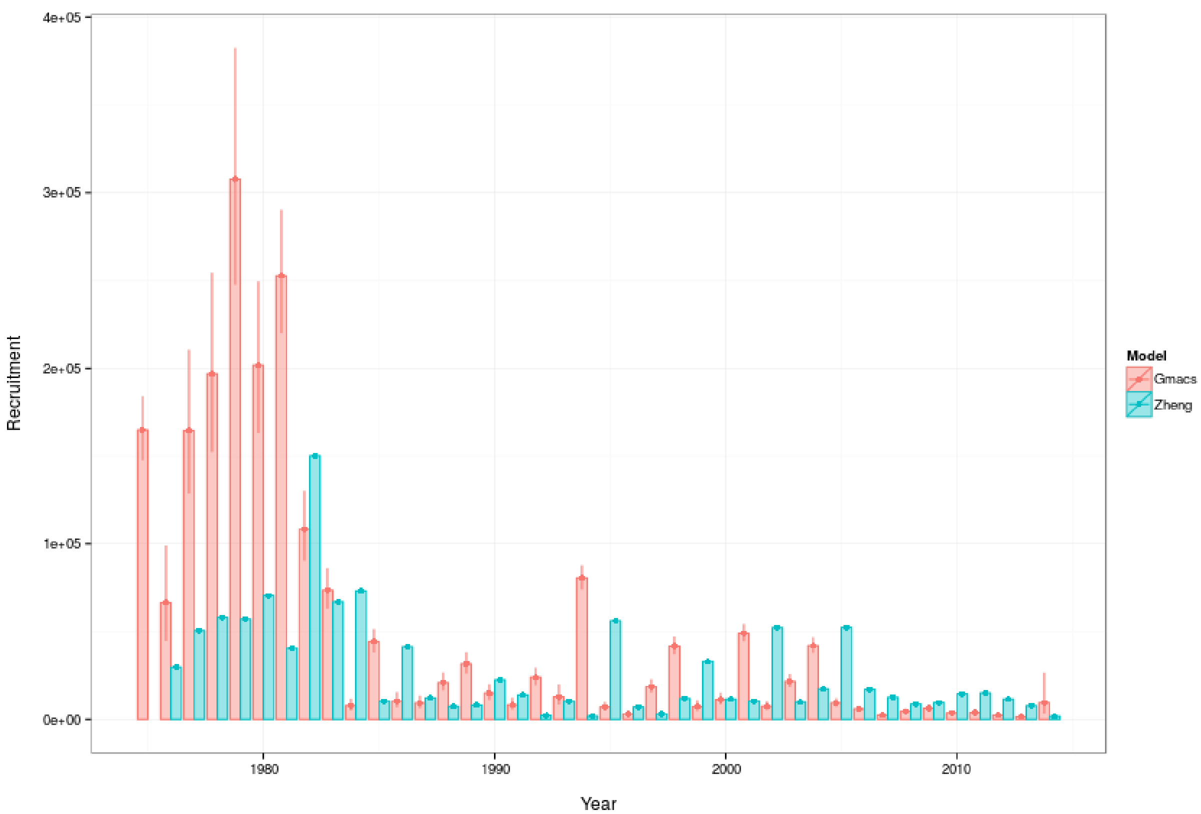

Figure 4: Estimated recruitment time series (R_t).

