Gmacs Example Stock Assessment

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Introduction

Gmacs is a generalized size-structured stock assessment modelling framework [more here on Gmacs].

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. 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

1. History of Modeling Approaches To reduce annual measurement errors associated with abundance estimates derived from the area-swept method, the ADF&G 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 Bristol Bay RKC 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 (Figure 1). 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. In this report, we present only the research model that was fit to the data from 1975 to 2013.

2. Model Description 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. A full model description is provided in Appendix A.

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.

ix. 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.

The length-weight relationship used between the two models differs somewhat (Figure 1).

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.

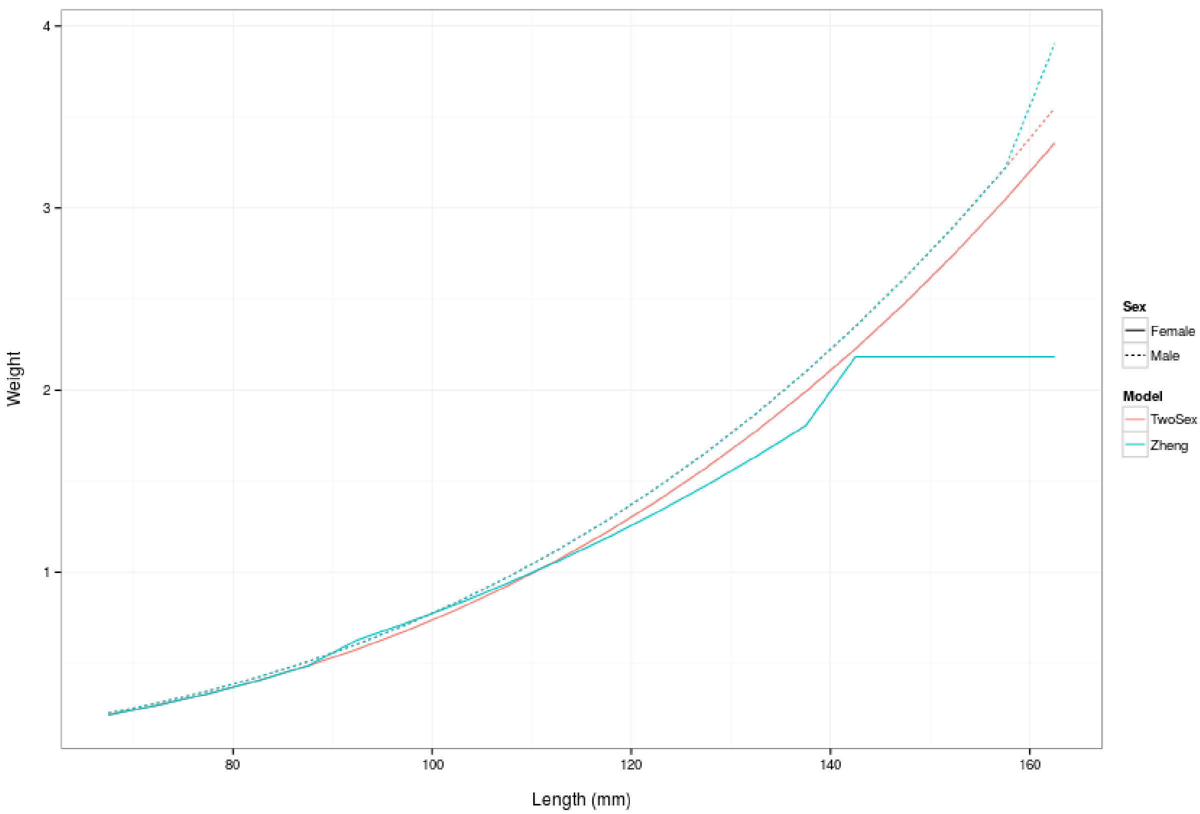


Figure 1: Relationship between length (mm) and weight (kg) by sex.

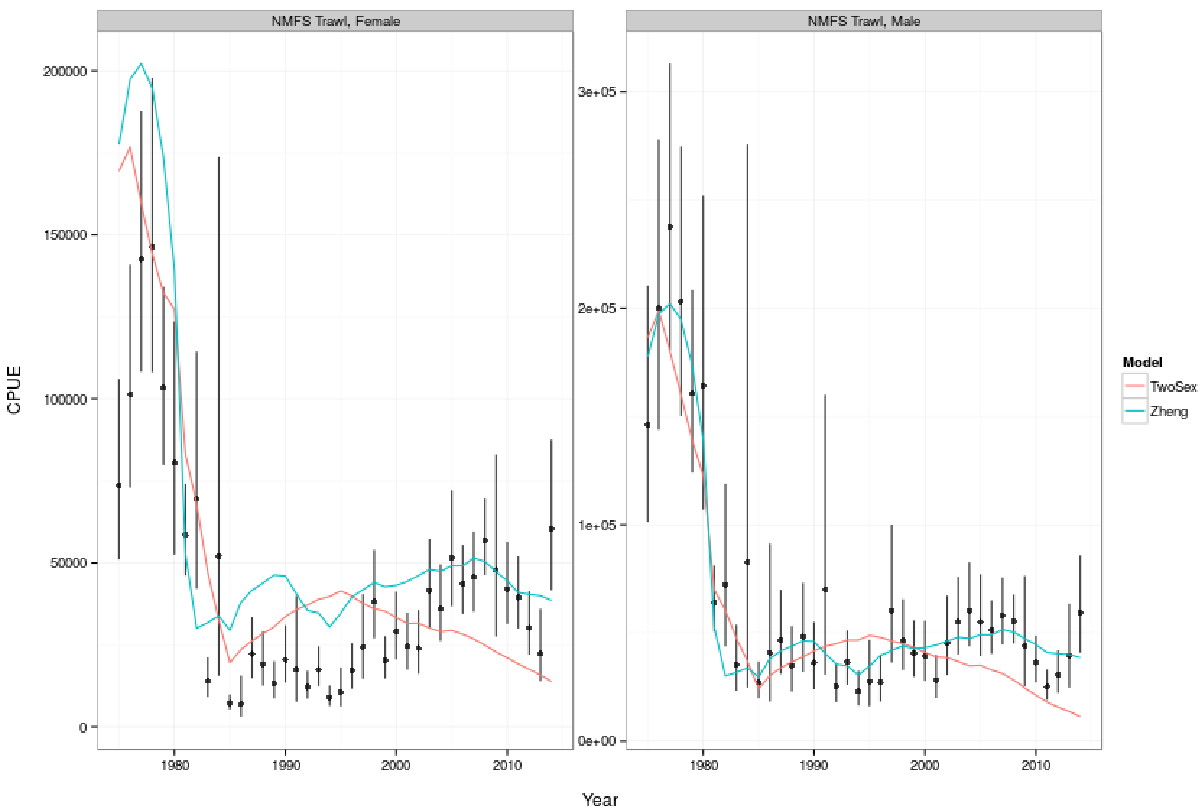


Figure 2: Survey biomass.

