Norton Sound Red King Crab Stock Assessment for the fishing year 2015/16
Progress Report

Toshihide Hamazaki[1] and Jie Zheng[2]
Alaska Department of Fish and Game Commercial Fisheries Division
[1]333 Raspberry Rd., Anchorage, AK 99518-1565
Phone: 907-267-2158
Email: Toshihide.Hamazaki@alaska.gov
[2]P.O. Box 115526, Juneau, AK 99811-5526
Phone : 907-465-6102
Email : Jie.Zheng@alaska.gov

Data Update: 2014

Trawl survey:

The triennial Norton Sound trawl survey was completed in August of 2014. Due to poor weather a total of 47 stations were trawled which was 28% lower than 2011 (65 stations). The total number of stations with red king crab in Norton Sound was 34 that was same as 2011. Estimated total male crab (> 73mm) is 5.4816 million crab (CV 48.6%) (Table 1). This was double that of 2011 (2.7017, CV 13%), and was the highest abundance ever recorded (previous highest record was 1976: 4.2475). However, 50% of this estimate was due to an anomalously large catch of 173 individuals, in a single tow at station 186 (Table 3, Figure 1). Length composition showed more <104mm crabs (Table 2).

Summer commercial fishery:

The commercial fishery opened June 25 and the last delivery came on August 15. A total of 129,956 crabs were harvested. Standardize CPUE was 1.23 that was higher 70% higher than 2013 (0.72), but lower than 2014-2013 average of 1.27 (Table 4). Catch length composition was similar to 2013 (Table 5).

Summer commercial discards:

Observer survey was conducted. The data are unavailable at this time.

Summer commercial fishery tag recovery:

Several tags were returned, but the data are unavailable at this time.

Discussion:

Obviously, trawl survey estimate is biased greatly high; however, our plan is to use the estimate as is. Hopefully, high survey CV will down weight the model influence. However, we are open to CPT's suggestions on this issue.

Data Analyses:

No data analyses have been conducted. I will start assessment as soon as all data become available. Alaska Department of Fish and Game biologists in Nome are still busy with the management of the salmon fisheries.

CPT and SSC recommendations and our response.

Since both CPT and SSC's comments are identical (SSC concurred with CPT, and a few additional comments were made), I list both comments first and respond as a whole.
All analyses were conducted using the SSC approved model (2io) and data (SAFE 2014).

CPT May 5-8 2014:

- The author plot likelihood profiles for a single M for all size classes and also likelihood profiles when M differs between the last size-class and the other size-classes..

- Explore different weighting schemes for the tag data; this may be important since there are a relatively small number of tags compared to other data. At present the tagging data may be overweighted because no account is taken of the possibility of overdispersion.

SSC June 2-4 2014

The SSC concurs with the CPT recommendations for future model improvements for NSRKC, including: (a) exploring different weighting schemes for the tag data; (b) relaxing some of the parameter bounds; and (c) constructing a likelihood profile for a single M for all size classes and one for when M differs between the last size-class and the other size-classes.

In addition, the SSC would like further information on the effects of sea ice and salinity on the winter survey, as suggested by public testimony.

The SAFE should acknowledge the importance of NSRKC to subsistence users. The SSC also requests in the future that the authors and CPT provide a clear and thorough rationale for their choice of a preferred model and the selection of the Tier level.

In light of the choice of Model 2io (with growth estimation inside the model) as the preferred model, it would be useful to reconsider Models 1, 3, and 4 (pooled selectivity over the two surveys and treatment of the winter survey data) with this feature.

Author response to CPT and SSC

- **likelihood profiles for a single M for all size classes and also likelihood profiles when M differs between the last size-class and the other size-classes..**

  Likelihood profiles were constructed for M ranging 0.1- 0.5 on 1) single M for all size classes, and 2) M differs between the last size class and other size classes.

Single M for all size classes (Figures 2-7)

Similar to the results of 2013 SAFE, the total likelihood was lowest when M = 0.4 (Figure 2,3). However, lowest M differed among individual likelihood. While trawl survey and length comp was minimized at M = 0.4, summer commercial length comp was minimized at M = 0.3.

Effects of increasing M on estimates of parameters seem to appear greatly on winter pot selectivity and NOAA trawl survey selectivity (Figure 4,5,6). At default M = 0.18, both winter pot and NOAA trawl survey selectivity was 1.0 (Figure 5); however, at M = 0.4 winter pot survey selectivity was similar to that model 0 of 2013 SAFE, and selectivity of NOAA trawl became differ from that of ADFG (Figure 6).

Increasing M also affected MMB trajectories (Figure 7), Between scenarios, most of changes affected greatly model fits of pre 1991 data.

M differ differs between the last size class and other size classes (Figures 8-13)

Expectedly, likelihood became lowest around M = 0.2 (Figures 7, 8). This is exactly what it should be, because M = 0.628 for the last size class was selected to minimize total likelihood under M = 0.18 for all other classes (SAFE 2012).

- **Different weighting schemes for the tag data (Figures 14-20)**

  In the likelihood (SAFE 2014, Appendix 1, equation 31), weight was included as

$$\sum_{s=1}^{s=2}\sum_{t=1}^{t=3}\sum_{l'=1}^{l'=6} K_{l',t,s}\left[\sum_{l=1}^{l=6} P_{l',l,t}\ln(\hat{P}_{l',l,t,s}+\kappa) - \sum_{l=1}^{l=6} P_{l',l,t}\ln(P_{l',l,t,s}+\kappa)\right]$$

For implementation of this request, there are two ways of implementations: 1) change effective samples size (K), and 2) add weighting factor.

$$W\cdot\sum_{s=1}^{s=2}\sum_{t=1}^{t=3}\sum_{l'=1}^{l'=6} K_{l',t,s}\left[\sum_{l=1}^{l=6} P_{l',l,t}\ln(\hat{P}_{l',l,t,s}+\kappa) - \sum_{l=1}^{l=6} P_{l',l,t}\ln(P_{l',l,t,s}+\kappa)\right]$$

We chose the second option and changed W from 0.05 to 1.0 (Figures 14-20)

Unfortunately, the model did not converge at weight = 0.4; however, individual likelihood did not seem to change due to reduced weights (Figures 14-16).

Effects of weighting change is better estimation of winter pot selectivity parameter (Figures 17, 18).

Despite changes, projection of MMB was almost identical, regardless of varying weights (Figures 19, 20).

The SSC would like further information on the effects of sea ice and salinity on the winter survey, as suggested by public testimony.

Sea ice conditions and salinity data have never been collected during the winter survey. However, other agencies may have collected data, which I am not aware of. SSC's suggestions for possible lead (e.g., who might know existing of data) are greatly appreciated.

The SAFE should acknowledge the importance of NSRKC to subsistence users. The SSC also requests in the future that the authors and CPT provide a clear and thorough rationale for their choice of a preferred model and the selection of the Tier level.

Winter subsistence and commercial fishery catch is unlimited. Despite that, winter subsistence catch 2013/14 season fell to 3,252, 50% down from 2012/13 season of 7,662 (Table 6). Commercial winter catch also fell to 14,986, 34% down from 2012/13 season of 22,639. CPT's suggestions on how to address subsistence needs in choice of a preferred model and the selection of the Tier level.

In light of the choice of Model 2io (with growth estimation inside the model) as the preferred model, it would be useful to reconsider Models 1, 3, and 4 (pooled selectivity over the two surveys and treatment of the winter survey data) with this feature.

The results were the same as those reported in SAFE 2014, and thus were not reported here. I present my thoughts about issues regarding model parsimony.

Discussion

Overall, profile likelihood with tagging data (i.e., growth transition matrix estimated within an assessment model) was similar to previous ones (i.e., growth transition matrix estimated separately outside the assessment model) (SAFE 2012, 2013). This seems to suggest that tag recovery data have strong information estimating growth transition matrix, and that estimating inside or outside of the assessment does not greatly affect model outcome, though reducing likelihood weight helps to estimate winter pot survey selectivity.

Model parsimony

The SSC notes that from model parsimony one would select combined trawl selectivity parameters, especially if treating them separately does not improve model fit. In fact the two selectivity have been combined based on previous works on model parsimony until 2013 SAFE when a CPT member challenged this long held assumption. My observation is that shape of the NOAA and ADFG trawl selectivity are affected by choice of M, changing of weights, and inclusion of exclusion of data. This suggests that combining two selectivity may be justified in one assessment year but may not be justified in other assessment years.

Theoretically, catch selectivity of NOAA and ADFG trawl surveys should be different because they used different survey net configurations, boat, trawling survey protocols. This is also the case for separating commercial catch selectivity between 1977-1992 and 1993-present, even though shape of the two selectivity seem very close enough to be combined as one (Figures 4, 5). Further extending, summer commercial fishery gear configuration changed in 2008 when installation of escapement mechanism became mandatory. Then, should summer commercial catch selectivity be divided into 3 periods: 1977-1992, 1993-2007, 2008-2014? Guidelines for combining or not combining selectivity parameters are greatly appreciated.

Tagging Weights

Down-weighting tag recovery data helped estimating winter pot selectivity parameter, even though this did not greatly improve model fit and model projection. Since winter catch is miniscule compared to summer, uncertainties of catch composition had little effects on overall model fit. However, this does not necessarily justify ignoring winter catch/pot selectivity. I will down weight tag-recovery data for 2015 SAFE.

What to do about M?

Also discussed in 2013 SAFE, the biggest factor influencing model fit is setting up of M. Under M = 0.18 assumption, M of the last length class need to be increased for model fit, even though there is little biological justifications. Increase of M with constant for all length class (e.g. M = 0.4) is more justified in terms of model fit and reasonable biological assumption. However, higher M will result in higher OFL and ABC. Under assumption of M = 0.18, OFL is 16.4% and ABC is 14.8% (ABC = 0.9*OFL) of harvestable biomass. When M = 0.4 OFL is 33.0% and ABC is 29.7% of harvestable biomass. In other words, under M = 0.4 OFL and ABC will be increased by 100%. This may not be considered precautionary approach for a stock of little information. Hence, CPT and SSC did not recommend alternative models with higher M constant for all length classes (SAFE 2013).

Alternatively, CPT/SSC may adopt higher M and higher ABC buffer of NSRKC stock (say, M = 0.4, and ABC buffer 55%: ABC = 0.45*OFL) based on uncertainty. If this option were to be considered, I request CPT's guideline for selection of a buffer.

2015 SAFE model alternatives

Based on the above results, our plan for 2015 SAFE alternative model configurations are

1. Convert 2014 SAFE model 2io from July-June schedule to Feb-Jan schedule
2. Down-weight tagging data likelihood to 0.1
3. M = 0.18 for length classes 1-5 and M=0.648 for the last length class
4. Other suggestions are welcome.

Table 1. Summary of triennial trawl survey Norton Sound male red king crab abundance estimates. Trawl survey abundance estimate is based on 10×10 nmil^2 grid, except for 2010 (20×20 nmil^2).

				Survey coverage			Abundance ≥74 mm	
Year	Dates	Survey Agency	Survey method	surveyed stations	Stations w/ NSRKC	n mile^2 covered		CV
1976	9/02 - 9/05	NMFS	Trawl	103	62	10260	**4247.5**	**0.31**
1979	7/26 - 8/05	NMFS	Trawl	85	22	8421	**1417.2**	**0.20**
1980	7/04 - 7/14	ADFG	Pots				2092.3	N/A
1981	6/28 - 7/14	ADFG	Pots				2153.4	N/A
1982	7/06 - 7/20	ADFG	Pots				1140.5	N/A
1982	9/05 - 9/11	NMFS	Trawl	58	37	5721	**2791.7**	**0.29**
1985	7/01 - 7/14	ADFG	Pots				2320.4	0.083
1985	9/16 -10/01	NMFS	Trawl	78	49	7688	**2306.3**	**0.25**
1988	8/16 - 8/30	NMFS	Trawl	78	41	7721	**2263.4**	**0.29**
1991	8/22 - 8/30	NMFS	Trawl	52	38	5183	**3132.5**	**0.43**
1996	8/07 - 8/18	ADFG	Trawl	50	30	4938	**1264.7**	**0.317**
1999	7/28 - 8/07	ADFG	Trawl	53	31	5221	**2276.1**	**0.194**
2002	7/27 - 8/06	ADFG	Trawl	57	37	5621	**1747.6**	**0.125**
2006	7/25 - 8/08	ADFG	Trawl	101	45	10008	**2549.7**	**0.288**
2008	7/24 - 8/11	ADFG	Trawl	74	44	7330	**2707.1**	**0.164**
2010[a]	7/27 - 8/09	NMFS	Trawl	35	15	13749	**2041.0**	**0.455**
2011	7/18 - 8/15	ADFG	Trawl	65	34	6447	**2701.7**	**0.133**
2014	7/18 - 7/30	ADFG	Trawl	47	34	4700	**5481.5**	**0.486**

Table 2. Summer Trawl Survey size/shell composition

		New Shell						Old Shell					
Year	Sample	74-83	84-93	94-103	104-113	114-123	124+	74-83	84-93	94-103	104-113	114-123	124+
1976	1311	0.0214	0.1053	0.1915	0.3455	0.1831	0.0290	0.0046	0.0114	0.0252	0.032	0.0366	0.0145
1979	133	0.0151	0.0075	0.0301	0.0752	0.0827	0.0602	0	0.0075	0.0301	0.1203	0.3835	0.188
1982	256	0.0898	0.2031	0.2891	0.2109	0.0352	0.0078	0	0.0156	0.0195	0.043	0.0234	0.0625
1985	311	0.1190	0.2122	0.1865	0.1768	0.0643	0.0193	0	0	0.0193	0.0514	0.0868	0.0643
1988	306	0.2255	0.1405	0.1536	0.1275	0.0686	0.0392	0	0.0065	0.0131	0.0392	0.0882	0.0980
1991	250	0.0967	0.0223	0.0372	0.0743	0.0409	0.0223	0.0706	0.0297	0.0967	0.197	0.1747	0.1375
1996	196	0.2959	0.1786	0.1224	0.0816	0.0051	0.0153	0.0051	0.0357	0.0459	0.0612	0.0612	0.0918
1999	274	0.0109	0.1058	0.2993	0.2701	0.1314	0.0401	0	0.0036	0.0292	0.0511	0.0401	0.0182
2002	230	0.1261	0.1435	0.1565	0.0304	0.0348	0.0348	0.0304	0.0739	0.1087	0.0957	0.0913	0.0739
2006	208	0.3235	0.2614	0.1405	0.0752	0.0458	0.0294	0	0	0.0196	0.0458	0.0458	0.0131
2008	242	0.1743	0.2407	0.1286	0.112	0.0332	0.029	0.0083	0.0498	0.0705	0.0954	0.0125	0.0456
2010	68	0.1202	0.1366	0.2077	0.1257	0.1093	0.0437	0.0109	0.0328	0.082	0.071	0.0383	0.0219
2011	320	0.1282	0.0989	0.1282	0.2051	0.1612	0.0476	0.0037	0.0147	0.0256	0.0989	0.0513	0.0366
2014	361	0.1607	0.2576	0.1939	0.0997	0.0166	0.0233	0	0.0277	0.1053	0.0554	0.0471	0.0139