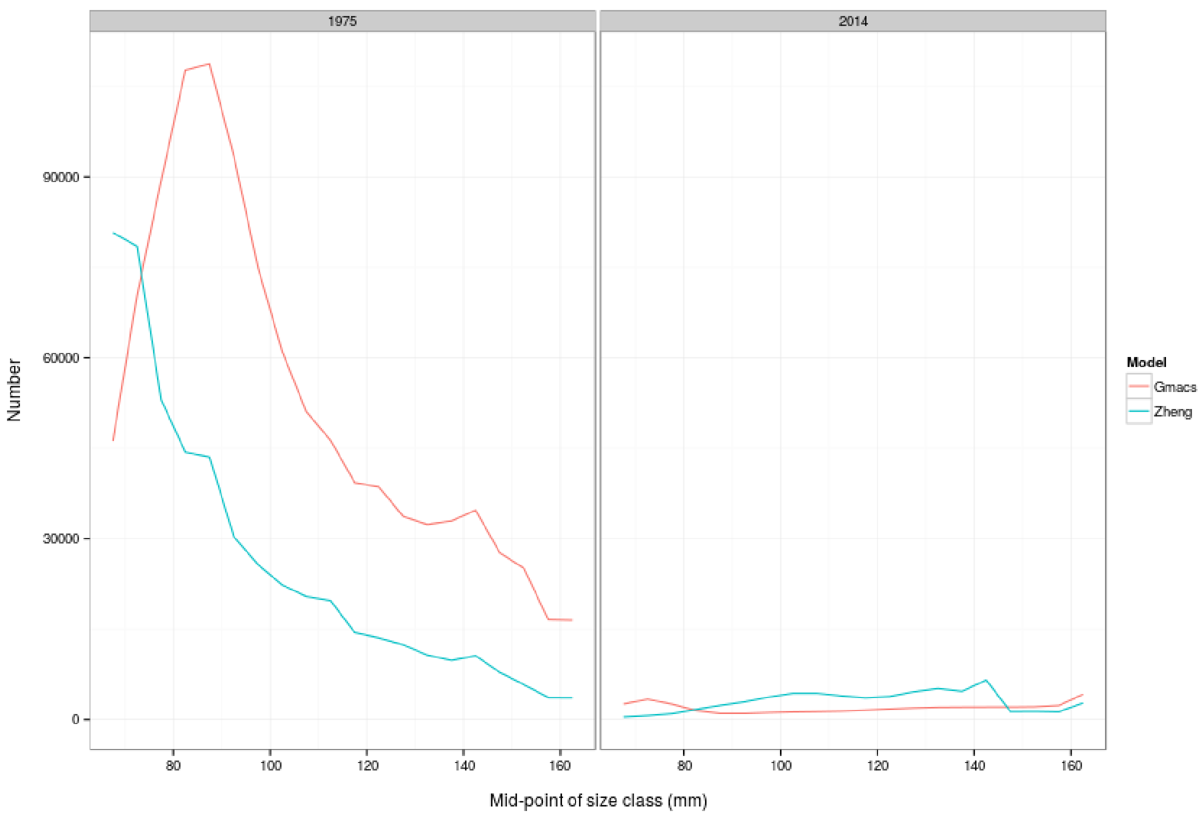

Figure 5: Numbers at length.

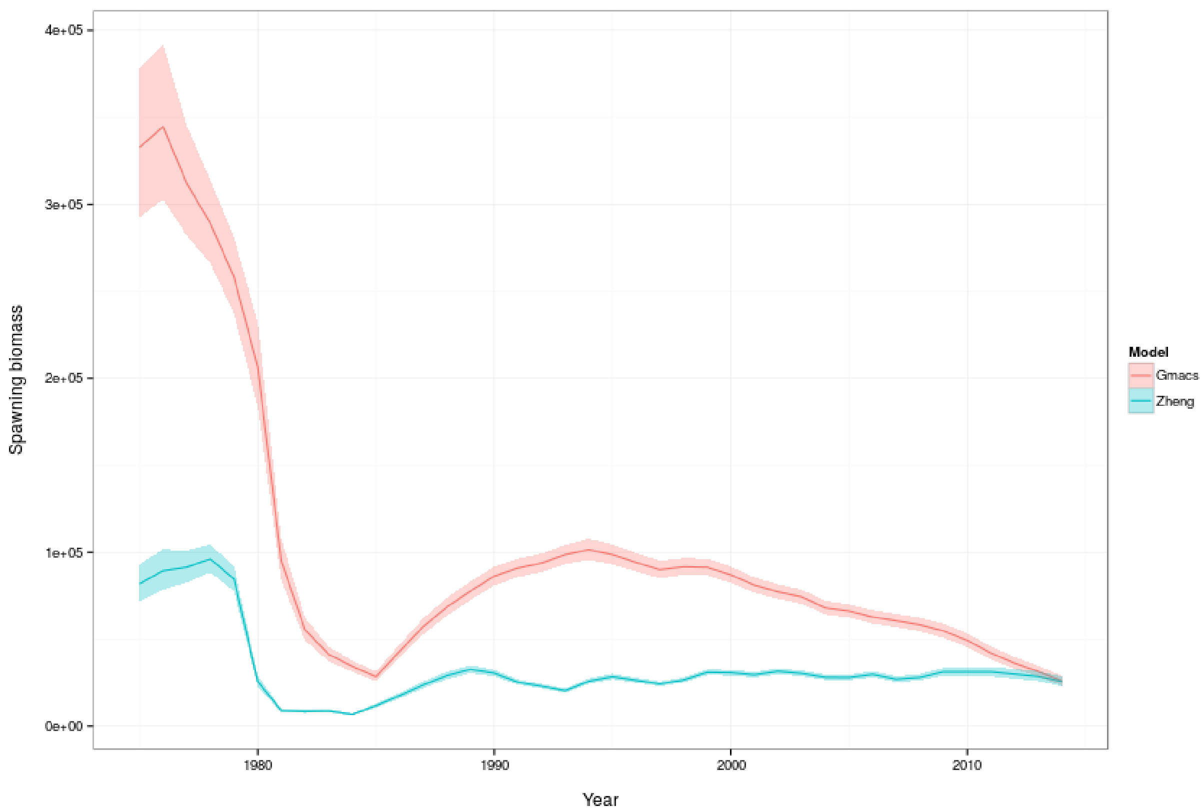

Figure 6: Mature male biomass.

Gmacs Results

We need to be able to produce a table of the comparative likelihoods (by component) of the alternative models. For best practice, just try and do what we do with SS models for SESSF stocks anyway. See the pink link report, and enter a section for each of those, and see if we can emulate a report of that type.

In what follows, we demonstrate the use of the **gmr** package to process the output of the Gmacs-BBRKC model and produce plots that can be used in assessment reports.

The fit of the Gmacs-BBRKC model to the catch (Figure 7).