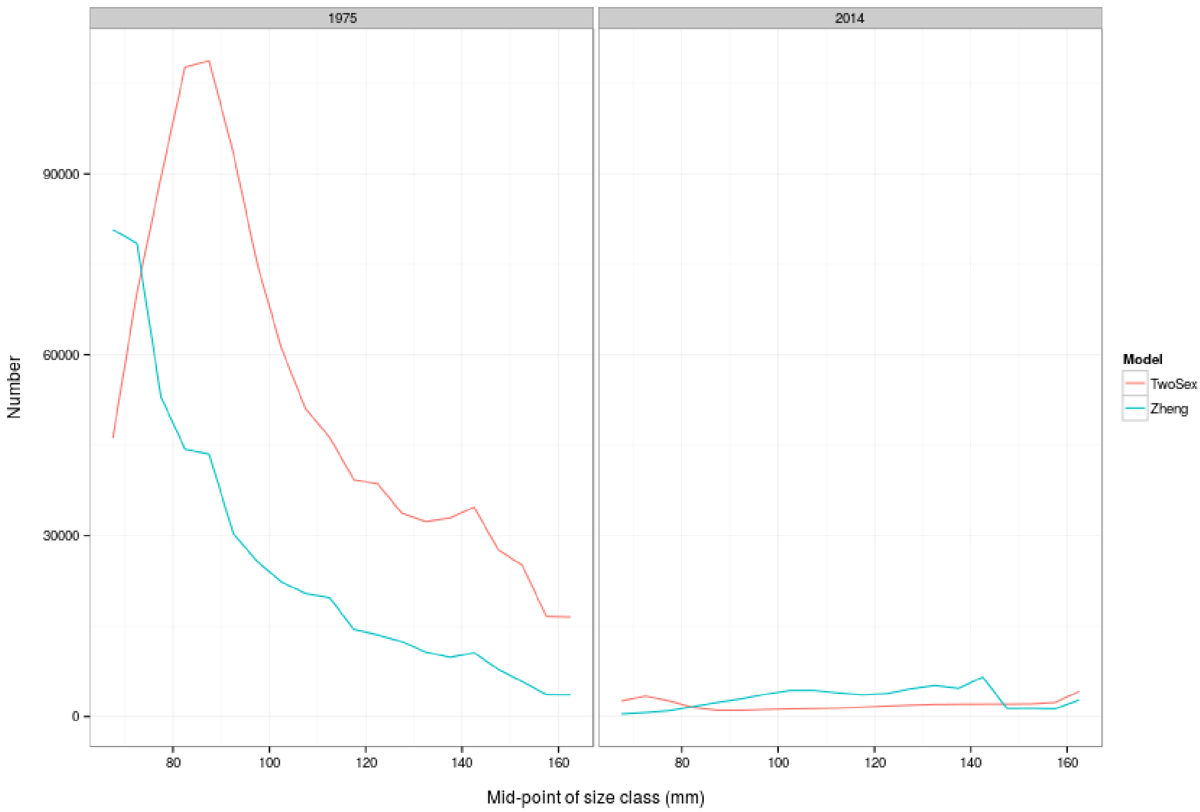


Figure 3: Numbers at length.

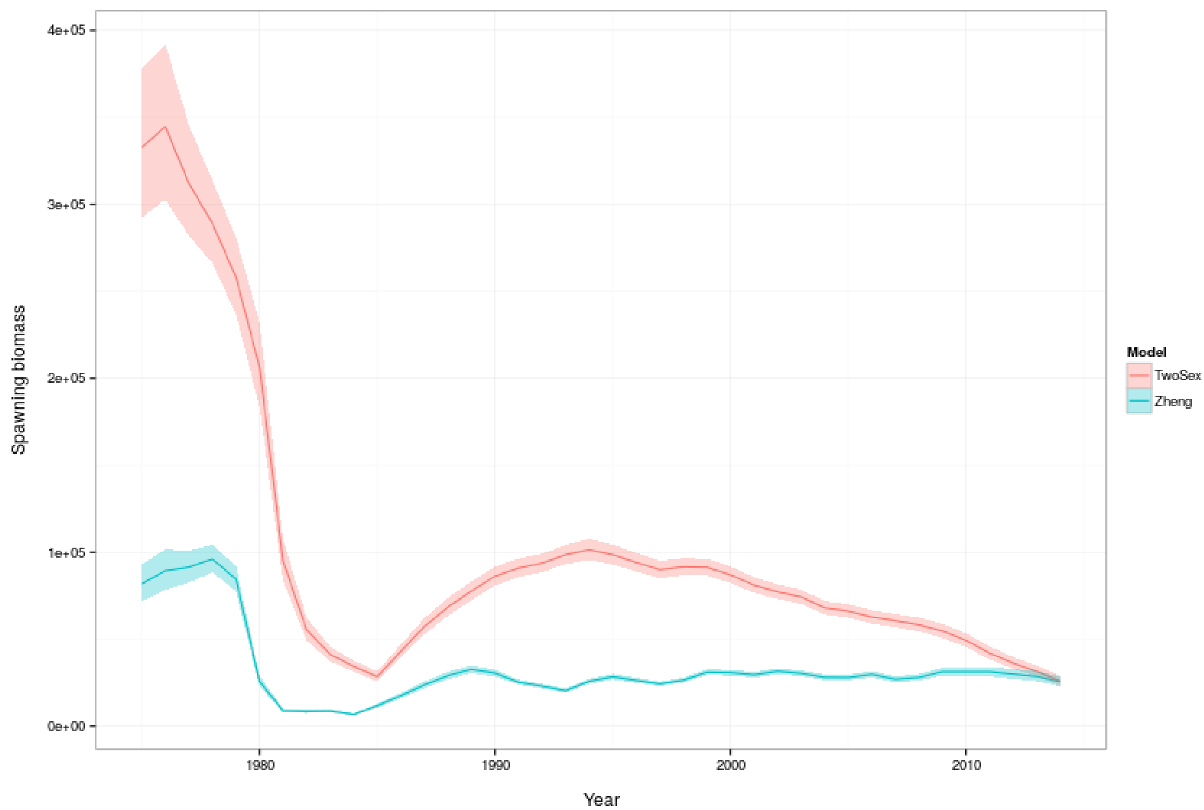


Figure 4: Spawning stock biomass.