Table 3: 2014 Trawl survey crab catch by station

Station	Legal (CW > 4.75 inch)	P-1 CL (90-104mm)	P-2 CL (76-89mm)	Females
78	0	0	0	0
79	0	0	0	0
80	1	1	1	0
81	0	0	0	0
82	0	0	0	0
103	0	2	2	2
104	0	1	1	0
105	6	1	1	1
106	6	0	0	0
107	0	0	0	0
123	0	0	0	0
124	2	0	1	0
125	4	0	2	0
126	3	3	5	2
127	3	2	2	0
128	0	0	0	2
129	0	0	0	2
130	0	0	0	0
131	1	0	0	1
132	3	7	10	0
133	3	2	1	0
134	0	0	0	0
135	0	0	0	0
150	2	0	0	0
151	2	1	0	0
152	0	0	0	2
153	0	0	0	0
154	0	0	1	0
155	0	2	1	1
156	1	0	0	3
157	0	0	0	0
158	0	0	0	0
159	3	0	1	0
160	0	0	0	0
161	1	0	0	0
176	4	14	10	0
179	0	3	3	1
180	0	0	0	1
181	0	0	0	0
182	0	0	0	0
183	0	2	2	13
184	2	7	2	3
185	2	13	8	16
186	**60**	**74**	**40**	**5**
187	6	3	7	1
202	0	1	0	1
203	0	0	1	3

Table 4. Historical summer commercial red king crab fishery economic performance, Norton Sound Section, eastern Bering Sea, 1977-2014. Bold type shows data used for assessment model.

Year	Guideline Harvest Level (lbs) [b]	Commercial Harvest (lb) [a, b] Open Access	CDQ	Harvest	Total Number (Open Access) Vessels	Permits	Landings	Total Pots Registered	Pulls	ST CPUE CPUE	SD	Season Length Days	Dates	Mid-day from July 1
1977	[c]	0.52		**195,877**	7	7	13		5,457	**3.44**	**0.34**	60	[c]	**0.03**
1978	3.00	2.09		**660,829**	8	8	54		10,817	**2.82**	**0.23**	60	6/07-8/15	**0.03**
1979	3.00	2.93		**970,962**	34	34	76		34,773	**2.60**	**0.17**	16	7/15-7/31	**0.063**
1980	1.00	1.19		**329,778**	9	9	50		11,199	**2.43**	**0.25**	16	7/15-7/31	**0.063**
1981	2.50	1.38		**376,313**	36	36	108		33,745	**0.74**	**0.17**	38	7/15-8/22	**0.093**
1982	0.50	0.23		**63,949**	11	11	33		11,230	**0.13**	**0.25**	23	8/09-9/01	**0.14**
1983	0.30	0.37		**132,205**	23	23	26	3,583	11,195	**0.90**	**0.22**	3.8	8/01-8/05	**0.093**
1984	0.40	0.39		**139,759**	8	8	21	1,245	9,706	**1.09**	**0.23**	13.6	8/01-8/15	**0.107**
1985	0.45	0.43		**146,669**	6	6	72	1,116	13,209	**0.37**	**0.21**	21.7	8/01-8/23	**0.132**
1986	0.42	0.48		**162,438**	3	3		578	4,284	**1.00**	**0.43**	13	8/01-8/25	**0.153**
1987	0.40	0.33		**103,338**	9	9		1,430	10,258	**0.63**	**0.32**	11	8/01-8/12	**0.118**
1988	0.20	0.24		**76,148**	2	2		360	2,350	**1.51**	**0.70**	9.9	8/01-8/11	**0.115**
1989	0.20	0.25		**79,116**	10	10		2,555	5,149	**1.61**	**0.33**	3	8/01-8/04	**0.096**
1990	0.20	0.19		**59,132**	4	4		1,388	3,172	**1.18**	**0.42**	4	8/01-8/05	**0.099**
1991	0.34			**0**	No Summer Fishery									
1992	0.34	0.07		**24,902**	27	27		2,635	5,746	**0.26**	**0.31**	2	8/01-8/03	**0.093**
1993	0.34	0.33		**115,913**	14	20	208	560	7,063	**0.91**	**0.08**	52	7/01-8/28	**0.09**
1994	0.34	0.32		**108,824**	34	52	407	1,360	11,729	**0.81**	**0.05**	31	7/01-7/31	**0.044**
1995	0.34	0.32		**105,967**	48	81	665	1,900	18,782	**0.48**	**0.04**	67	7/01-9/05	**0.066**
1996	0.34	0.22		**74,752**	41	50	264	1,640	10,453	**0.45**	**0.06**	57	7/01-9/03	**0.096**
1997	0.08	0.09		**32,606**	13	15	100	520	2,982	**0.86**	**0.08**	44	7/01-8/13	**0.101**
1998	0.08	0.03	0.00	**10,661**	8	11	50	360	1,639	**0.75**	**0.12**	65	7/01-9/03	**0.088**
1999	0.08	0.02	0.00	**8,734**	10	9	53	360	1,630	**0.78**	**0.12**	66	7/01-9/04	**0.101**
2000	0.33	0.29	0.01	**111,728**	15	22	201	560	6,345	**1.28**	**0.06**	91	7/01- 9/29	**0.11**
2001	0.30	0.28	0.00	**98,321**	30	37	319	1,200	11,918	**0.71**	**0.05**	97	7/01- 9/09	**0.085**
2002	0.24	0.24	0.01	**86,666**	32	49	201	1,120	6,491	**1.23**	**0.06**	77	6/15-9/03	**0.074**
2003	0.25	0.25	0.01	**93,638**	25	43	236	960	8,494	**0.91**	**0.05**	68	6/15-8/24	**0.079**
2004	0.35	0.31	0.03	**120,289**	26	39	227	1,120	8,066	**1.40**	**0.05**	51	6/15-8/08	**0.063**
2005	0.37	0.37	0.03	**138,926**	31	42	255	1,320	8,867	**1.32**	**0.05**	73	6/15-8/27	**0.071**
2006	0.45	0.42	0.03	**150,358**	28	40	249	1,120	8,867	**1.46**	**0.05**	68	6/15-8/22	**0.09**
2007	0.32	0.29	0.02	**110,344**	38	30	251	1,200	9,118	**1.15**	**0.05**	52	6/15-8/17	**0.063**
2008	0.41	0.36	0.03	**143,337**	23	30	248	920	8,721	**1.50**	**0.05**	73	6/23-9/03	**0.063**
2009	0.38	0.37	0.03	**143,485**	22	27	359	920	11,934	**0.94**	**0.04**	98	6/15-9/20	**0.1**
2010	0.40	0.39	0.03	**149,822**	23	32	286	1,040	9,698	**1.35**	**0.05**	58	6/28-8/24	**0.096**
2011	0.36	0.37	0.03	**141,626**	24	25	173	1,040	6,808	**1.66**	**0.05**	33	6/28-7/30	**0.038**
2012	0.47	0.44	0.03	**161,113**	40	29	312	1,200	10,041	**1.42**	**0.04**	72	6/29-9/08	**0.077**
2013	0.50	0.37	0.02	**130,603**	37	33	460	1,420	15,058	**0.72**	**0.04**	74	7/3-9/14	**0.107**
2014	0.38	0.36	0.03	**129,656**	52	33	309	1,560	10,127	**1.23**	**0.05**	52	6/25-8/15	**0.052**

[a] Deadloss included in total. [b] Millions of pounds. [c] Information not available.

Table 5. Summer commercial catch size/shell composition. Sizes in this and Tables 5-10 and 12 are mm carapace length. Legal size (4.75 inch carapace width is approximately equal to 124 mm carapace length.

		New Shell						Old Shell					
Year	Sample	74-83	84-93	94-103	104-113	114-123	124+	74-83	84-93	94-103	104-113	114-123	124+
1977	1549	0	0	0.0032	0.4196	0.3422	0.1220	0	0	0	0.0626	0.040	0.0103
1978	389	0	0	0.0103	0.1851	0.473	0.3059	0	0	0	0.0051	0.0103	0.0103
1979	1660	0	0	0.0253	0.2325	0.3831	0.3217	0	0	0	0.0253	0.0006	0.0114
1980	1068	0	0	0.0037	0.0983	0.3062	0.5543	0	0	0	0.0028	0.0112	0.0234
1981	1748	0	0	0.0039	0.0734	0.1541	0.5090	0	0	0	0.0045	0.0504	0.2046
1982	1093	0	0	0.0421	0.1921	0.1647	0.5050	0	0	0.0037	0.0128	0.022	0.0576
1983	802	0	0	0.0387	0.4127	0.3579	0.0973	0	0	0.0037	0.0362	0.010	0.0436
1984	963	0	0	0.0966	0.4195	0.2804	0.0717	0	0	0.0104	0.0654	0.0488	0.0073
1985	2691	0	0.0004	0.0643	0.3122	0.3716	0.1747	0	0	0.0026	0.0334	0.0312	0.0097
1986	1138	0	0	0.029	0.3559	0.3937	0.1353	0	0	0.0018	0.0202	0.0378	0.0264
1987	1542	0	0	0.0166	0.1788	0.2912	0.3798	0	0	0.0025	0.0267	0.0650	0.0393
1988	1522	0.0007	0	0.0237	0.2004	0.3003	0.2181	0	0	0.0059	0.0644	0.0972	0.0894
1989	2595	0	0	0.0127	0.1643	0.3185	0.2148	0	0	0.0042	0.0555	0.1215	0.1084
1990	1289	0	0	0.0147	0.1435	0.3468	0.3251	0	0	0.0008	0.0372	0.0737	0.0582
1991													
1992	2566	0	0	0.0172	0.201	0.2662	0.2244	0	0	0.0027	0.0792	0.1292	0.080
1993	1813	0	0	0.0142	0.2312	0.3939	0.263	0	0	0.0004	0.0173	0.0437	0.0362
1994	404	0	0	0.0248	0.0941	0.0817	0.0891	0	0	0.0248	0.1881	0.25	0.2475
1995	1174	0	0	0.0392	0.2615	0.2853	0.207	0	0	0.0077	0.0486	0.0741	0.0767
1996	787	0	0	0.0318	0.2236	0.2389	0.141	0	0	0.014	0.1194	0.136	0.0953
1997	1198	0	0	0.0292	0.3656	0.3414	0.1244	0	0	0.0033	0.0559	0.0417	0.0384
1998	1055	0	0	0.0284	0.2332	0.2427	0.1071	0	0	0.0218	0.1118	0.1431	0.1118
1999	561	0	0	0.0026	0.2434	0.2698	0.3836	0	0	0	0	0.0423	0.0582
2000	17213	0	0	0.0194	0.2991	0.3917	0.1249	0	0	0.0028	0.0531	0.0654	0.0436
2001	20030	0	0	0.0243	0.2232	0.3691	0.2781	0	0	0.0008	0.0241	0.0497	0.0304
2002	5198	0	0	0.0442	0.2341	0.2814	0.3253	0	0	0.0046	0.0282	0.0419	0.0402
2003	5220	0	0	0.0232	0.3680	0.3197	0.1523	0	0	0.0011	0.0218	0.0465	0.0674
2004	9605	0	0	0.0087	0.3811	0.3880	0.1395	0	0	0.0004	0.0255	0.0347	0.0221
2005	5360	0	0	0.0022	0.2539	0.4709	0.1823	0	0	0	0.0205	0.0451	0.025
2006	6707	0	0	0.0021	0.1822	0.3484	0.199	0	0	0.0003	0.0498	0.1375	0.0807
2007	6125	0	0	0.0111	0.3574	0.3407	0.1714	0	0	0.0008	0.0247	0.0573	0.0366
2008	5766	0	0	0.0047	0.3512	0.3476	0.0668	0	0	0.0014	0.0895	0.0928	0.0461
2009	6026	0	0	0.0105	0.3445	0.3294	0.1339	0	0	0.0012	0.0768	0.0795	0.0242
2010	5902	0	0	0.0053	0.3855	0.3617	0.1095	0	0	0.0019	0.0546	0.0546	0.0271
2011	2552	0	0	0.0043	0.3170	0.3969	0.1387	0	0	0.0020	0.0611	0.0588	0.0212
2012	5056	0	0	0.0026	0.2421	0.4620	0.2067	0	0	0.0002	0.0259	0.0423	0.0182
2013	4203	0	0	0.0044	0.2388	0.3710	0.3020	0	0	0.0003	0.0140	0.0422	0.0272
2014	4682	0	0	0.0085	0.2828	0.2360	0.2565	0	0	0.0002	0.0412	0.0865	0.0882

Table 6. Historical winter commercial and subsistence red king crab fishery, Norton Sound Section, eastern Bering Sea, 1977-2013. Bold typed were used for assessment model.