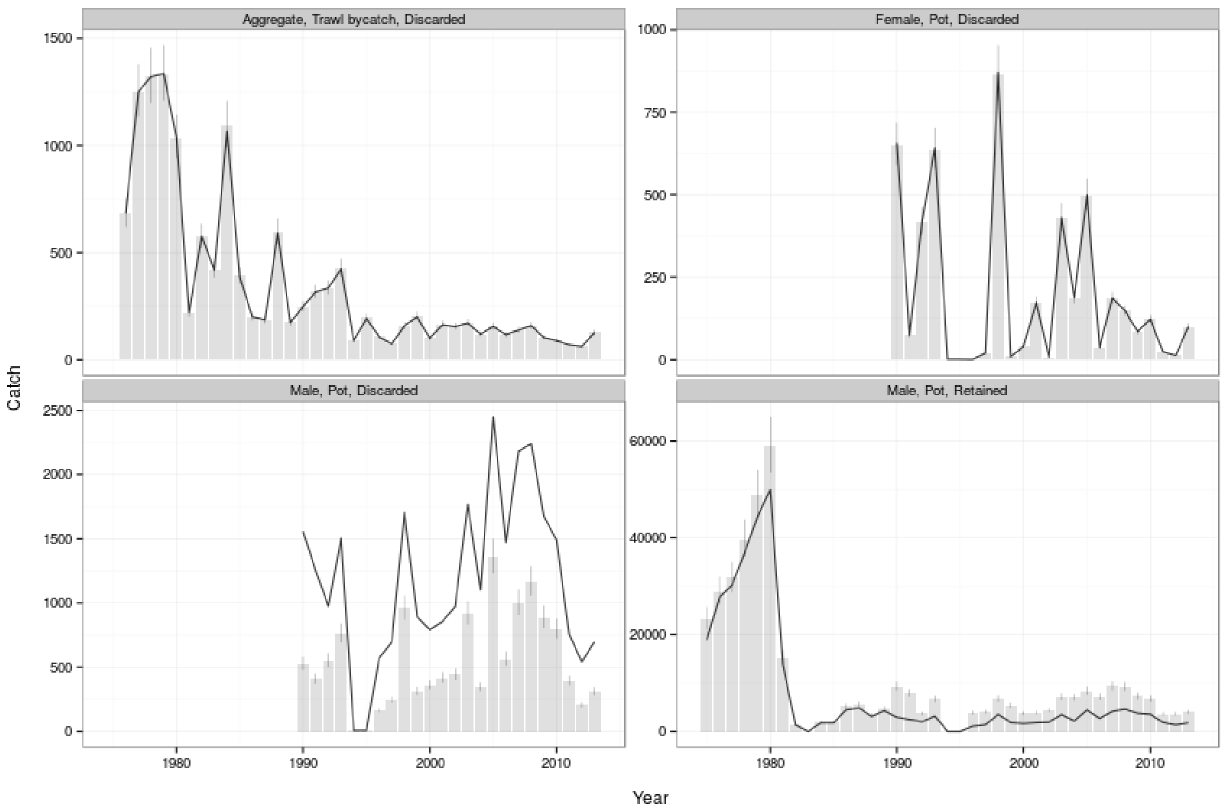

Figure 7: Retained catch and bycatch mortality biomasses for BBRKC from 1975 to 2013.

The selectivity by length (S_ℓ) for each of the fisheries (Figure 8).

The size transitions (Figure 9).

The growth increments (Figure 10).

The fit of the model to the size composition data (Figure 11). In the groundfish trawl bycatch fisheries for males (Figure 14) and females (Figure 15).

Comparison of Assessment Processes

File Description

- The `*.tpl` file is working, it builds and the `*.exe` file runs successfully.
- The main `*.dat` file is read in as expected (comments within).

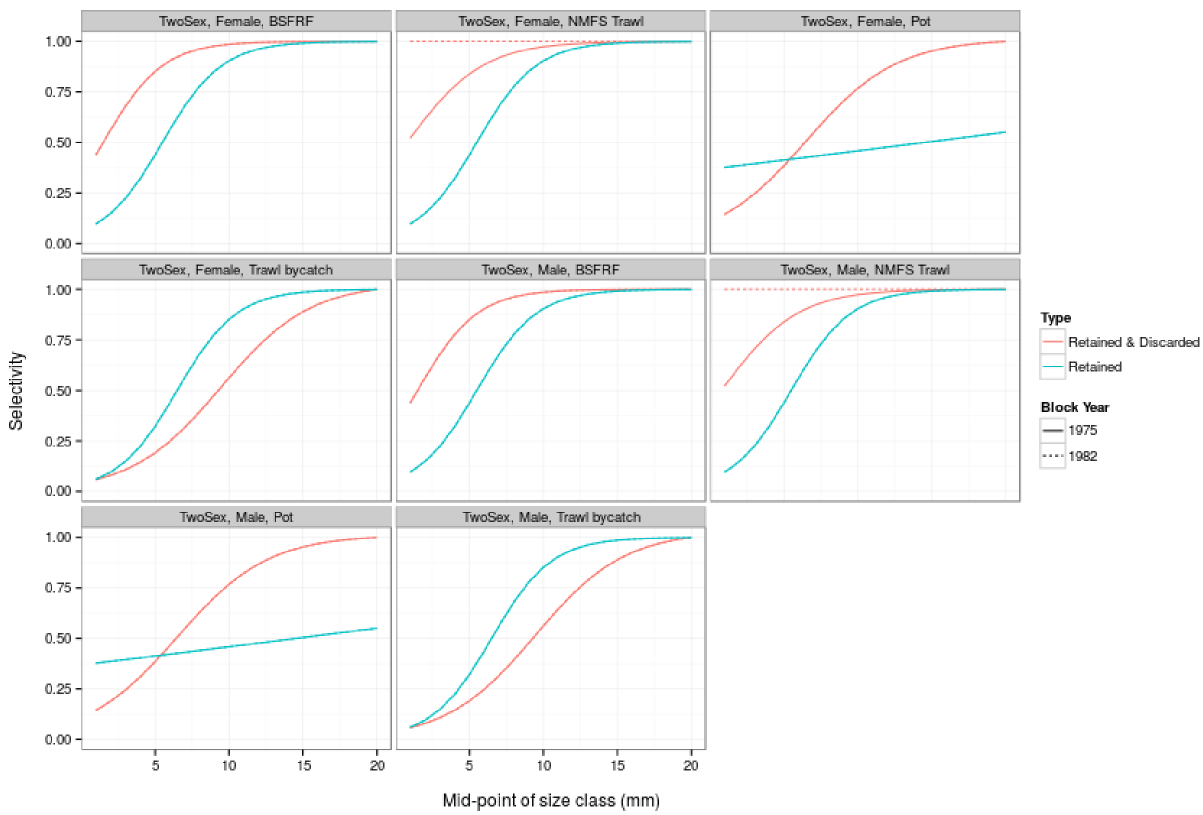

Figure 8: Estimated selectivity functions.