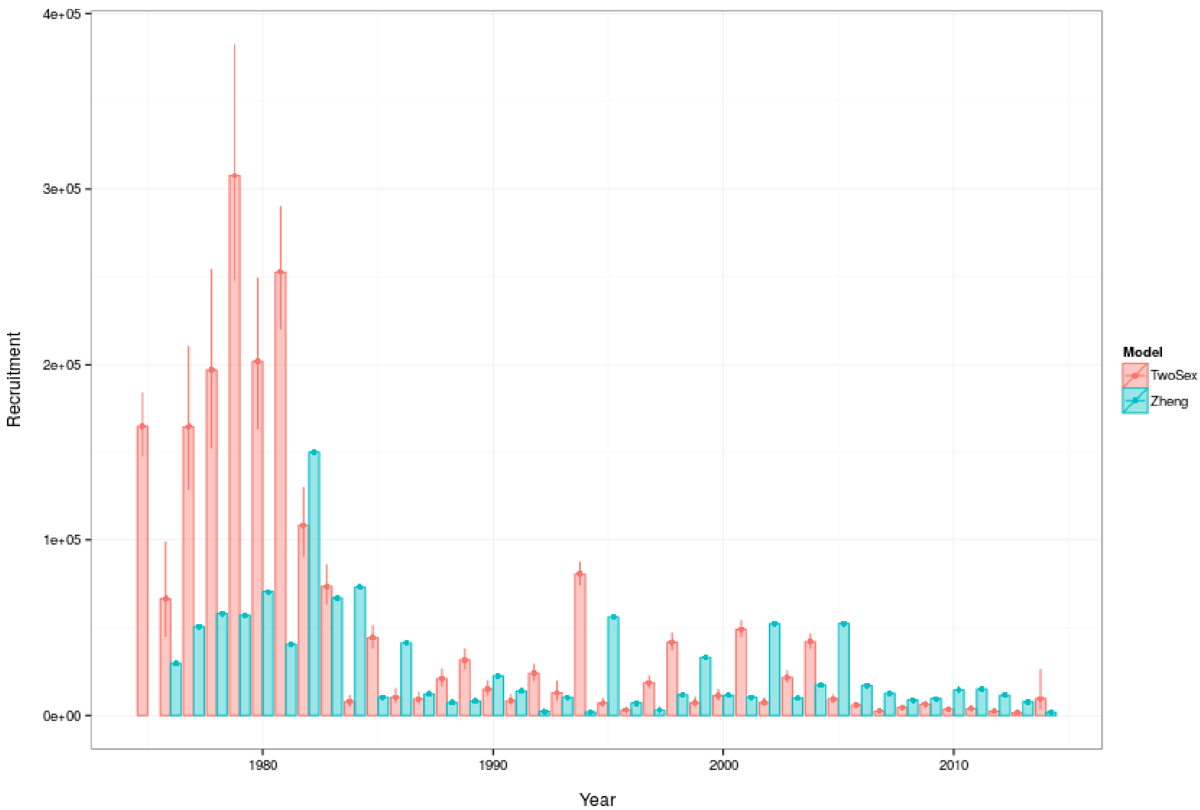


Figure 5: Recruitment.

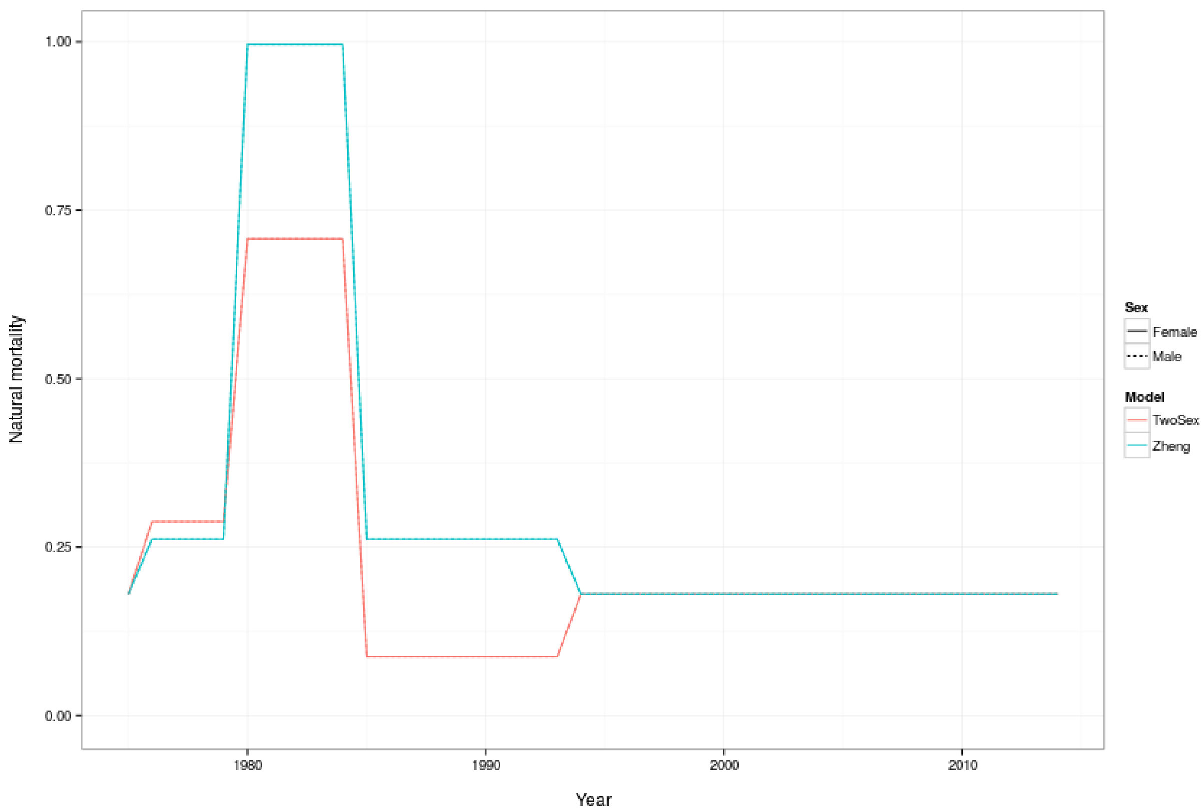


Figure 6: Time-varying natural mortality.