		Commercial			Subsistence				
					Permits			Total Crab	
Model Year	Year[a]	# of Fishers	# of Crab Harvested	Winter[b]	Issued	Returned	Fished	Caught[c]	Retained[d]
1978	1978	37	**9,625**	1977/78	290	206	149	**NA**	**12,506**
1979	1979	1[f]	**221[f]**	1978/79	48	43	38	**NA**	**224**
1980	1980	1[f]	**22[f]**	1979/80	22	14	9	**NA**	**213**
1981	1981	0	**0**	1980/81	51	39	23	**NA**	**360**
1982	1982	1[f]	**17[f]**	1981/82	101	76	54	**NA**	**1,288**
1983	1983	5	**549**	1982/83	172	106	85	**NA**	**10,432**
1984	1984	8	**856**	1983/84	222	183	143	**15,923**	**11,220**
1985	1985	9	**1,168**	1984/85	203	166	132	**10,757**	**8,377**
1986	1985/86	5	**2,168**	1985/86	136	133	107	**10,751**	**7,052**
1987	1986/87	7	**1,040**	1986/87	138	134	98	**7,406**	**5,772**
1988	1987/88	10	**425**	1987/88	71	58	40	**3,573**	**2,724**
1989	1988/89	5	**403**	1988/89	139	115	94	**7,945**	**6,126**
1990	1989/90	13	**3,626**	1989/90	136	118	107	**16,635**	**12,152**
1991	1990/91	11	**3,800**	1990/91	119	104	79	**9,295**	**7,366**
1992	1991/92	13	**7,478**	1991/92	158	105	105	**15,051**	**11,736**
1993	1992/93	8	**1,788**	1992/93	88	79	37	**1,193**	**1,097**
1994	1993/94	25	**5,753**	1993/94	118	95	71	**4,894**	**4,113**
1995	1994/95	42	**7,538**	1994/95	166	131	97	**7,777**	**5,426**
1996	1995/96	9	**1,778**	1995/96	84	44	35	**2,936**	**1,679**
1997	1996/97	2[f]	**83[f]**	1996/97	38	22	13	**1,617**	**745**
1998	1997/98	5	**984**	1997/98	94	73	64	**20,327**	**8,622**
1999	1998/99	5	**2,714**	1998/99	95	80	71	**10,651**	**7,533**
2000	1999/2000	10	**3,045**	1999/2000	98	64	52	**9,816**	**5,723**
2001	2000/01	3	**1,098**	2000/01	50	27	12	**366**	**256**
2002	2001/02	11	**2,591**	2001/02	114	61	45	**5,119**	**2,177**
2003	2002/03	13	**6,853**	2002/03	107	70	61	**9,052**	**4,140**
2004	2003/04	2[f]	**522** [f]	2003/04[g]	96	77	41	**1,775**	**1,181**
2005	2004/05	4	**2,091**	2004/05	170	98	58	**6,484**	**3,973**
2006	2005/06	1[f]	**75[f]**	2005/06	98	97	67	**2,083**	**1,239**
2007	2006/07	8	**3,313**	2006/07	129	127	116	**21,444**	**10,690**
2008	2007/08	9	**5,796**	2007/08	139	137	108	**18,621**	**9,485**
2009	2008/09	7	**4,951**	2008/09	105	105	70	**6,971**	**4,752**
2010	2009/10	10	**4,834**	2009/10	125	123	85	**9,004**	**7,044**
2011	2010/11	5	**3,365**	2010/11	148	148	95	**9,183**	**6,640**
2012	2011/12	35	**9,157**	2011/12	204	204	138	**11,341**	**7,311**
2013	2012/13	26	**22,639**	2012/13	149	148	104	**21,524**	**7,622**
2014	2013/14	21	**14,986**	2013/14	103	103	75	**5,421**	**3,252**

a Prior to 1985 the winter commercial fishery occurred from January 1 - April 30. As of March 1985, fishing may occur from November 15 - May 15.

b The winter subsistence fishery occurs during months of two calendar years (as early as December, through May).

c The number of crab actually caught; some may have been returned.

d The number of crab Retained is the number of crab caught and kept.

f Confidentiality was waived by the fishers.

h Prior to 2005, permits were only given out of the Nome ADF&G office. Starting with the 2004-5 season, permits were given out in Elim, Golovin, Shaktoolik, and White Mountain.

Figure 1: 2014 trawl survey station. Large cicrcle indicates the station of highest catch (station 186).

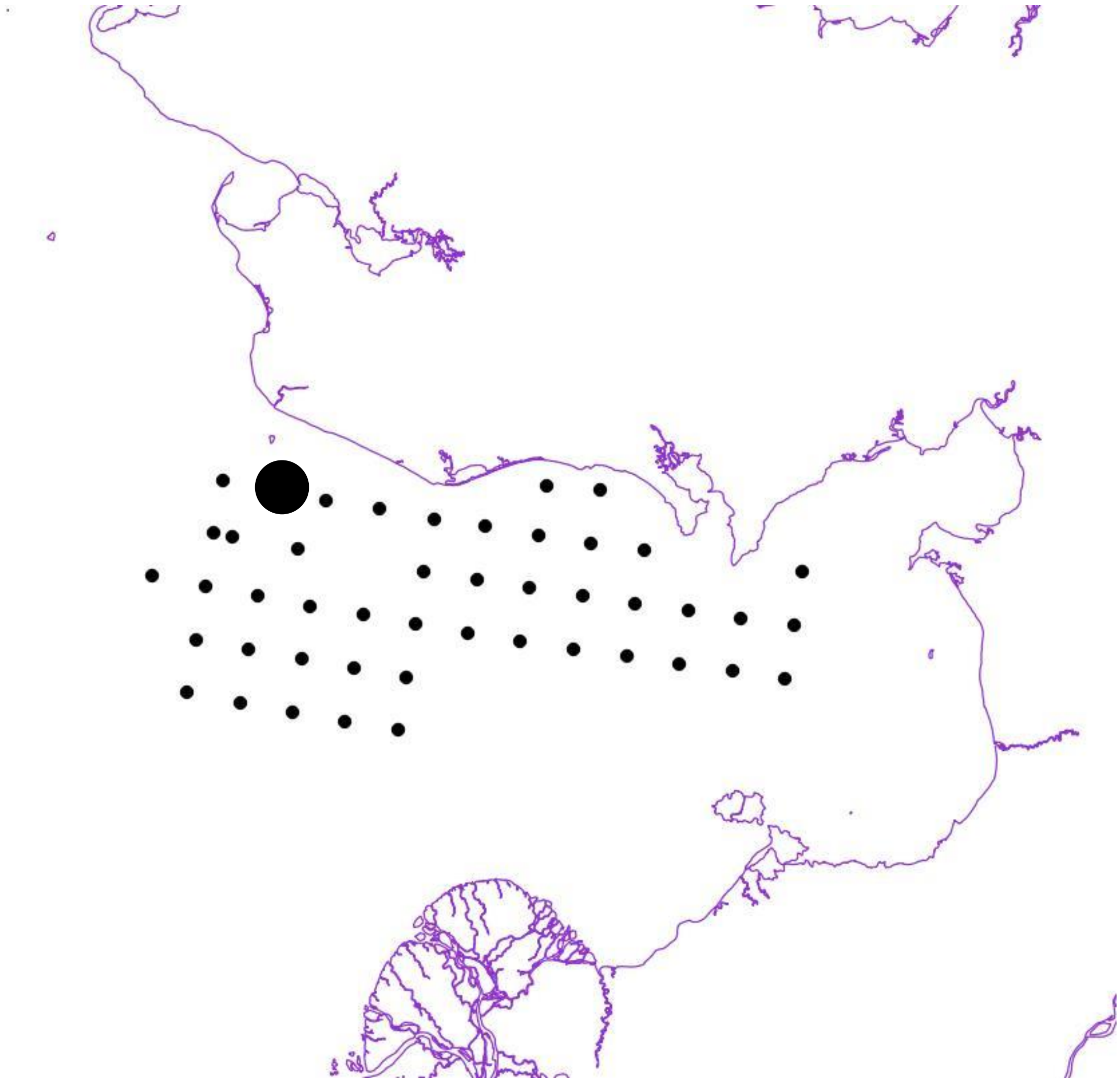

Figure 2: Likelihood profile M: 0.1 – 0.5 equal for all length classes

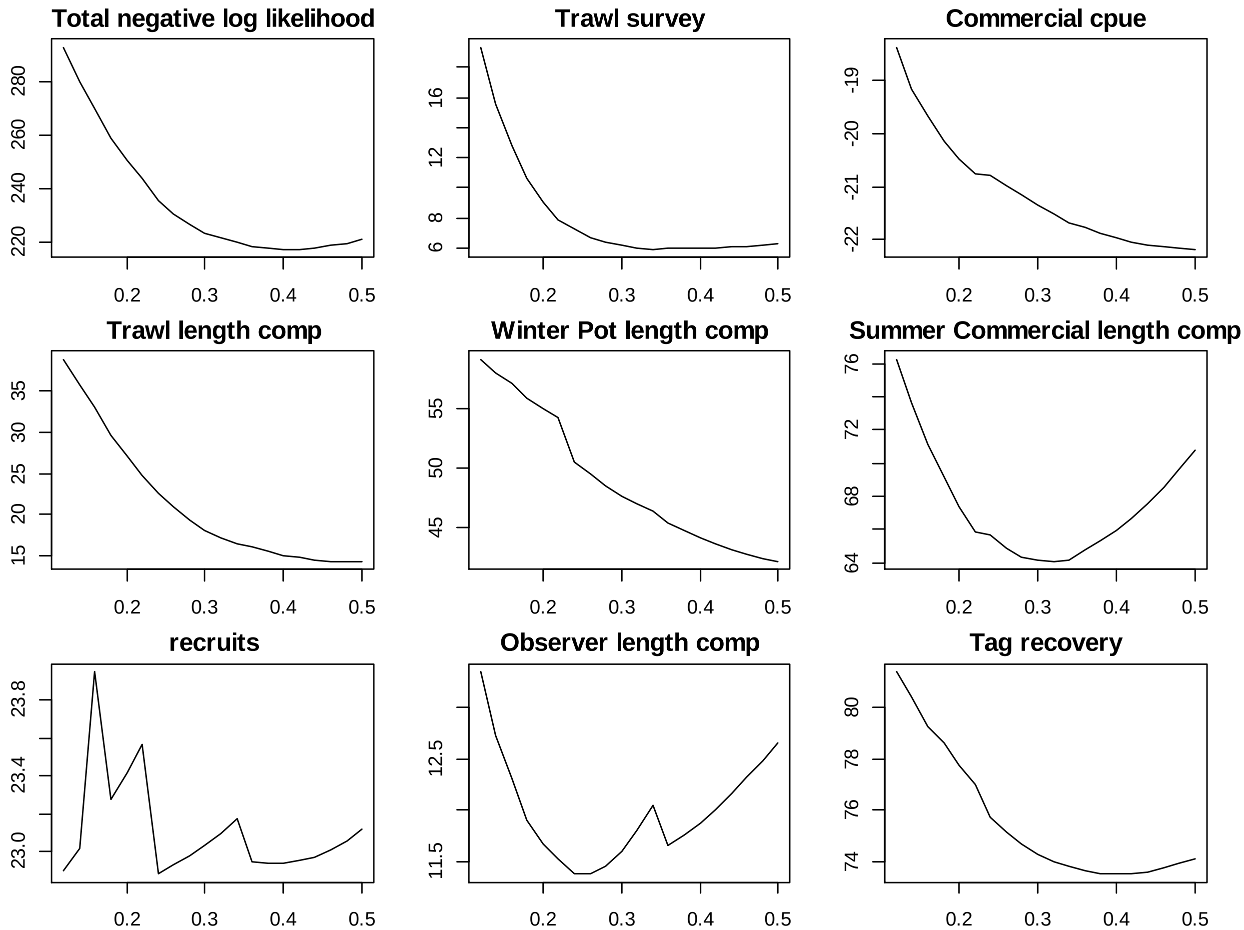

Figure 3: Likelihood profile M: 0.1 – 0.5 equal for all length classes

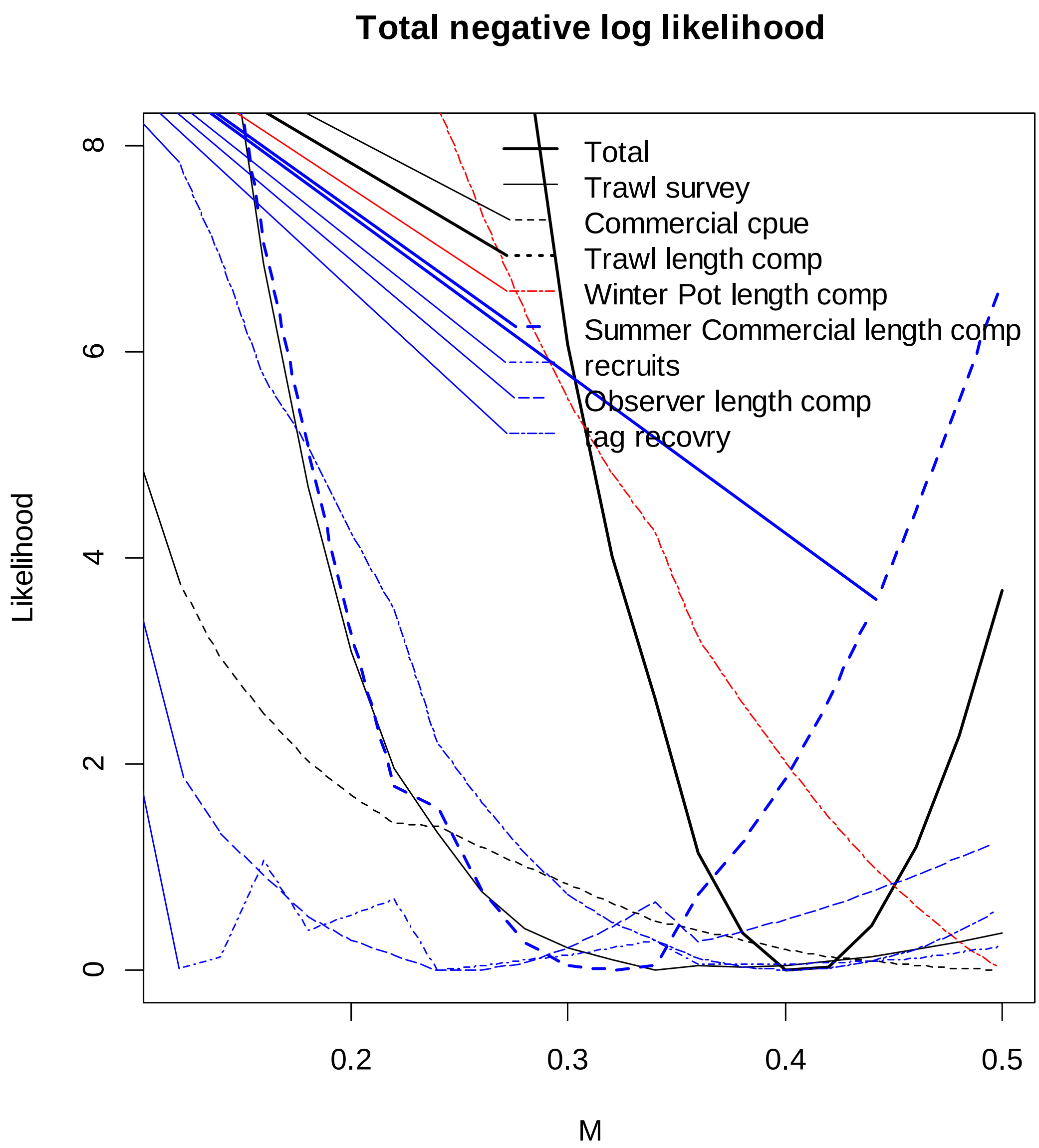

Figure 4: Changes of parameter estimates M: 0.1 – 0.5 equal for all length classes