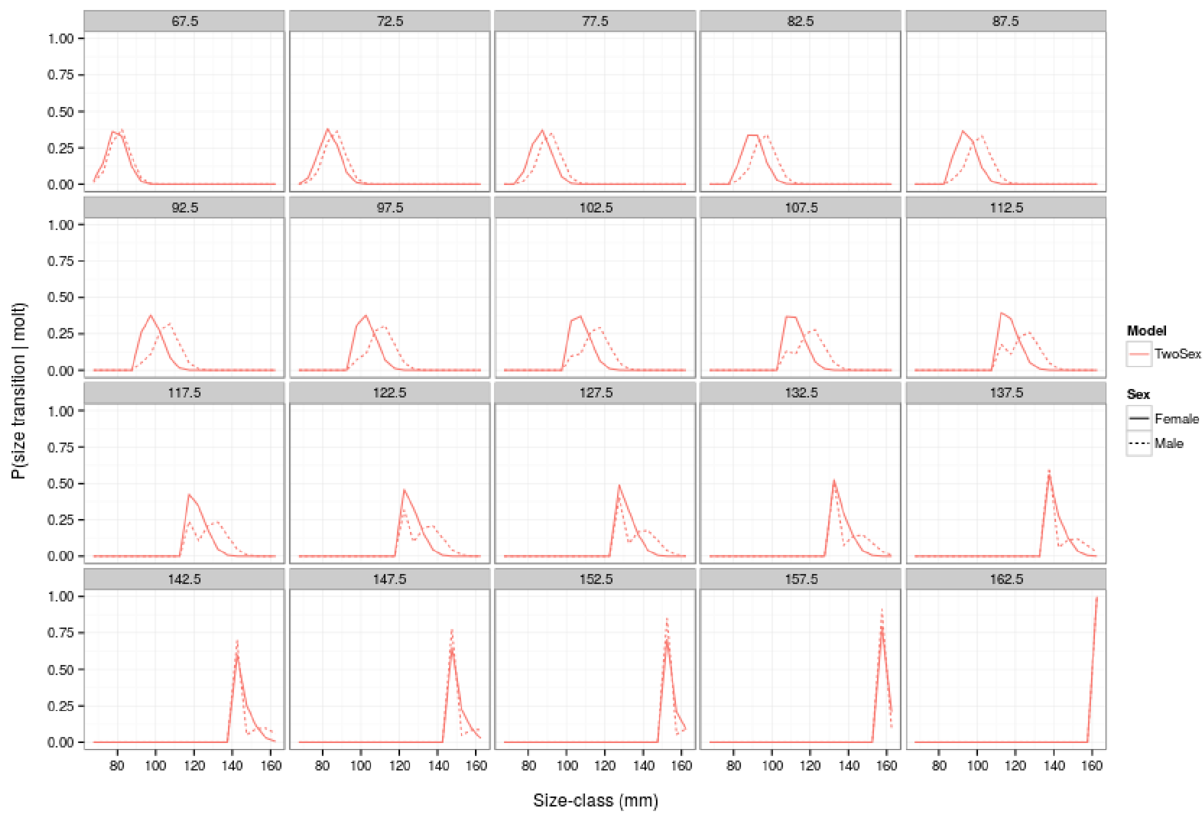

Figure 9: Probability of size transition.