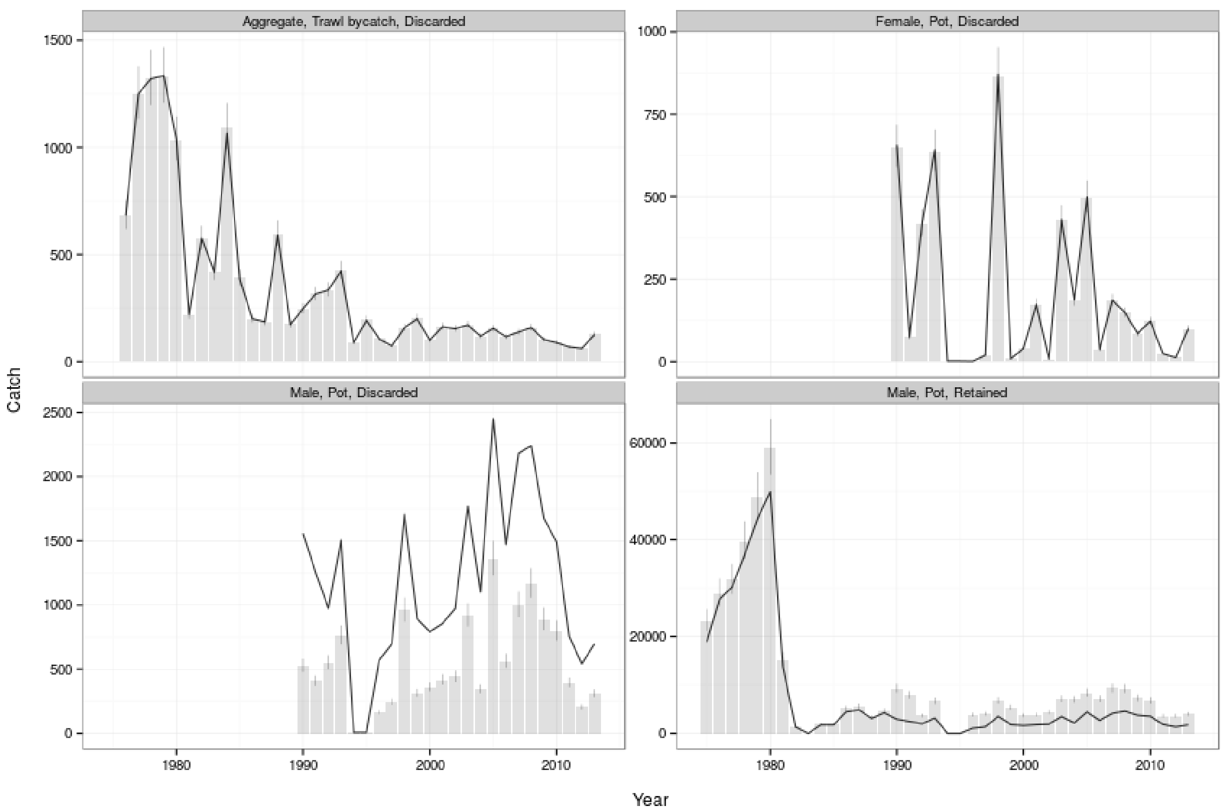


Figure 7: Catch.

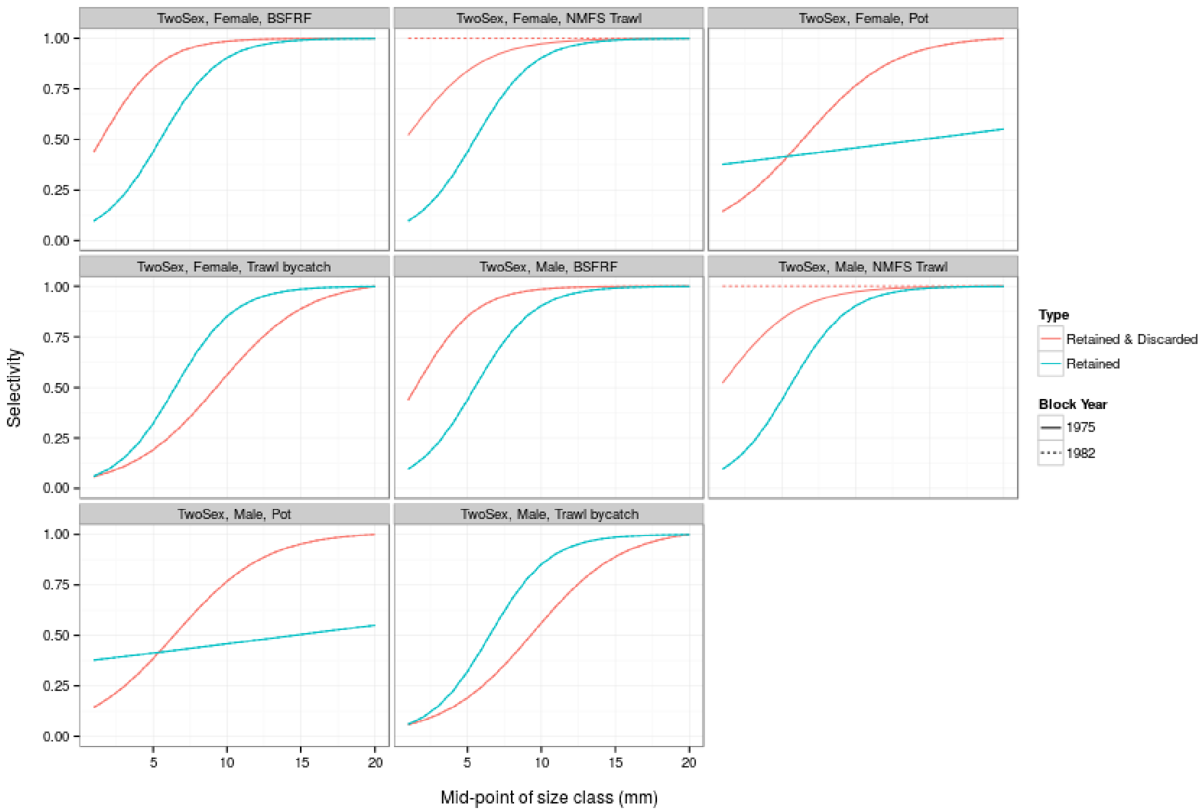


Figure 8: Selectivity.