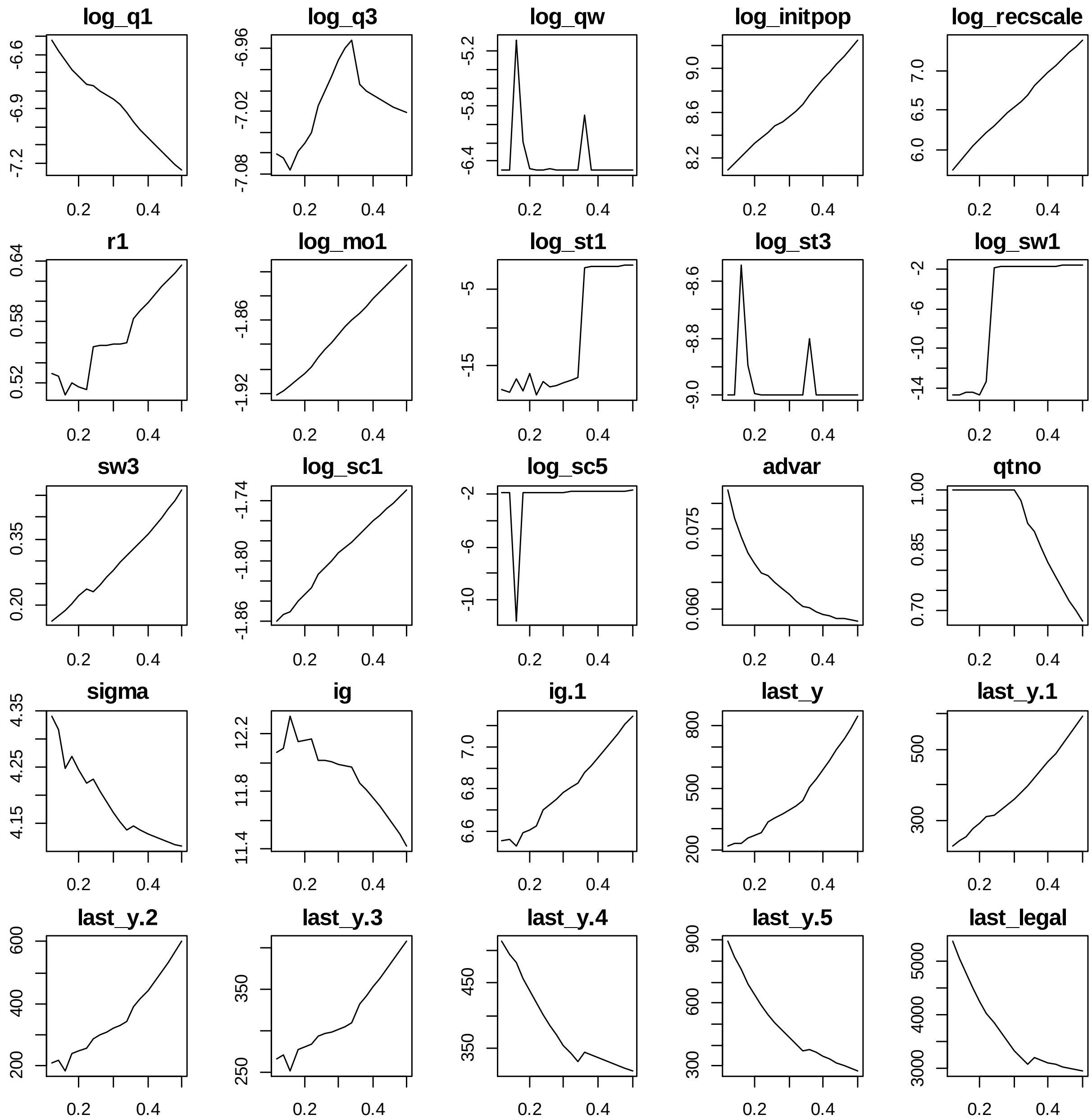

Figure 5: Selectivity-molting parameters baseline from SAFE 2014

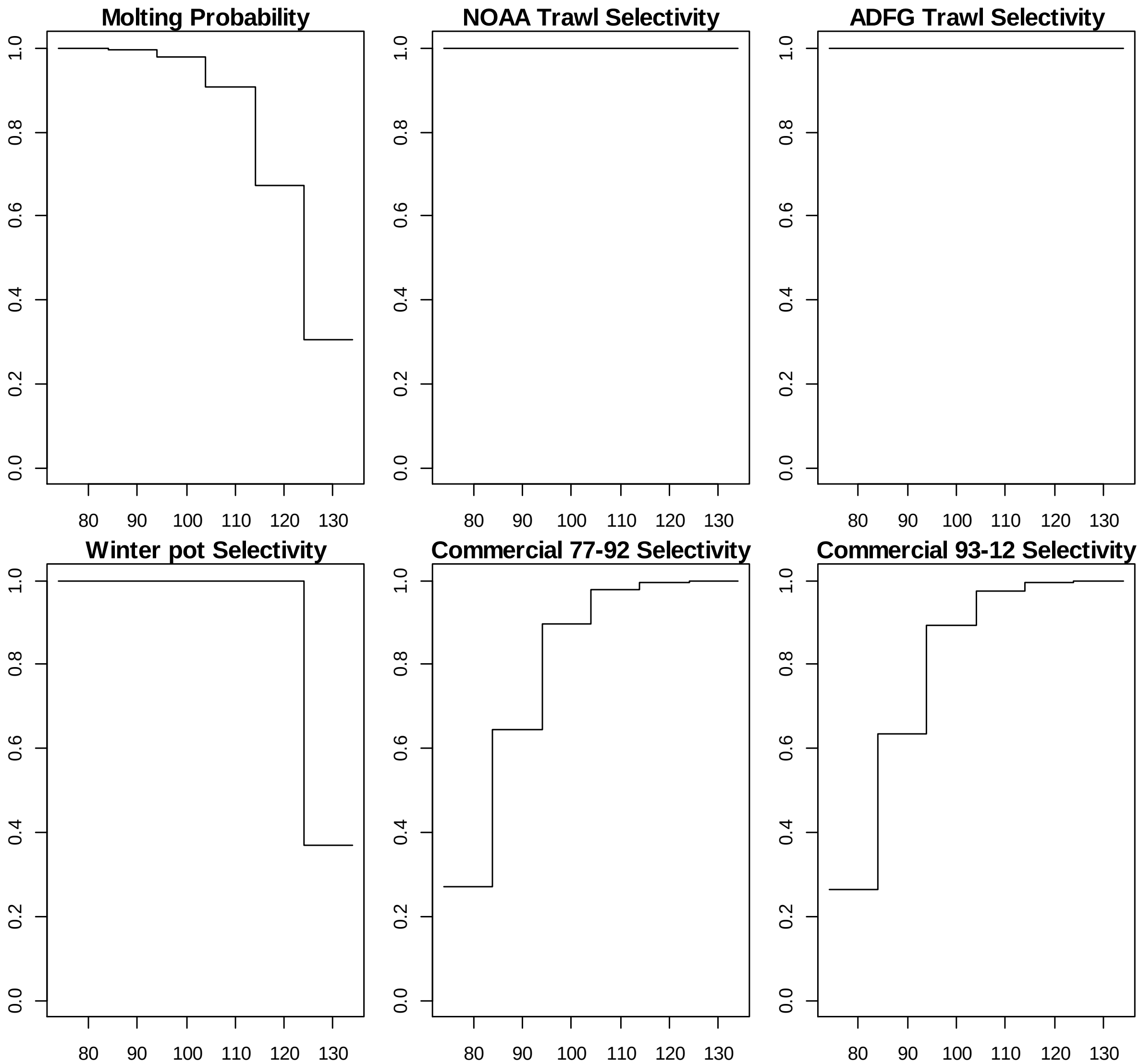

Figure 6: Selectivity-molting parameters M = 0.4 for all length classes

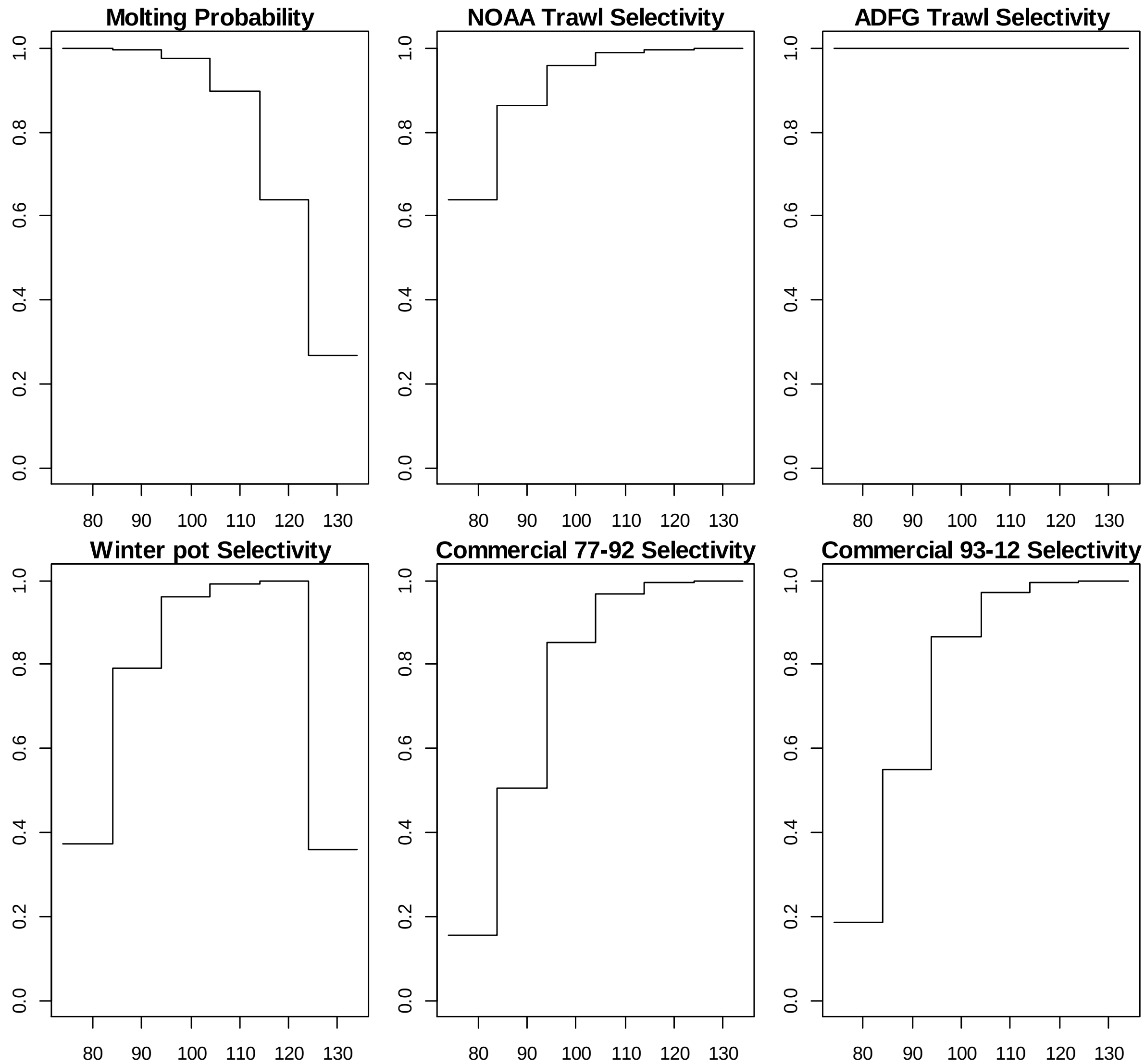

Figure 7: MMB projection, M: 0.1 – 0.5 equal for all length classes

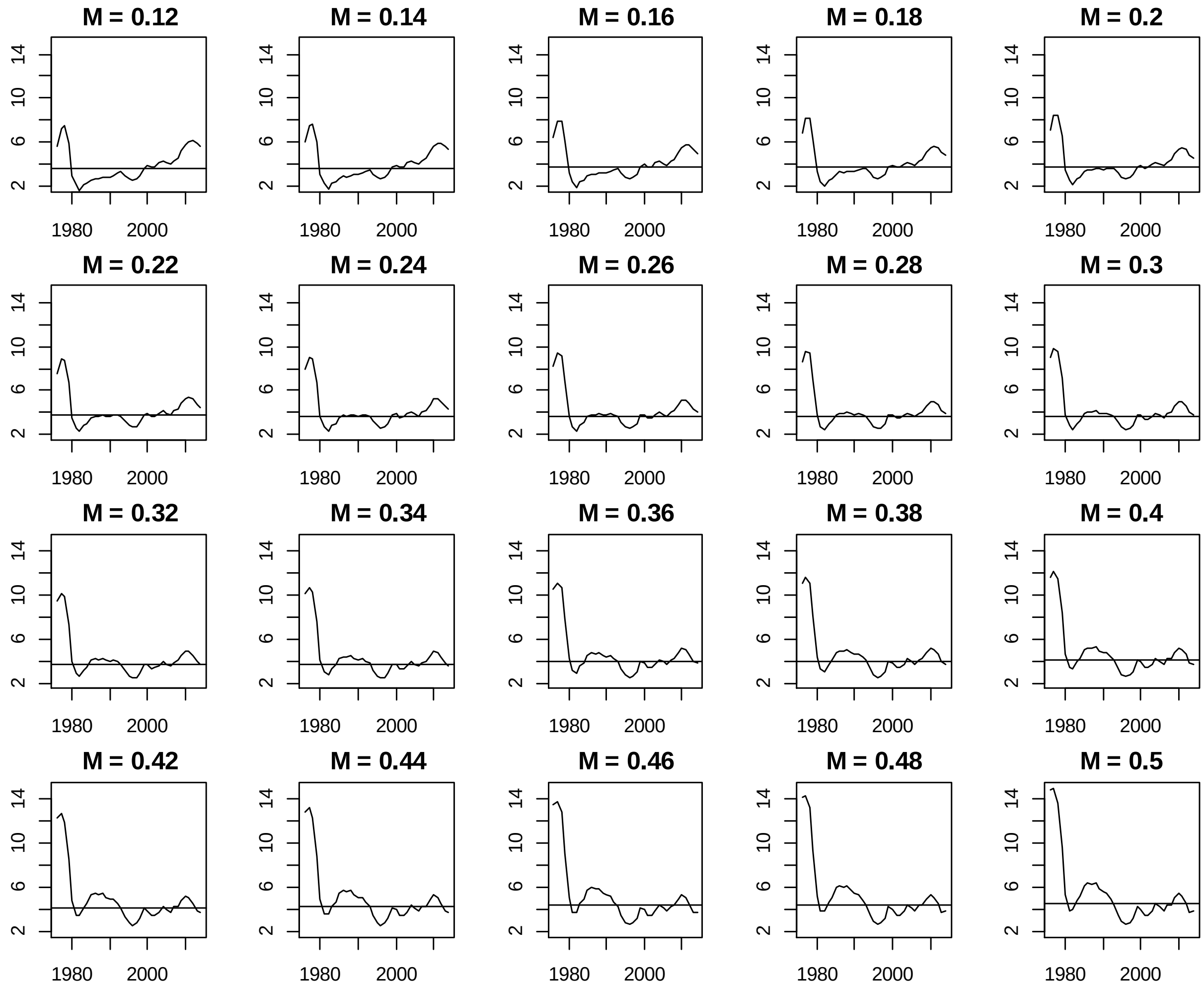