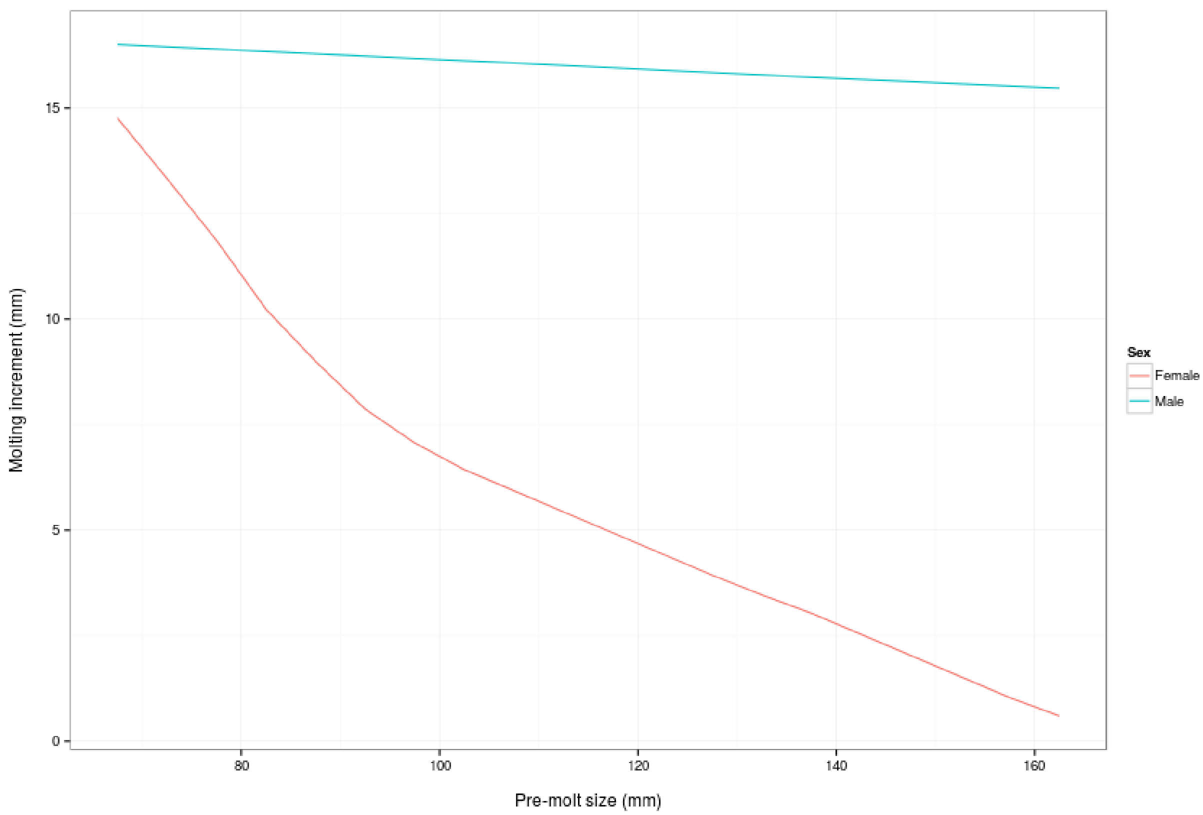

Figure 10: Growth increment.

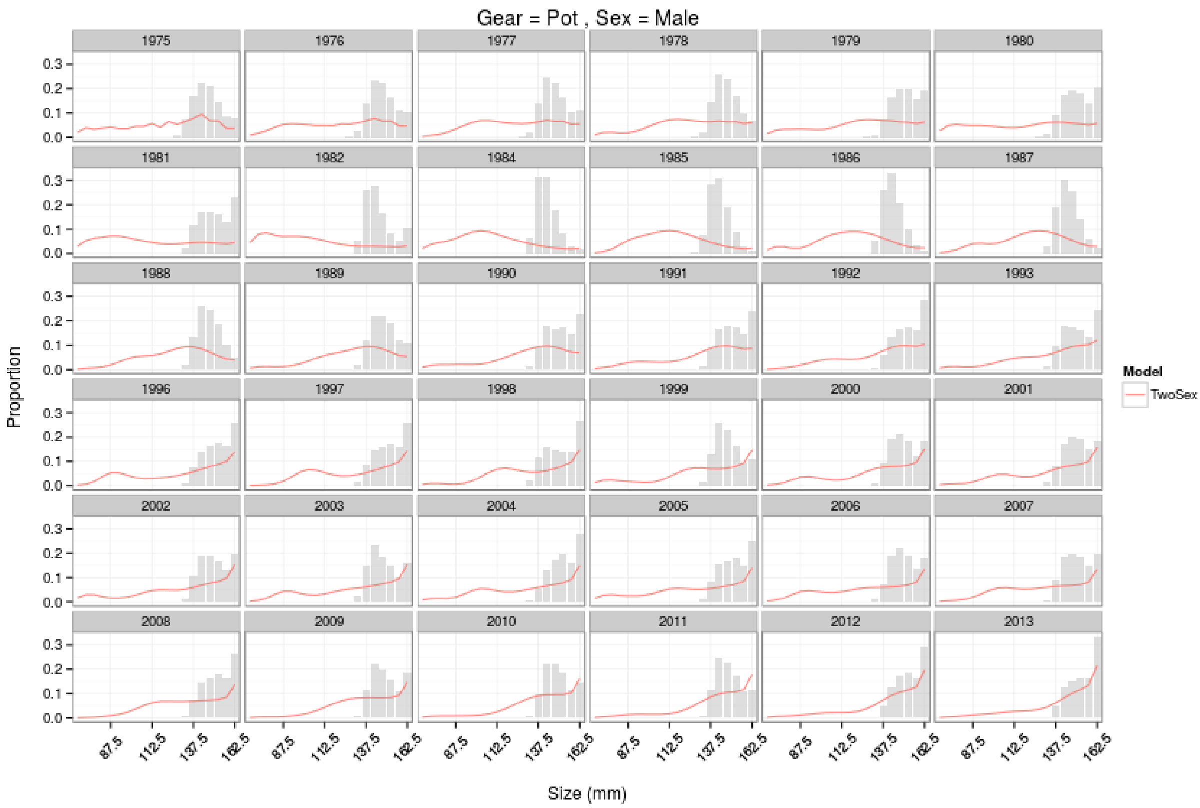

Figure 11: Observed and model estimated length-frequencies of male BBRKC by year retained in the directed pot fishery.