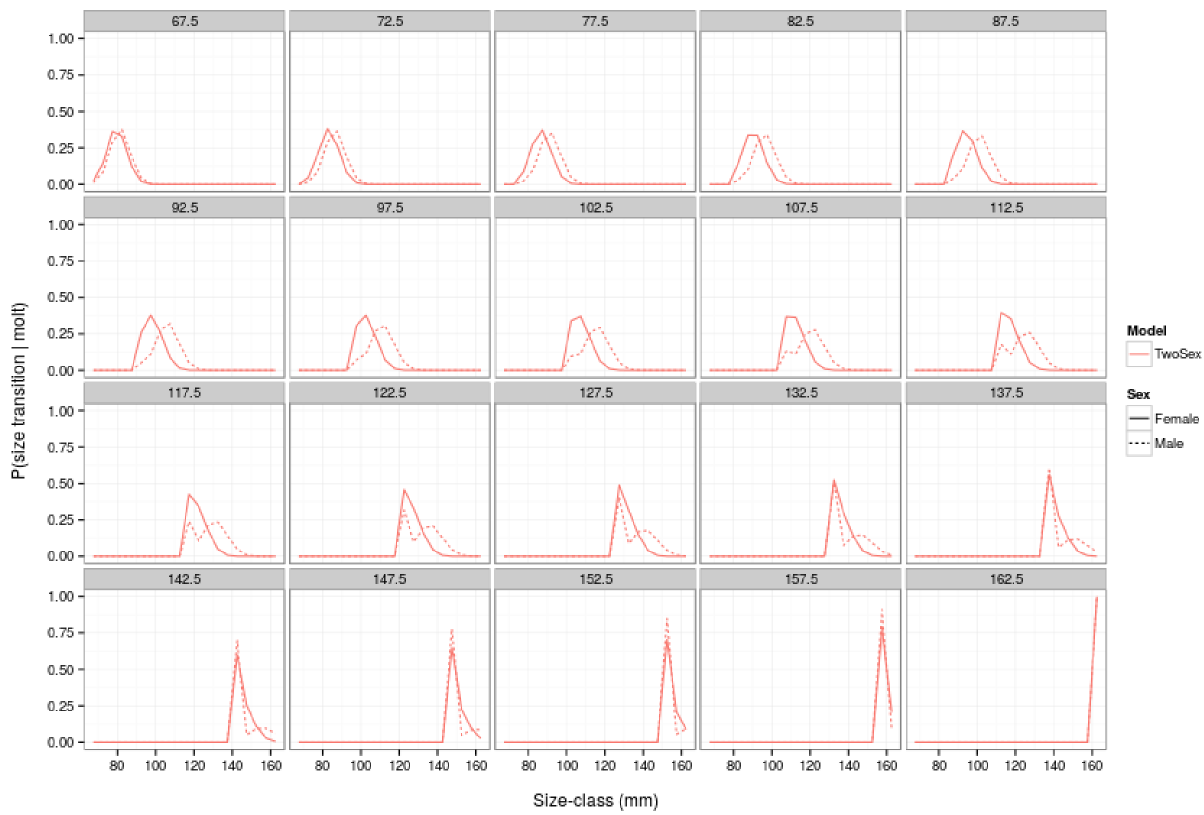


Figure 9: Probability of size transition.

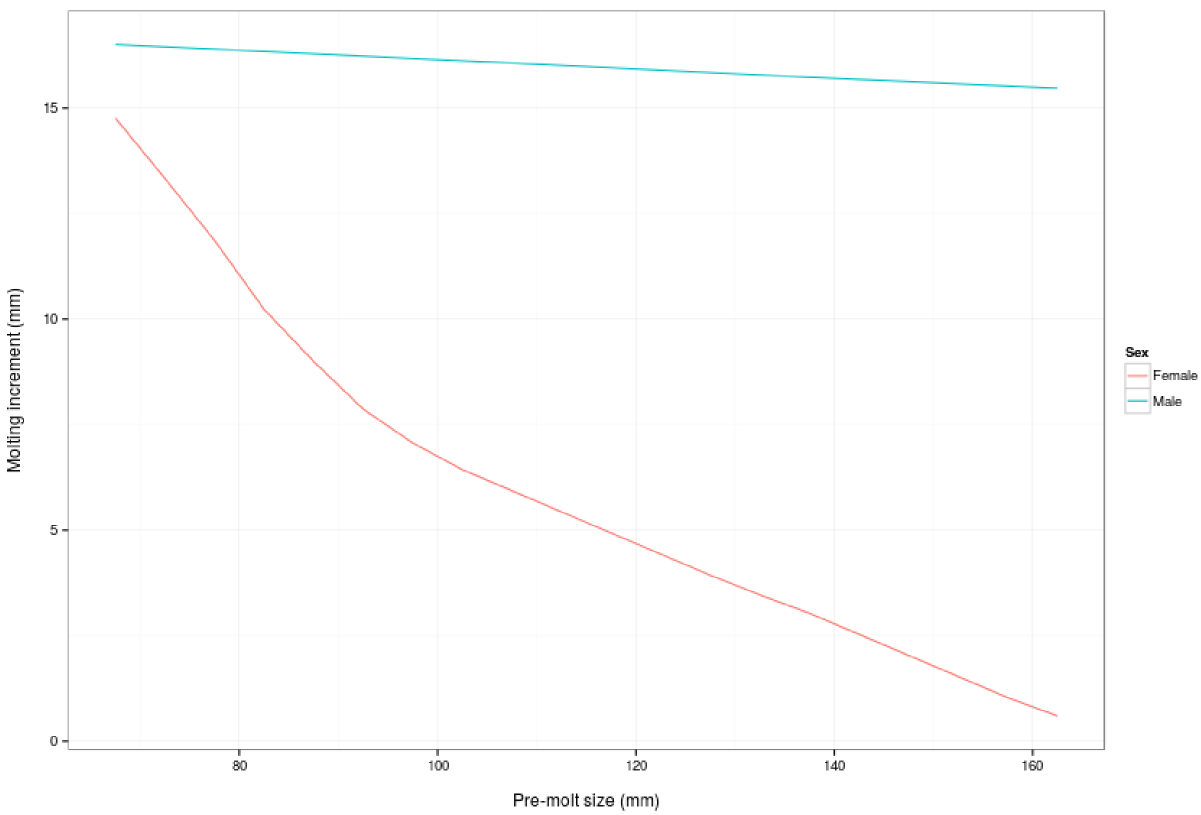
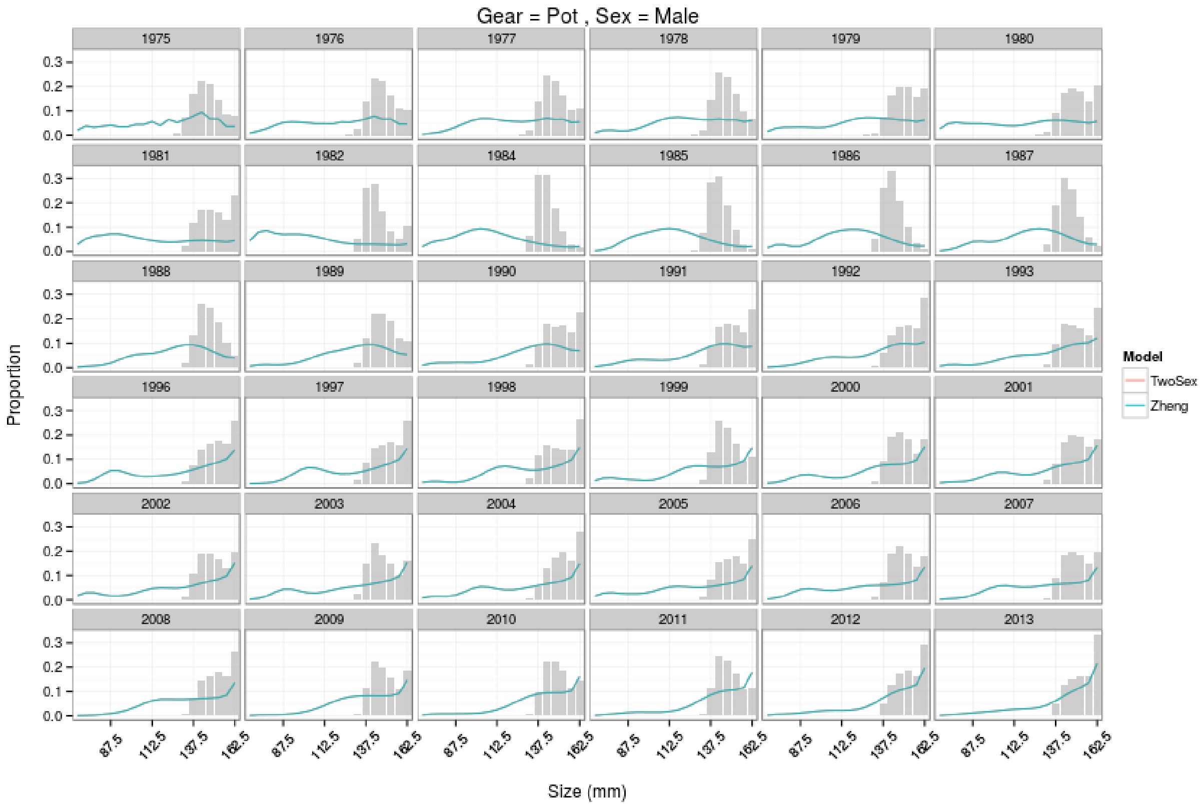