Figure 8: MMB projection for M: 0.1 – 0.5 equal for all length classes

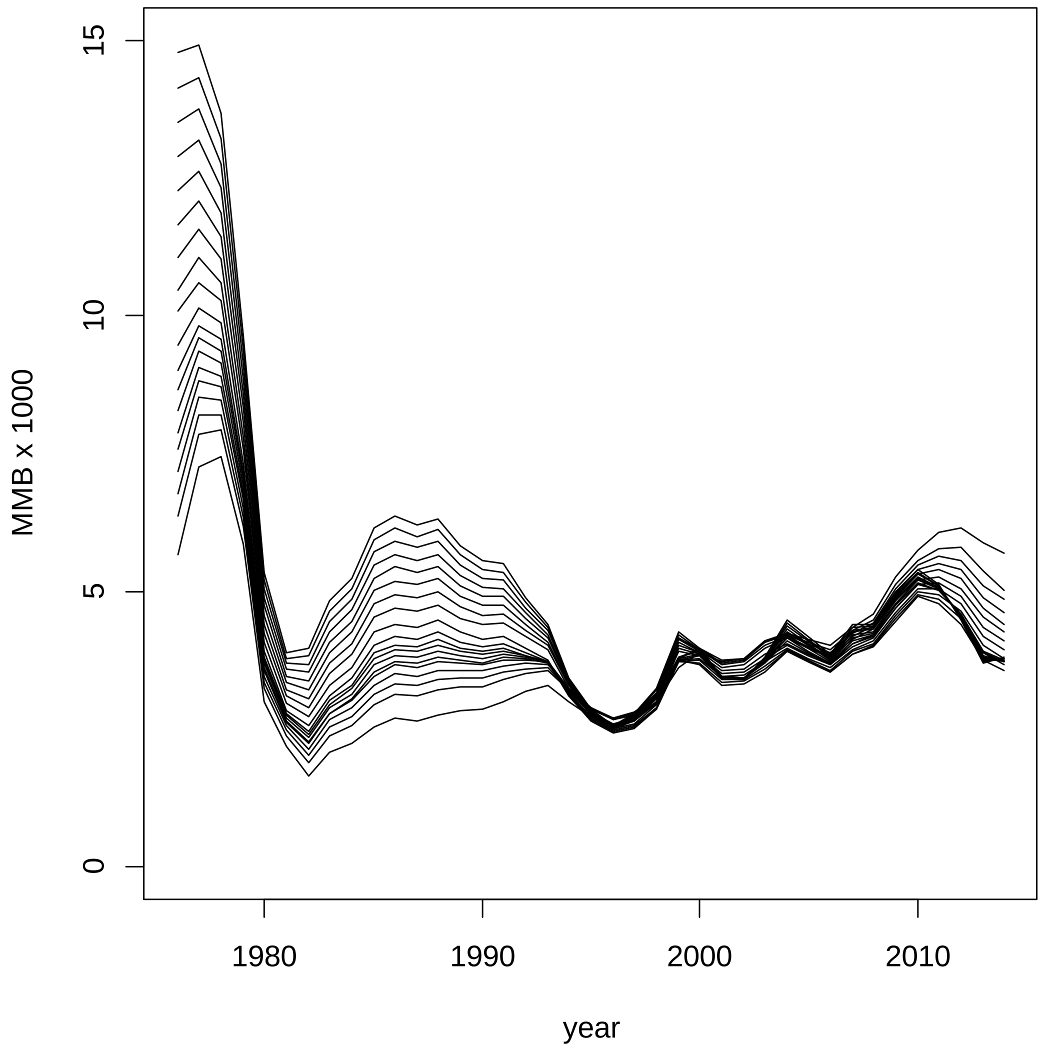

Figure 9: Likelihood profile: M 0.1-0.5 with last length class different.

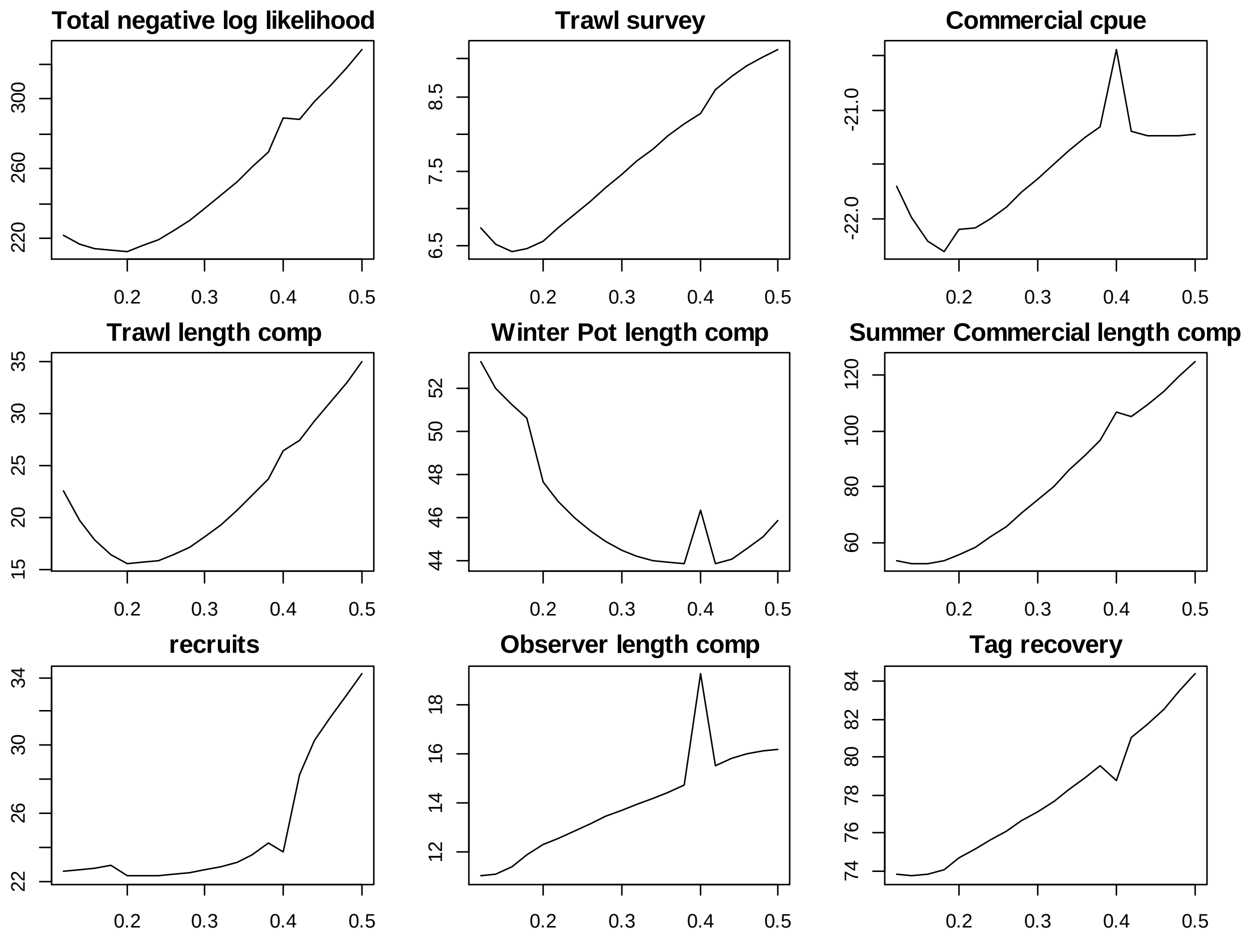

Figure 10: Likelihood profile: M 0.1-0.5 with last length class different.

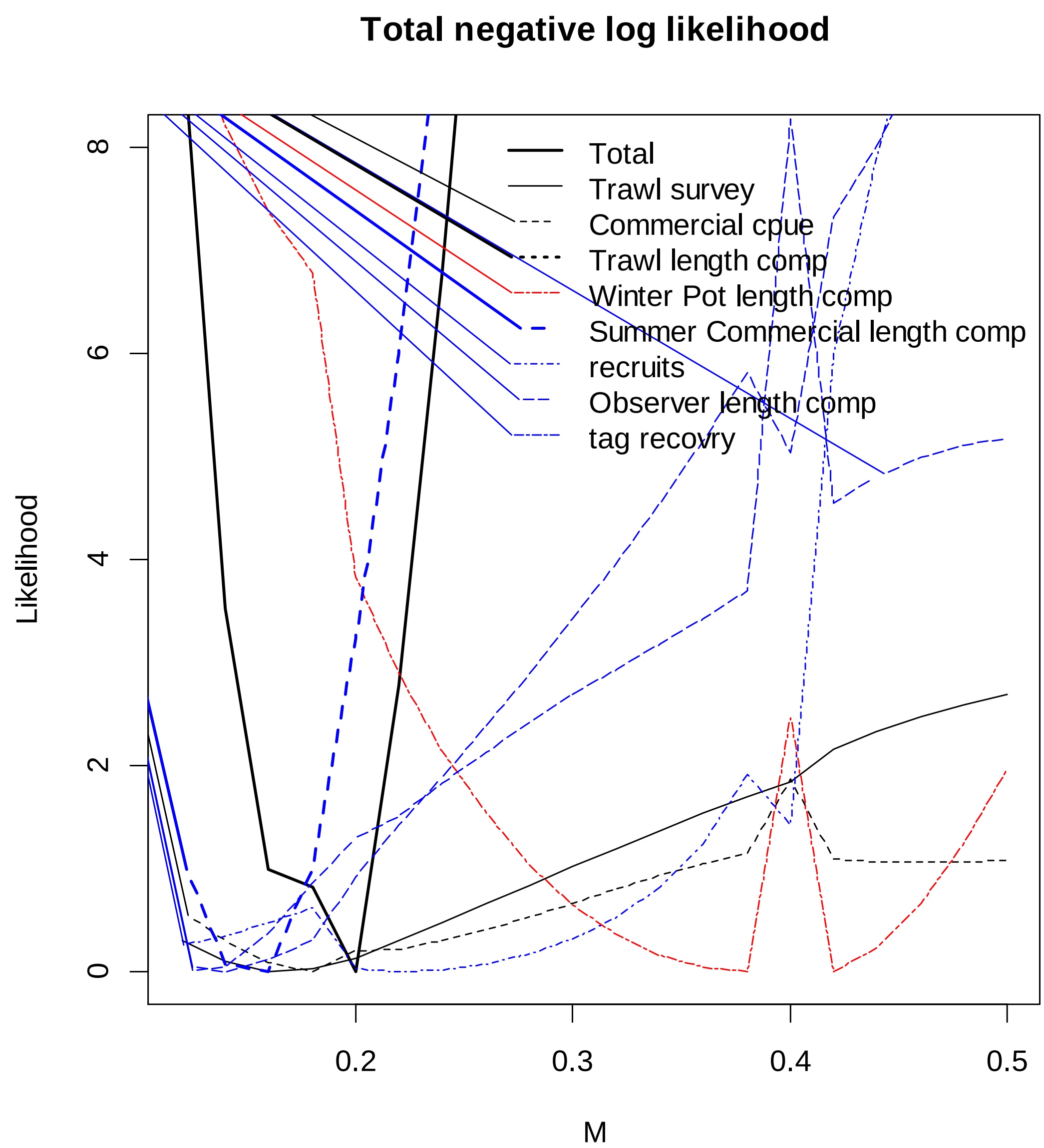

Figure 11: Change of parameters : M 0.1-0.5 with last length class different.

