Gmacs Example Stock Assessment

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Contents

Introduction

Gmacs is a generalized size-structured stock assessment modeling 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 (2012). 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

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.

Comparison of Data and Model Specifications

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

The table below currently just uses basic markdown table formatting. There is an option for Rmd to use something like this:

```r
knitr::kable(mtcars)
```

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160.0	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160.0	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108.0	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258.0	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360.0	175	3.15	3.440	17.02	0	0	3	2
Valiant	18.1	6	225.0	105	2.76	3.460	20.22	1	0	3	1
Duster 360	14.3	8	360.0	245	3.21	3.570	15.84	0	0	3	4
Merc 240D	24.4	4	146.7	62	3.69	3.190	20.00	1	0	4	2
Merc 230	22.8	4	140.8	95	3.92	3.150	22.90	1	0	4	2
Merc 280	19.2	6	167.6	123	3.92	3.440	18.30	1	0	4	4
Merc 280C	17.8	6	167.6	123	3.92	3.440	18.90	1	0	4	4
Merc 450SE	16.4	8	275.8	180	3.07	4.070	17.40	0	0	3	3
Merc 450SL	17.3	8	275.8	180	3.07	3.730	17.60	0	0	3	3
Merc 450SLC	15.2	8	275.8	180	3.07	3.780	18.00	0	0	3	3
Cadillac Fleetwood	10.4	8	472.0	205	2.93	5.250	17.98	0	0	3	4
Lincoln Continental	10.4	8	460.0	215	3.00	5.424	17.82	0	0	3	4
Chrysler Imperial	14.7	8	440.0	230	3.23	5.345	17.42	0	0	3	4
Fiat 128	32.4	4	78.7	66	4.08	2.200	19.47	1	1	4	1

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Honda Civic	30.4	4	75.7	52	4.93	1.615	18.52	1	1	4	2
Toyota Corolla	33.9	4	71.1	65	4.22	1.835	19.90	1	1	4	1
Toyota Corona	21.5	4	120.1	97	3.70	2.465	20.01	1	0	3	1
Dodge Challenger	15.5	8	318.0	150	2.76	3.520	16.87	0	0	3	2
AMC Javelin	15.2	8	304.0	150	3.15	3.435	17.30	0	0	3	2
Camaro Z28	13.3	8	350.0	245	3.73	3.840	15.41	0	0	3	4
Pontiac Firebird	19.2	8	400.0	175	3.08	3.845	17.05	0	0	3	2
Fiat X1-9	27.3	4	79.0	66	4.08	1.935	18.90	1	1	4	1
Porsche 914-2	26.0	4	120.3	91	4.43	2.140	16.70	0	1	5	2
Lotus Europa	30.4	4	95.1	113	3.77	1.513	16.90	1	1	5	2
Ford Pantera L	15.8	8	351.0	264	4.22	3.170	14.50	0	1	5	4
Ferrari Dino	19.7	6	145.0	175	3.62	2.770	15.50	0	1	5	6
Maserati Bora	15.0	8	301.0	335	3.54	3.570	14.60	0	1	5	8
Volvo 142E	21.4	4	121.0	109	4.11	2.780	18.60	1	1	4	2

The above is the output of an R data.frame. This could be useful for reproducing model results or inputs from Gmacs i/o files.

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	5	

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

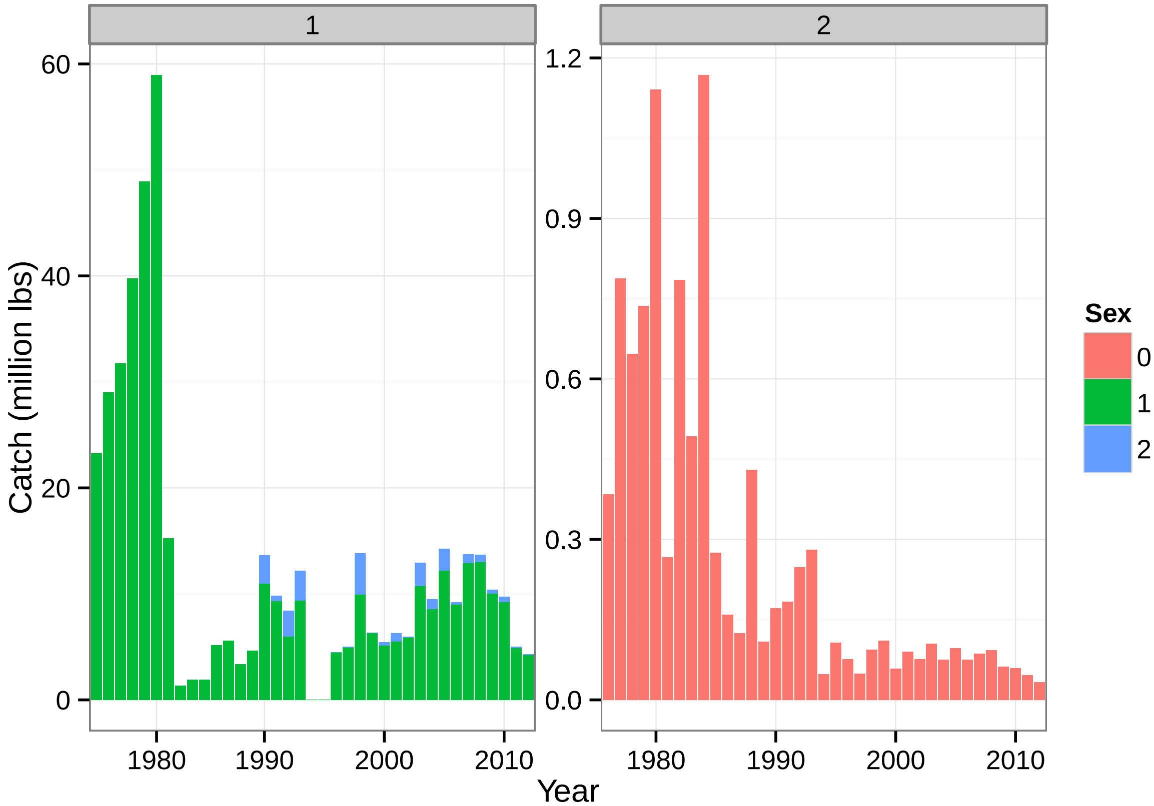
Comparison of Model Results

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

Gmacs Results

In what follws, 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.

```
## Loading required package: ggplot2
## The ggplot theme has been set to bw for this working session
```



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, Andre E, Tzuchuan Huang, and Mark N Maunder. 2012. "Review of Integrated Size-Structured Models for Stock Assessment of Hard-to-Age Crustacean and Mollusc Species." *ICES Journal of Marine Science* 70 (1): 16–33. doi:10.1093/icesjms/fss185. http://icesjms.oxfordjournals.org/cgi/doi/10.1093/icesjms/fss185.

Zheng, J, and MSM Siddeek. 2014. "Bristol Bay Red King Crab Stock Assessment in Spring 2014." *Notes*. Alaska Department of Fish & Game.