Figure 10: Growth increment.


Gear = Pot , Sex = Male
1975
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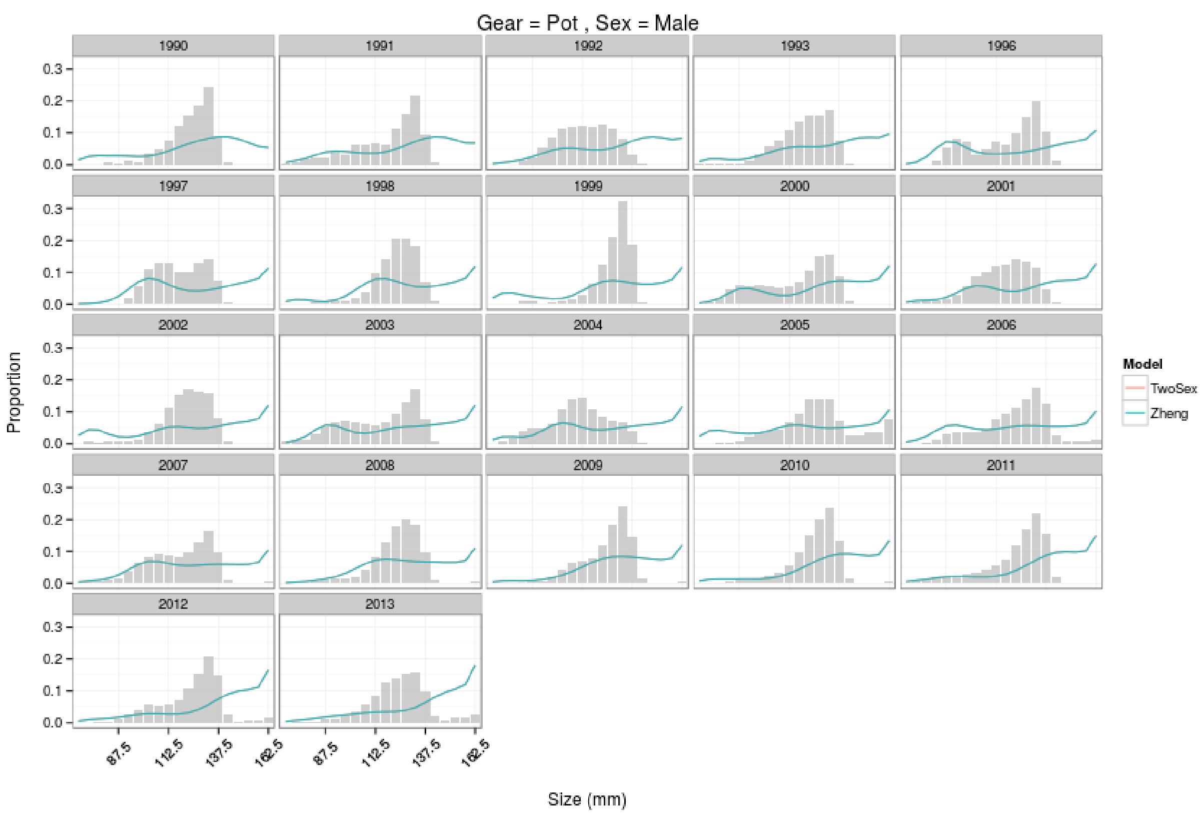
2009
2010
2011
2012
2013
Proportion
Size (mm)
Model
TwoSex
Zheng