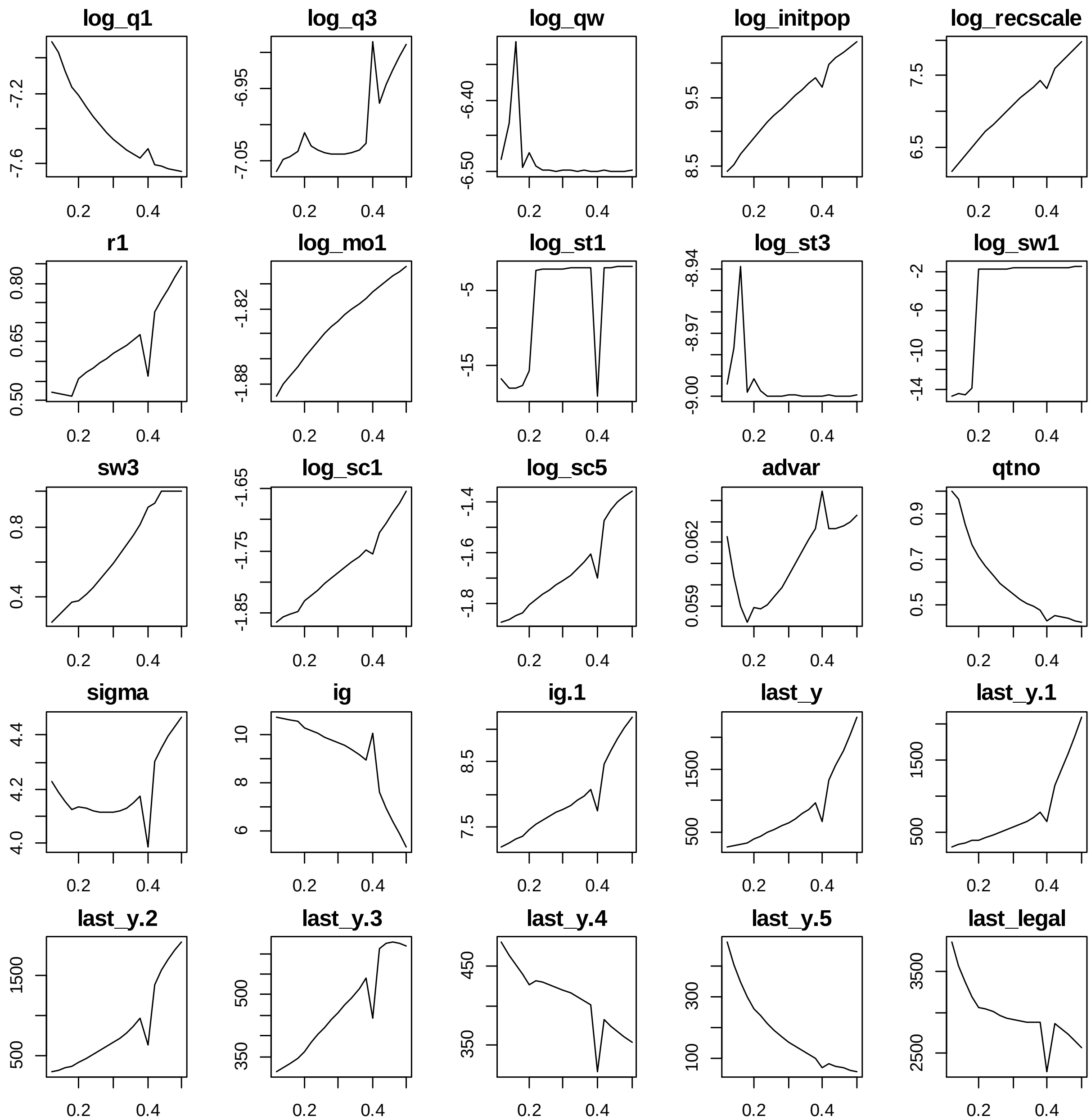

Figure 12: MMB projection : M 0.1-0.5 with last length class different.

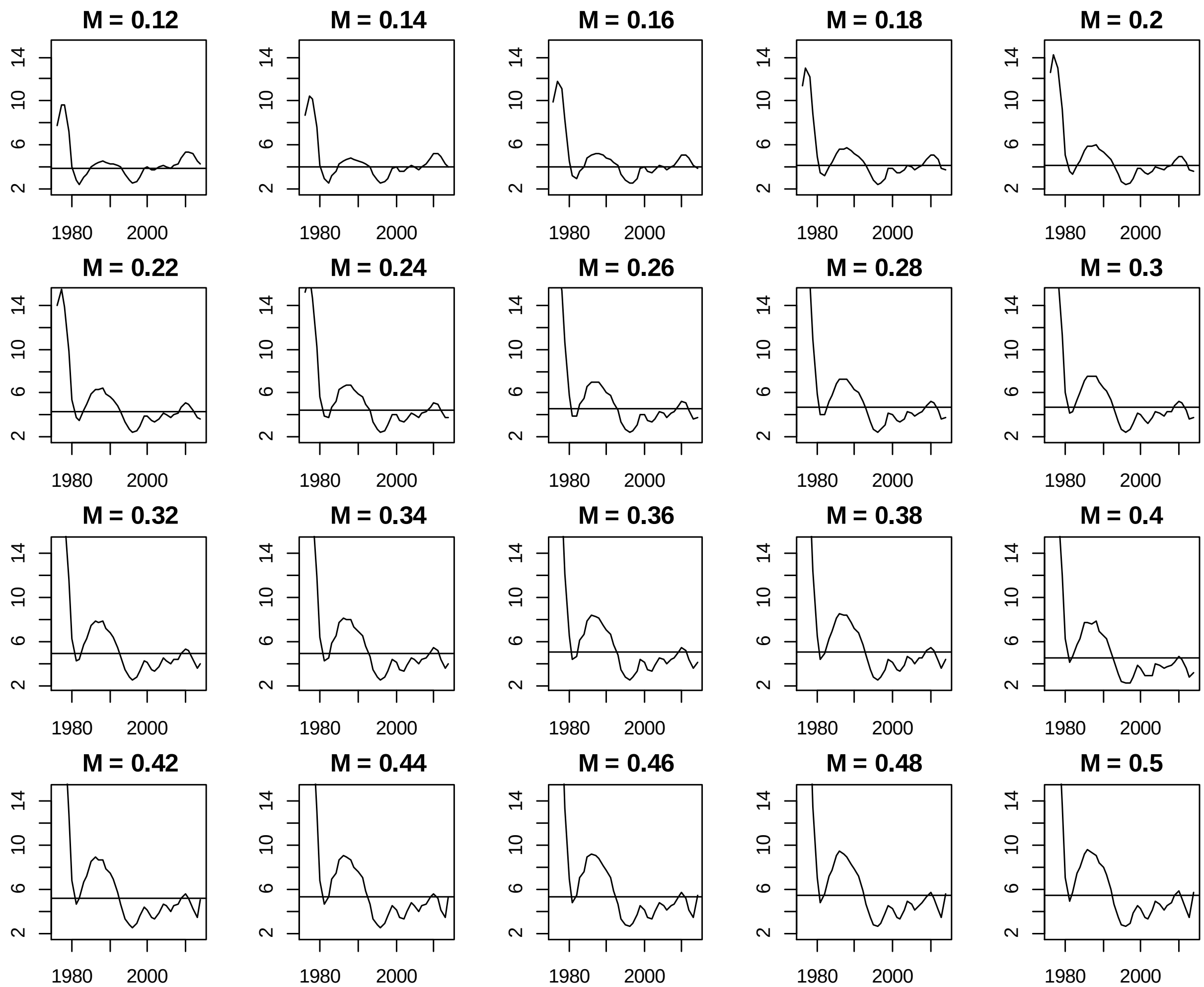

Figure 13: MMB projection : M 0.1-0.5 with last length class different.