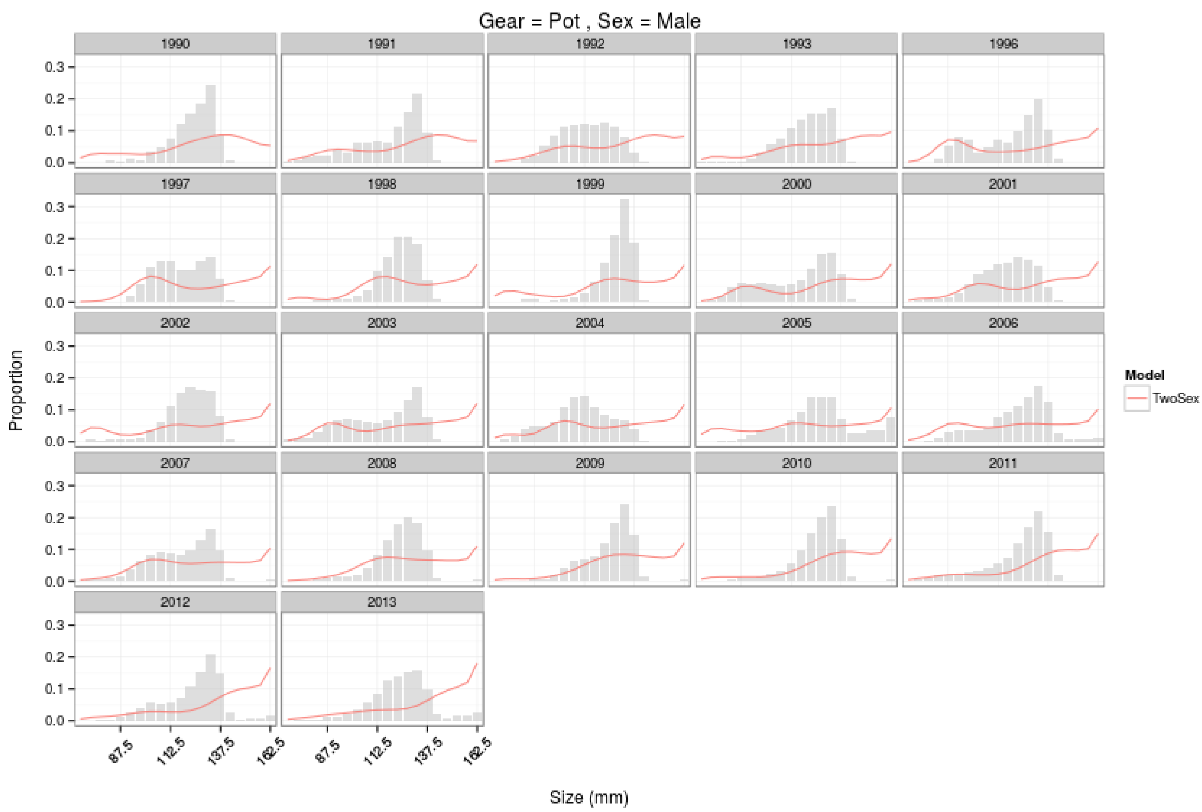

Figure 12: Observed and model estimated length-frequencies of male BBRKC by year discarded in the directed pot fishery.

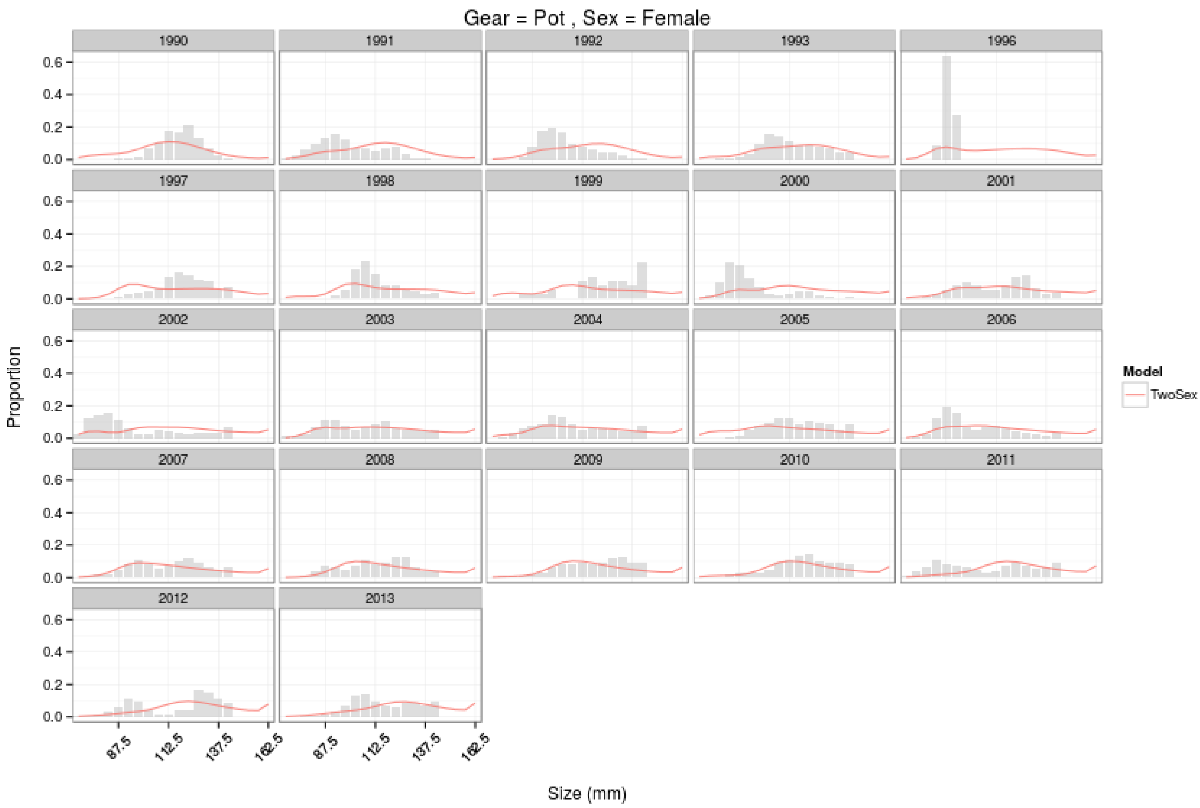

Figure 13: Observed and model estimated length-frequencies of female BBRKC by year discarded in the directed pot fishery.