Gear = Pot , Sex = Male
1990
1991
1992
1993
1996
1997
1998
1999
2000
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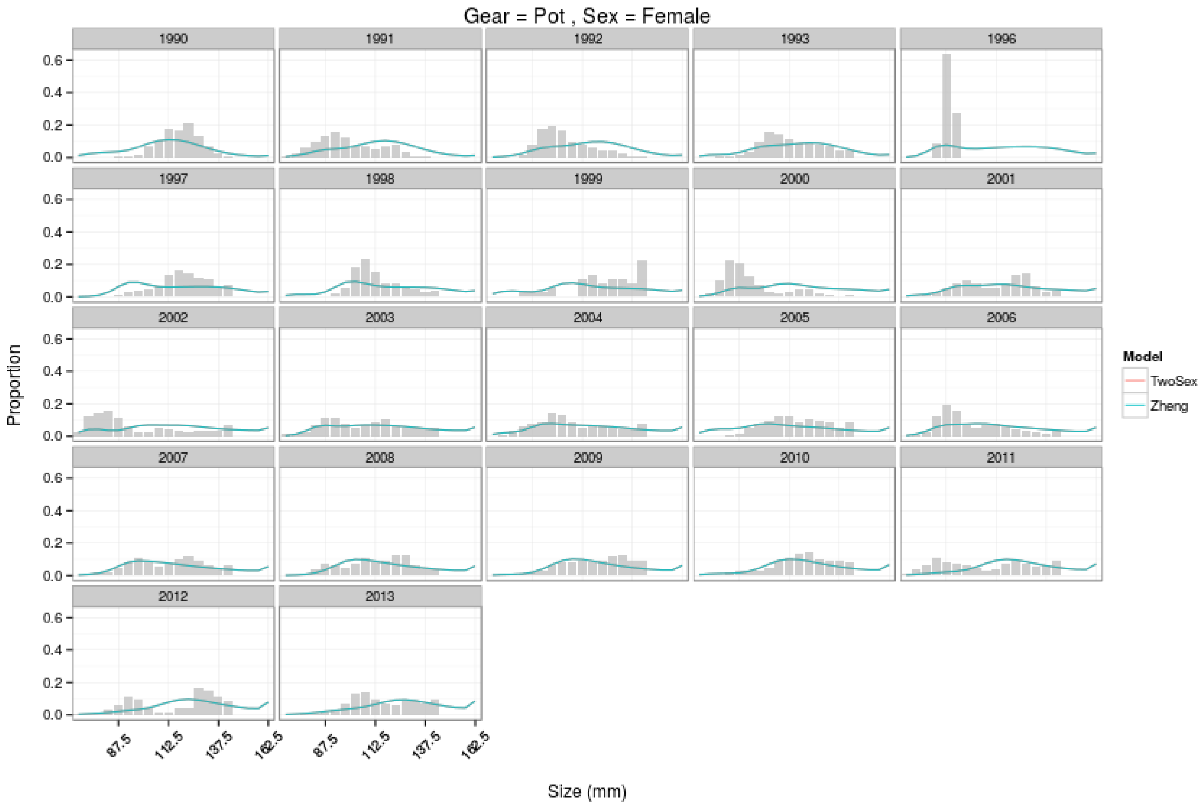
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Proportion
Size (mm)
Model
TwoSex
Zheng



Gear = Pot , Sex = Female
1990
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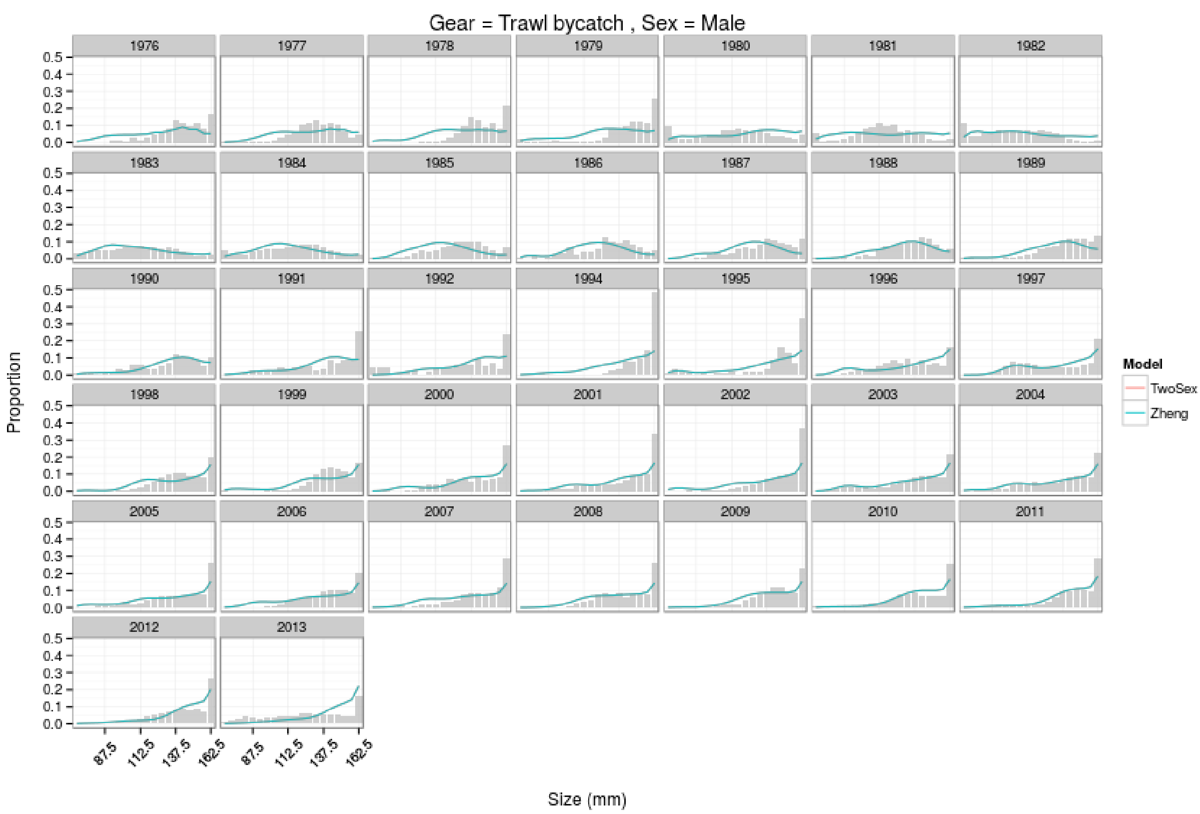
1992
1993
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Proportion
0.0
0.2
0.4
0.6
87.5
112.5
137.5
162.5
Size (mm)
Model
TwoSex
Zheng