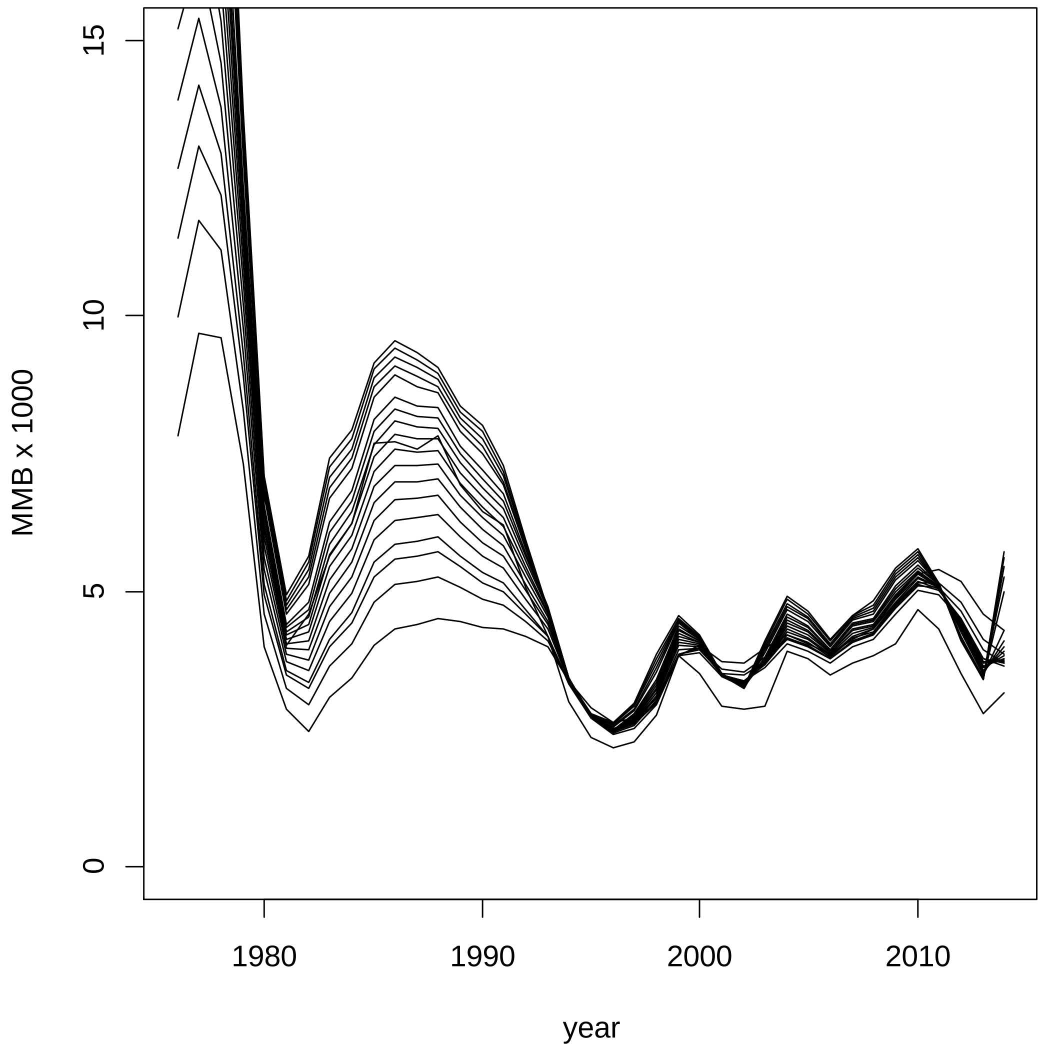

Figure 14: Likelihood profile: tag recovery weight 0.1-1.0

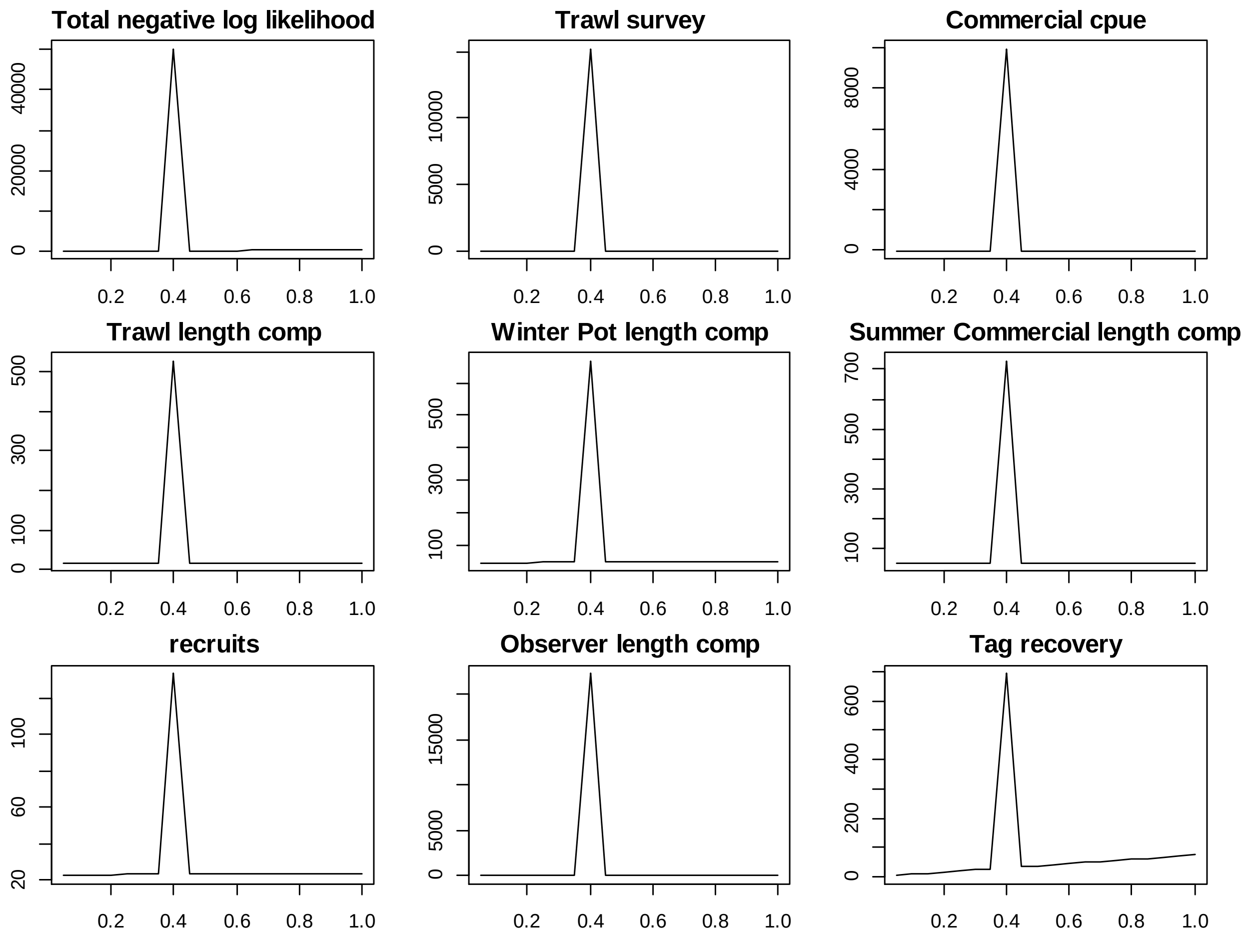

Figure 15a: Likelihood profile: tag recovery weight 0.05-0.35

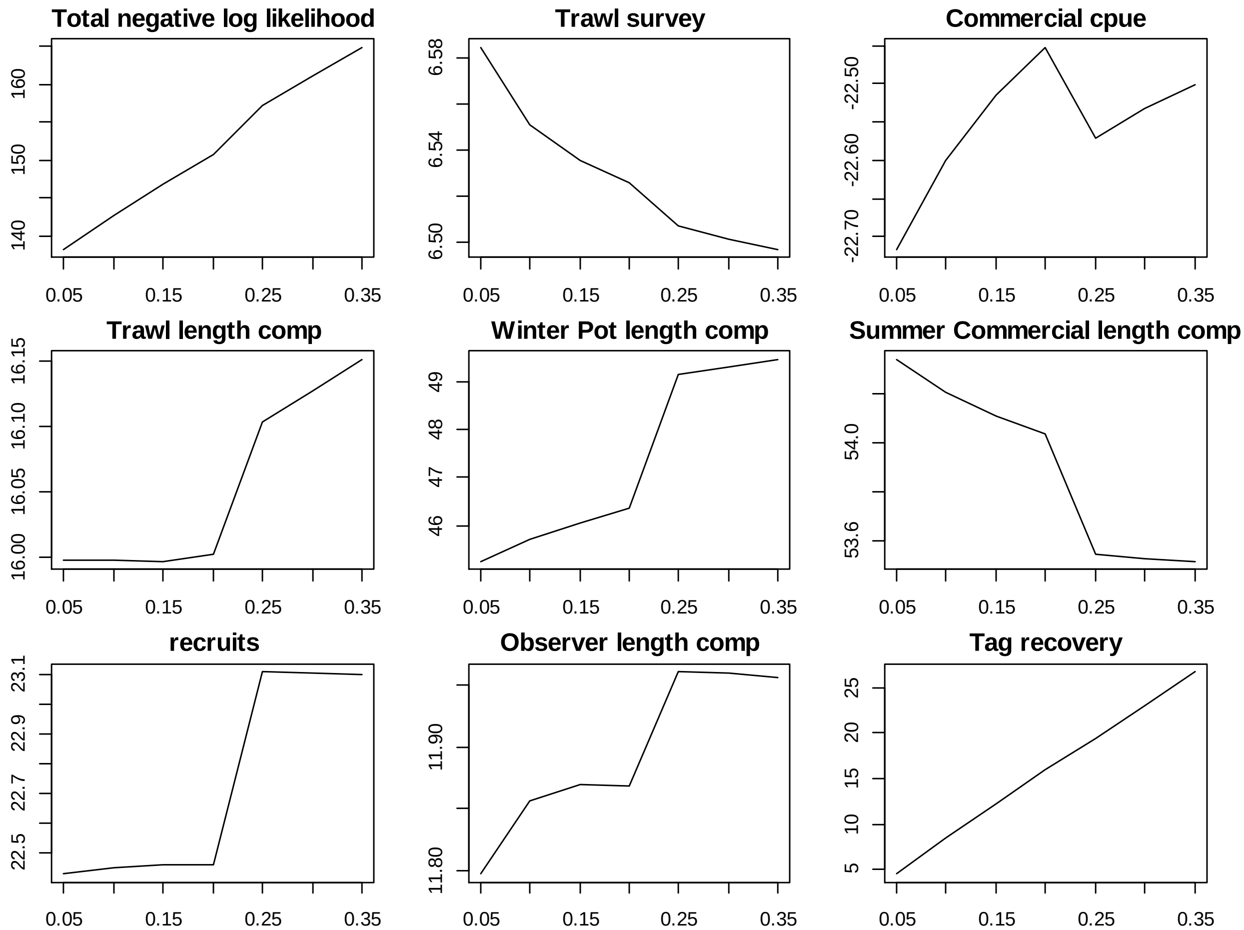

Figure 15b: Likelihood profile: tag recovery weight 0.5-1.0

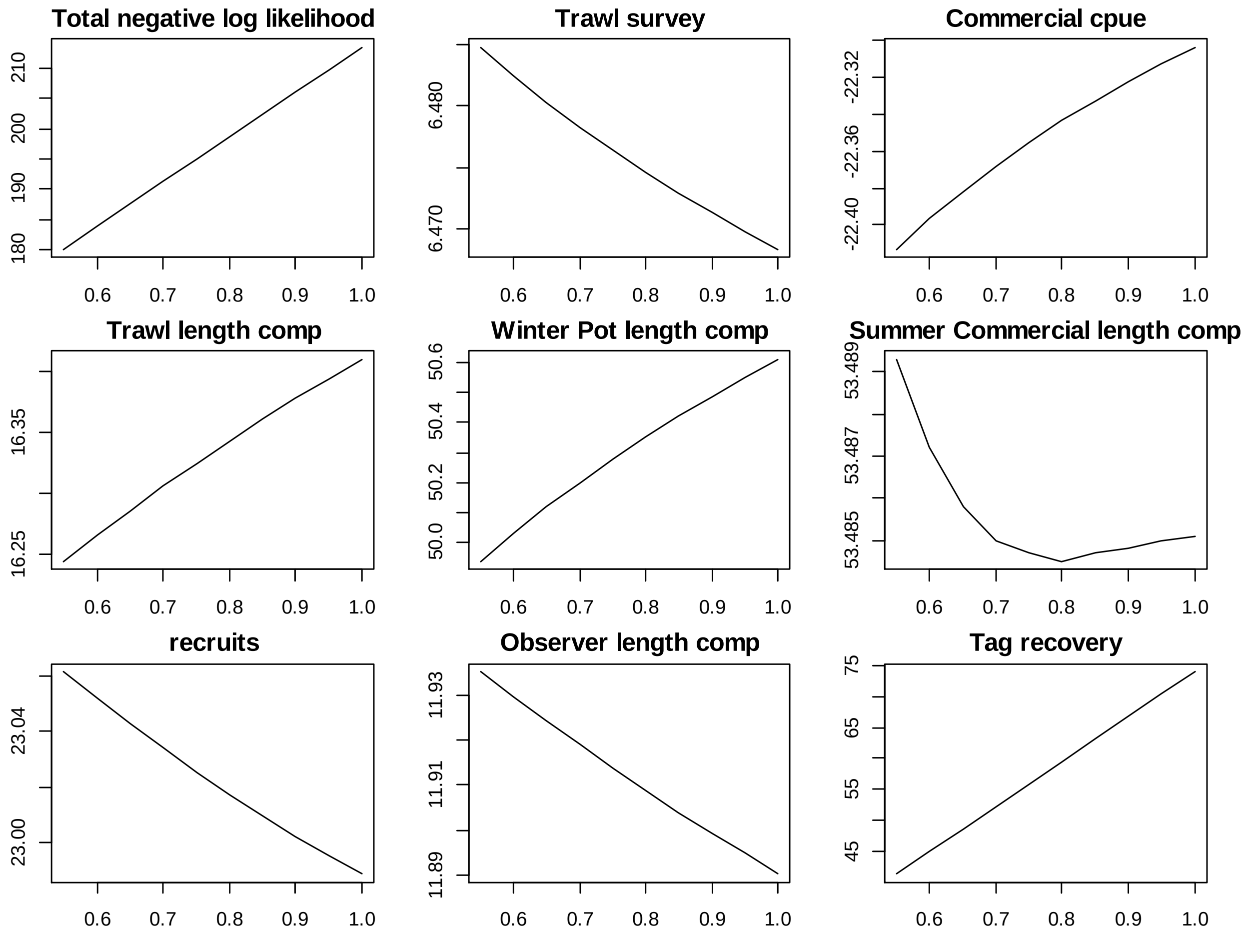

Figure 16a: Likelihood profile: tag recovery weight 0.05-0.35.

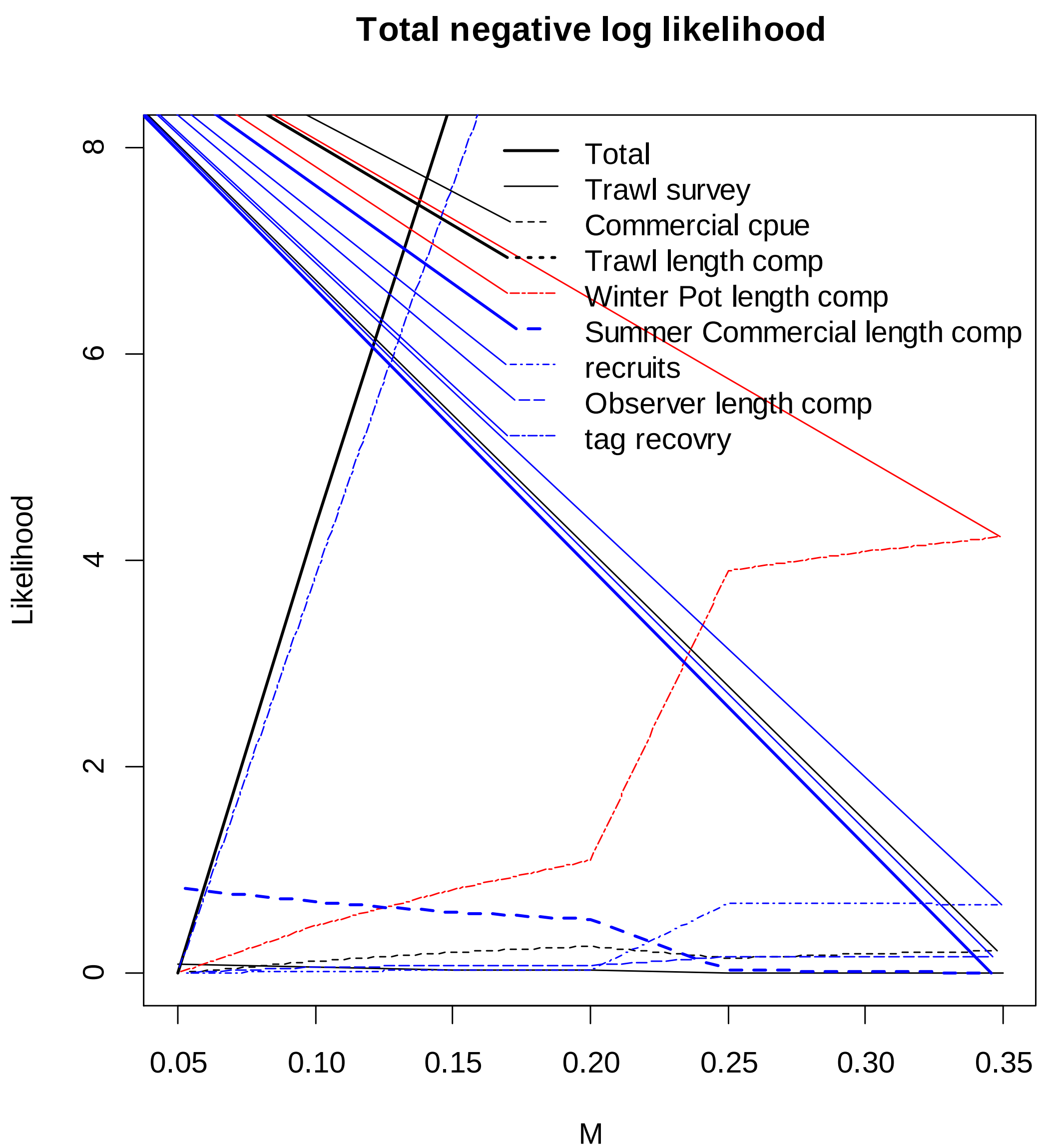

Figure 16b: Likelihood profile: tag recovery weight 0.05-0.35.