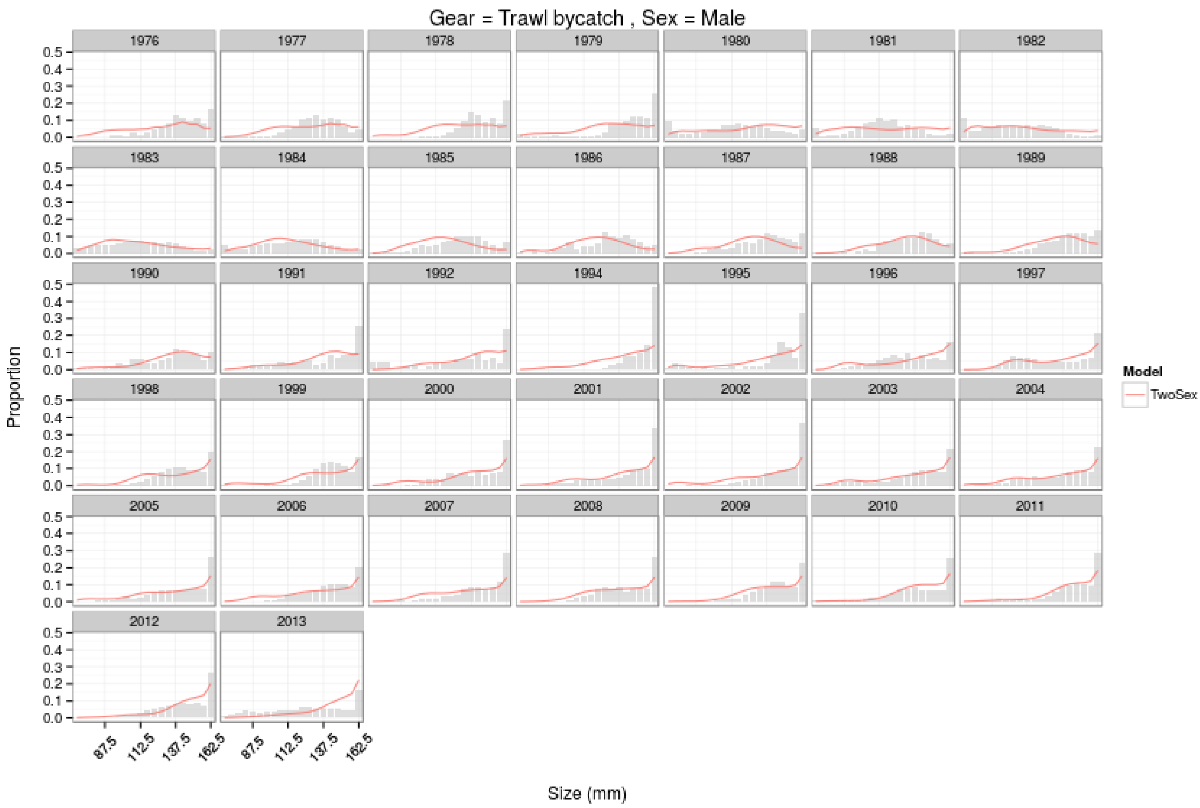

Figure 14: Observed and model estimated length-frequencies of male BBRKC by year in the groundfish trawl bycatch fisheries.