Gear = Trawl bycatch , Sex = Male
1976
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1991
1992
1994
1995
1996
1997
1998
1999
2000
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2002
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2009
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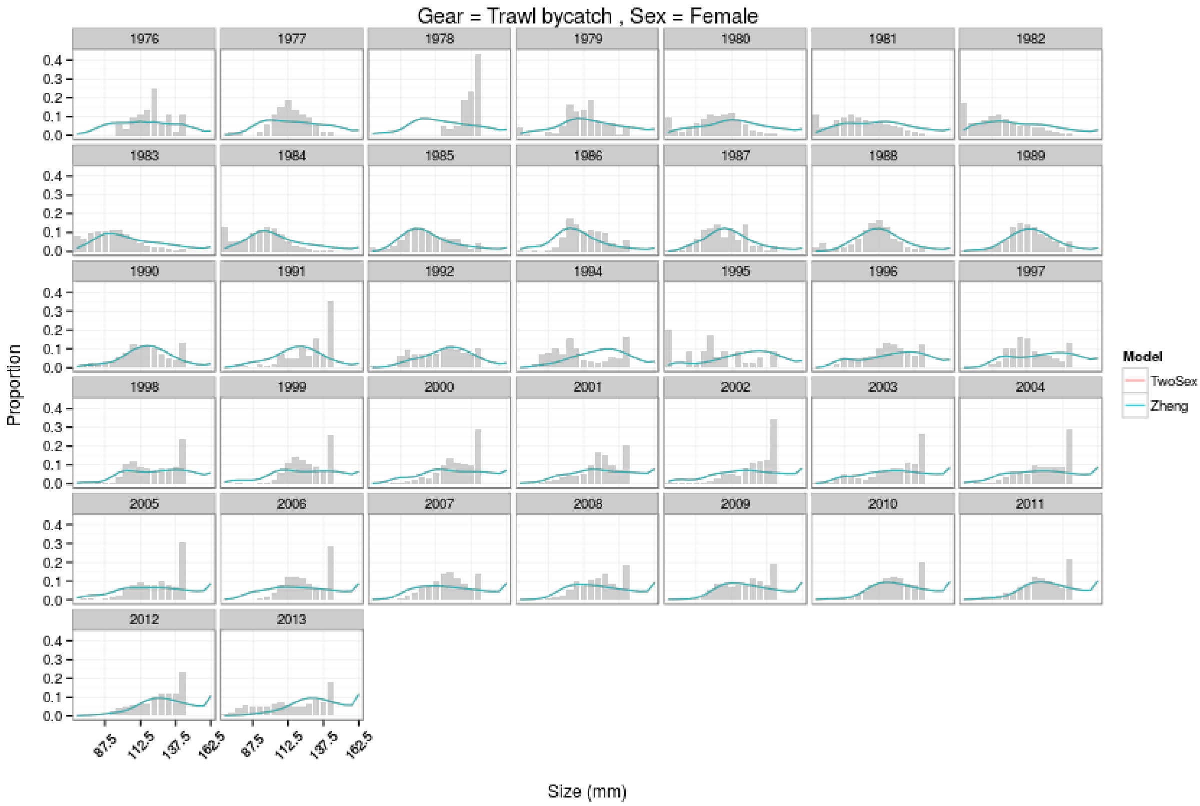
2011
2012
2013
Proportion
0.0
0.1
0.2
0.3
0.4
0.5
87.5
112.5
137.5
162.5
Size (mm)
Model
TwoSex
Zheng


Gear = Trawl bycatch , Sex = Female
1976
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1994
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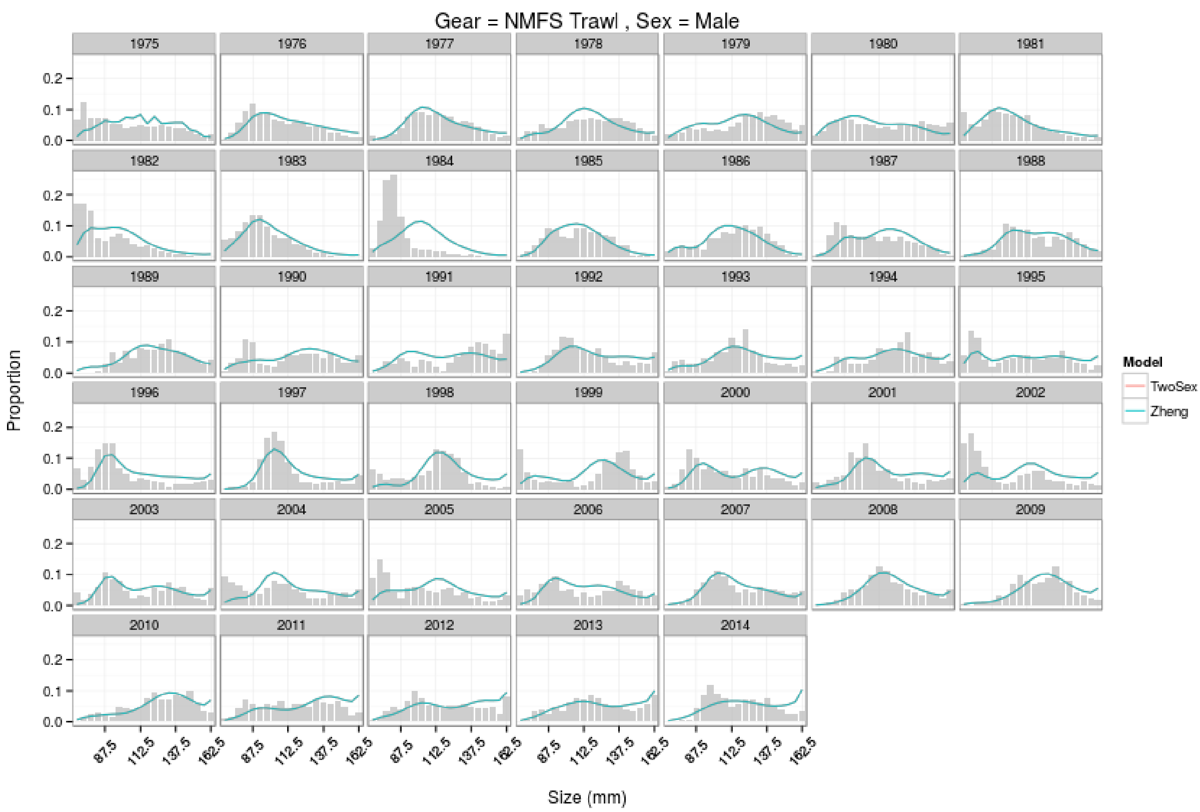
2011
2012
2013
Proportion
Size (mm)
Model
TwoSex
Zheng


Gear = NMFS Trawl , Sex = Male
1975
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1996
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1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Proportion
Size (mm)
Model
TwoSex
Zheng

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).
- 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.