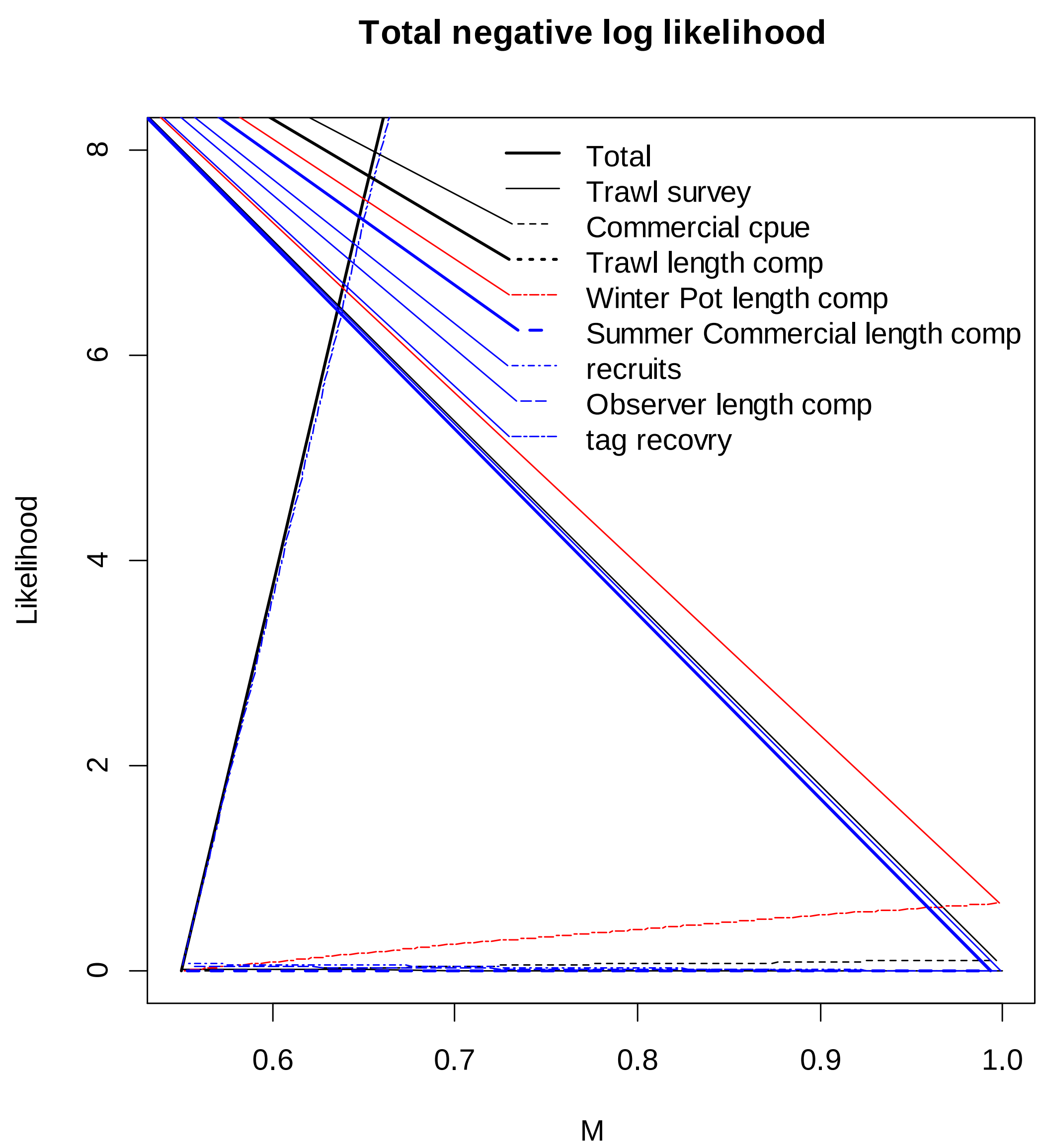

Figure 17: Parameter estimates: tag recovery weight 0.1-1.0

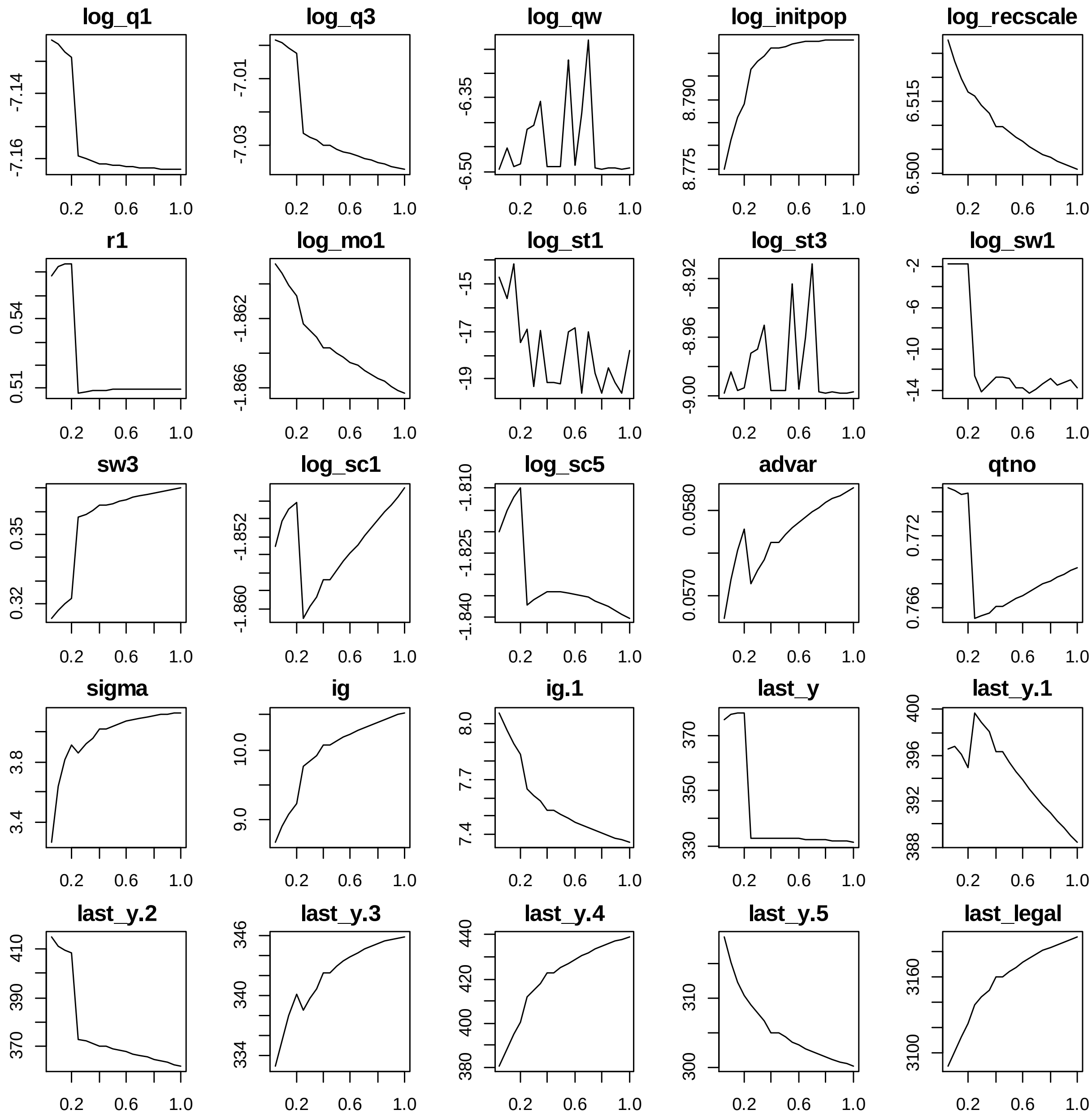

Figure 18: selectivity-molting: tag recovery weight = 0.1

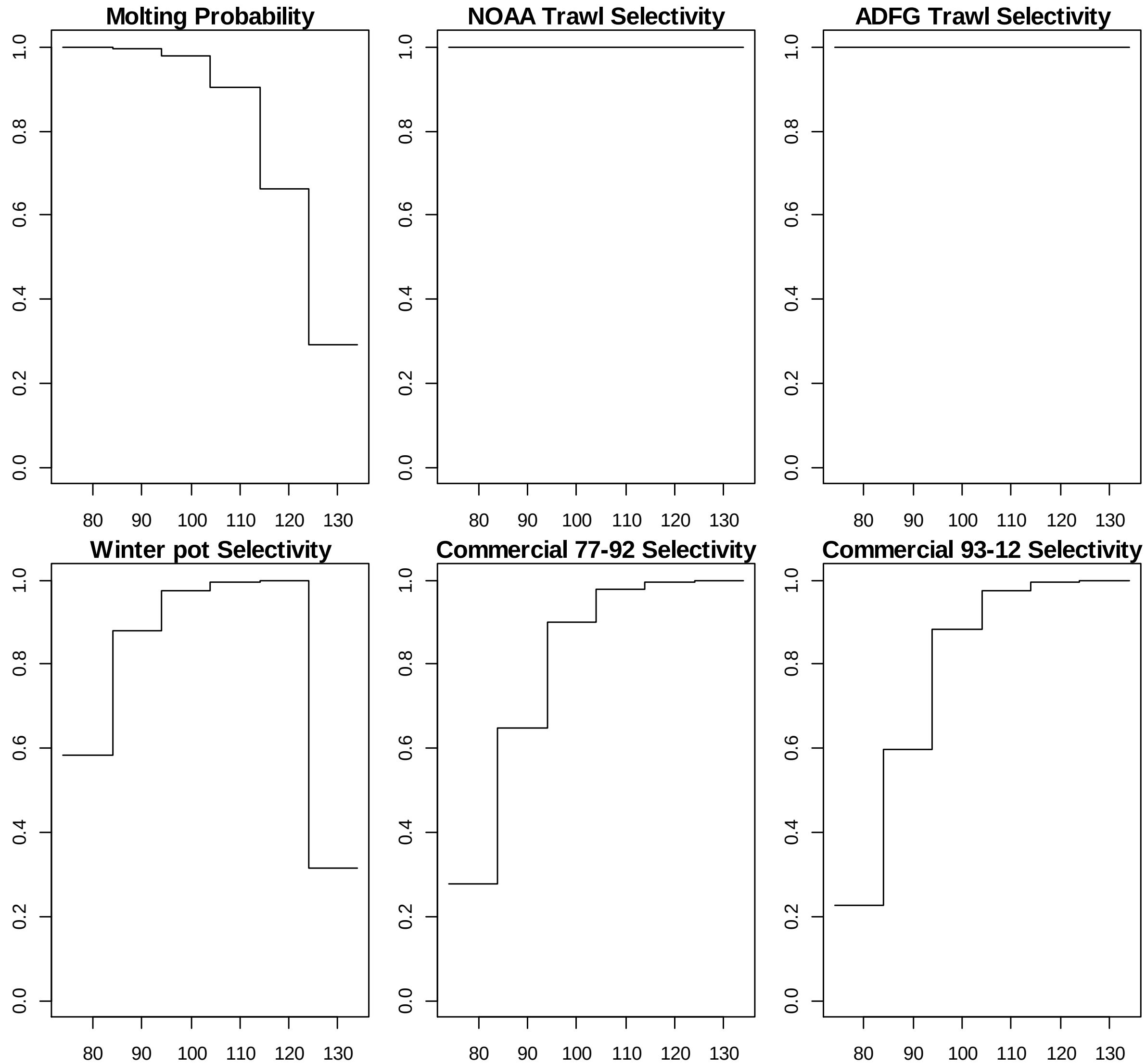

Figure 19: MMB projection: tag recovery weight 0.05-1.0

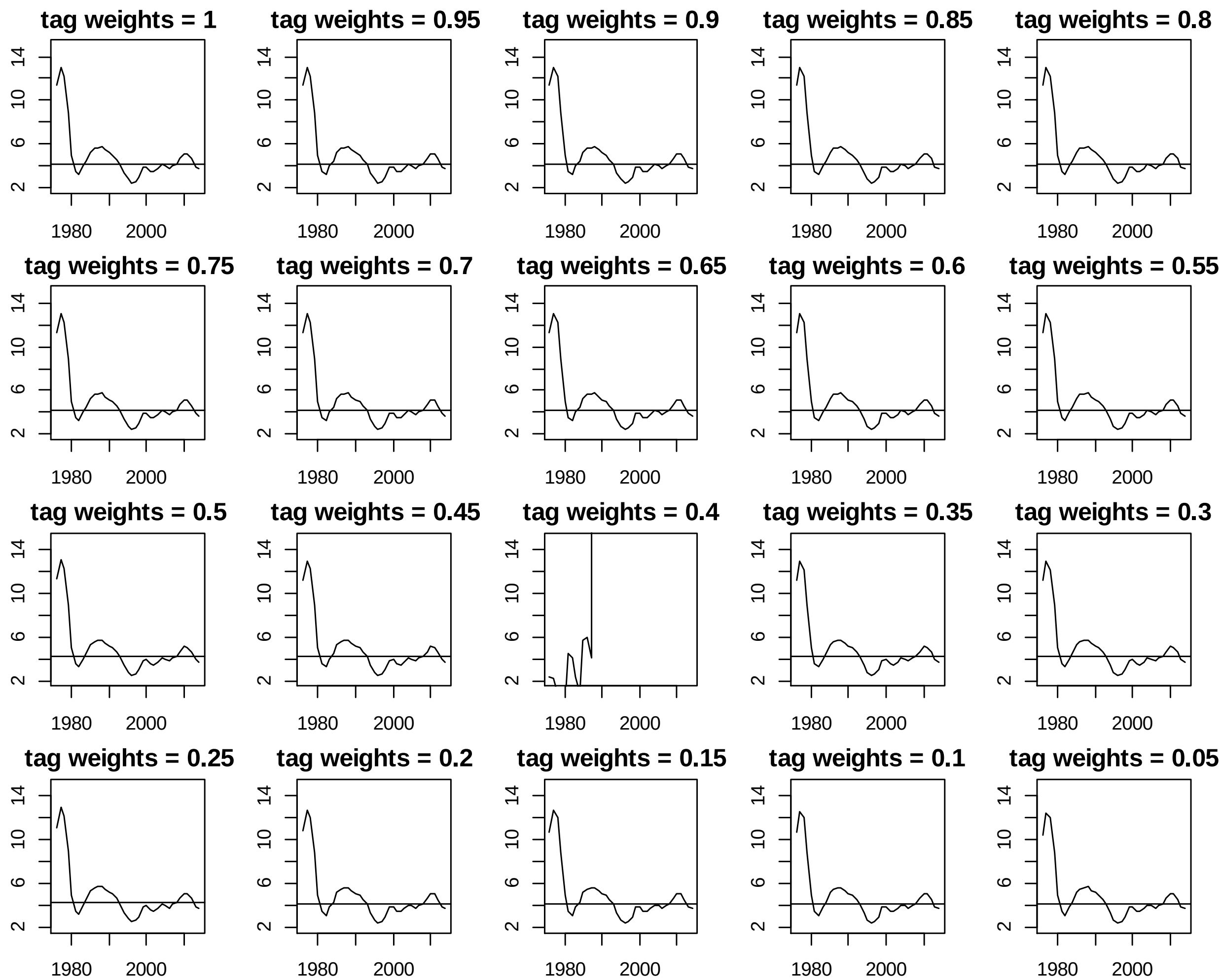

Figure 20: MMB projection: tag recovery weight 0.05-1.0