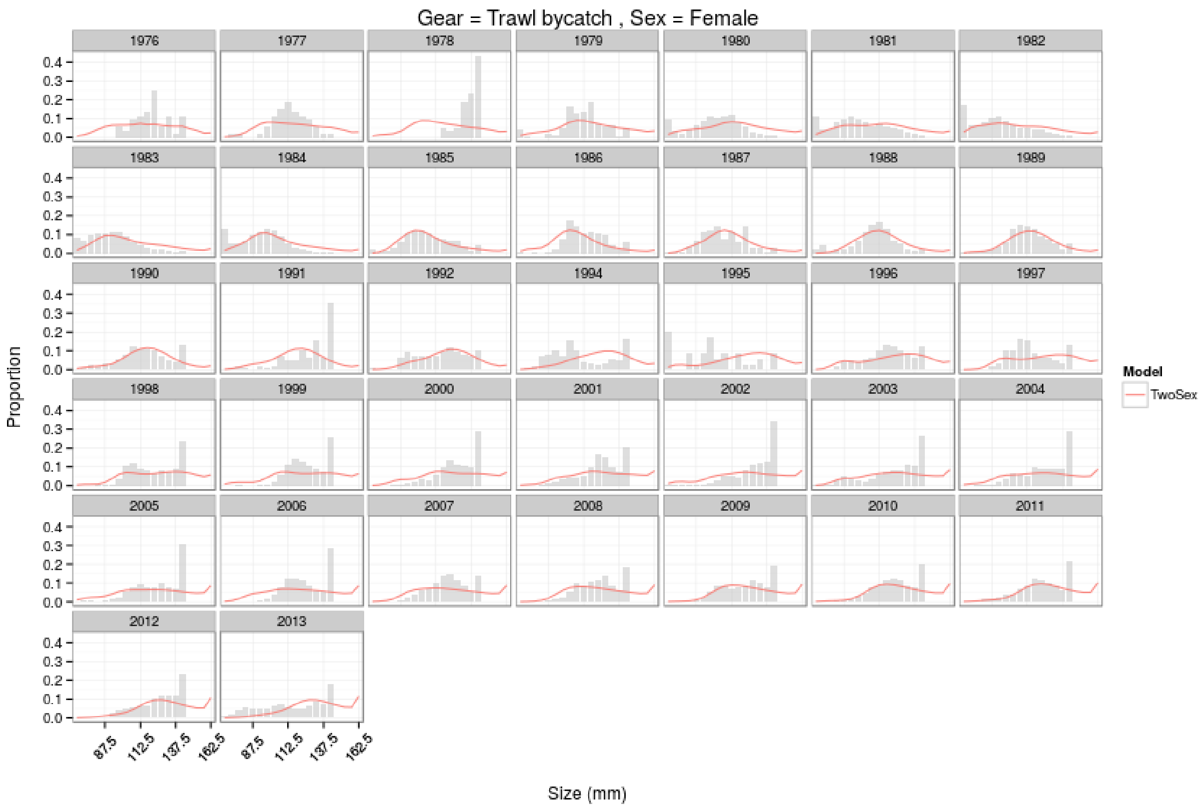

Figure 15: Observed and model estimated length-frequencies of female BBRKC by year in the groundfish trawl bycatch fisheries.

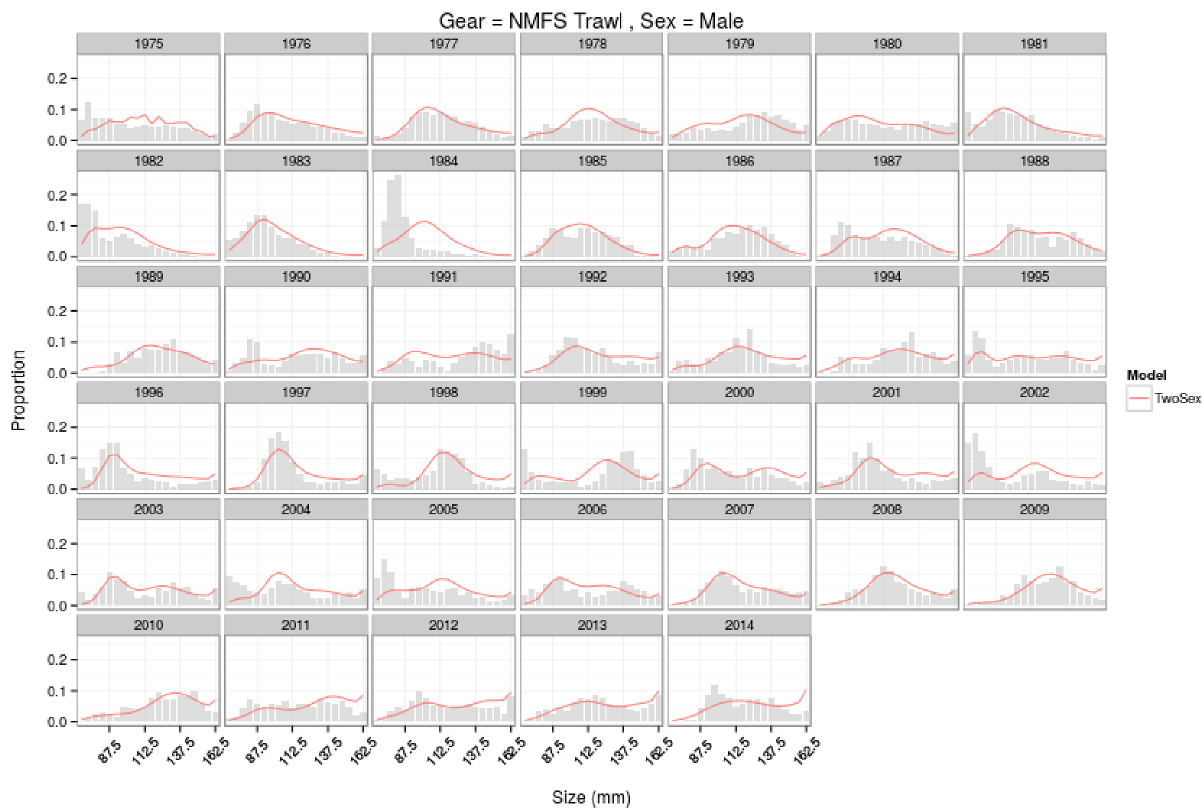

Figure 16: Observed and model estimated length-frequencies of male BBRKC by year in the NMFS trawl fishery.

- There is a second data file `rksize13s.dat` with sample sizes for various rows of size-comp data. See lines 81-87 of `*.tpl`.
- Input sample sizes appear to be capped to the constant numbers entered in the main data file under 'number of samples' or 'sample sizes' (variously).
- There is a third data file `tc7513s.dat` specifically for data from the tanner crab fishery (with red crab bycatch).
- There is a standard control file `*.ctl` with internal comments.
- There is an excel spreadsheet which can be used to read in the model output files and display related plots (it's a bit clunky).
- There are two batch files in the model directory: `clean.bat` and `scratch.bat`. The 'clean' batch file deletes files related to a single model run. The 'scratch' batch file deletes all files relating to the model build and leaves only source and data files.

Discussion

This discussion will focus on the challenges in developing a Gmacs version of the BBRKC model: those met, and those yet to be met.

References

Punt, A. E., T. Huang, and M. N. Maunder. 2013. "Review of Integrated Size-Structured Models for Stock Assessment of Hard-to-Age Crustacean and Mollusc Species." *ICES Journal of Marine Science* 70 (1) (January): 16–33. doi:10.1093/icesjms/fss185. http://icesjms.oxfordjournals.org/cgi/doi/10.1093/icesjms/fss185.

Zheng, J., and M.S.M Siddeek. 2014. "Bristol Bay Red King Crab Stock Assessment in Spring 2014." *Alaska Department of Fish and Game*: 149.