Norton Sound Red King Crab modeling issues:

Major problems:

1. **Molting growth matrix fixed: Unless we get more data, there is probably nothing we can do.**
2. **Natural Mortality: M = 0.18 and last length class mortality (M6) is 0.648, and is constant through years.**
   No evidence to confirm M = 0.18.
   No evidence to confirm M6 = 0.648.
   No evidence to confirm M is constant through time.
   But, no evidence to reject the above, either…

Model vs. Data discrepancy that need to be solved.

Discrepancy between expected projection from length composition and survey biomass projection.

Length proportion projection expects high crab abundance of the largest length class (class 6), but survey biomass of the class 6 is low.

1. **Kill them : High mortality of class 6 - > M6 = 0.648**
2. **Hide them : Survey q is not 1.0 (model estimates)**
3. **Grow them : High molting probability (model estimates)**

There are only a few moving parts to solve this discrepancies.

M: Natural mortality = 0.18
ms6: multiplier of last length class ms = 3.6 M6 = 0.648
weights: recruitment
Effective sample size for length composition

Confounding issues:

1. Data does not have any information estimating M or ms6.
2. M and molting probability is confounded.
   Low M ➔ High molting probability (Grow faster and die)
   High M ➔ Low molting probability (Grow slower)

Past Attempts

Lower effective sample size (How low can we go?)
Change weights: recruitment weights (SSC/CPT recommended 2013)

CPT recommended to change weigh to 0.5 recruit weight was converted from simple multiplier (W_R) to standard deviation form (sd).

$$W_R \sum_{t=1} \tau_t^2 \Rightarrow \sum_{t=1} \frac{\tau_t^2}{2sd^2}$$

For t = 38 (38 years) with sd = 0.5, the conversion increases weight from W_R = 0.01 to = 4.75. ($W_R = t/2sd^2$). sd corresponding to W_R = 0.01 is sd = 43.6

Increase M and make it constant for all length classes: (Caution!!: higher M will increase OFL/ABC. Do you want to increase OFL/ABC for population you really don't know?)

Separate NOAA and ADFG survey selectivity (Implemented)

Raw data issue

Available survey, catch, and tagging data

Data	Data type	Raw data
Summer trawl survey	Biomass	Trawl survey data # crab caught per swept at each survey station Male only
Summer trawl survey	Length Frequency	Trawl survey data # crab length class/# crab caught (10mm increments: New and Old Shell): All survey data combined. No stratification
Winter pot survey	Length Frequency	# crab length class/# crab caught (10mm increments: New and Old Shell): All survey data combined. No stratification
Summer commercial fishery	Length Frequency	# crab length class/# crab caught (10mm increments: New and Old Shell): All commercial season combined. No stratification: Surveyed at dock
Summer commercial fishery	Catch / # pot lifts	Fish ticket data
Summer commercial Observer	Length Frequency	# crab length class/# crab caught (10mm increments: New and Old Shell): All commercial season combined. No stratification: Limited fishermen
Winter commercial and subsistence fishery	Catch	Fish ticket data (Commercial) Permit data (Self reporting)

CPT/SSC 2014 recommendation

1. Likelihood profile for M
2. Likelihood profile for SDR

Results:

1. Likelihood profile for M

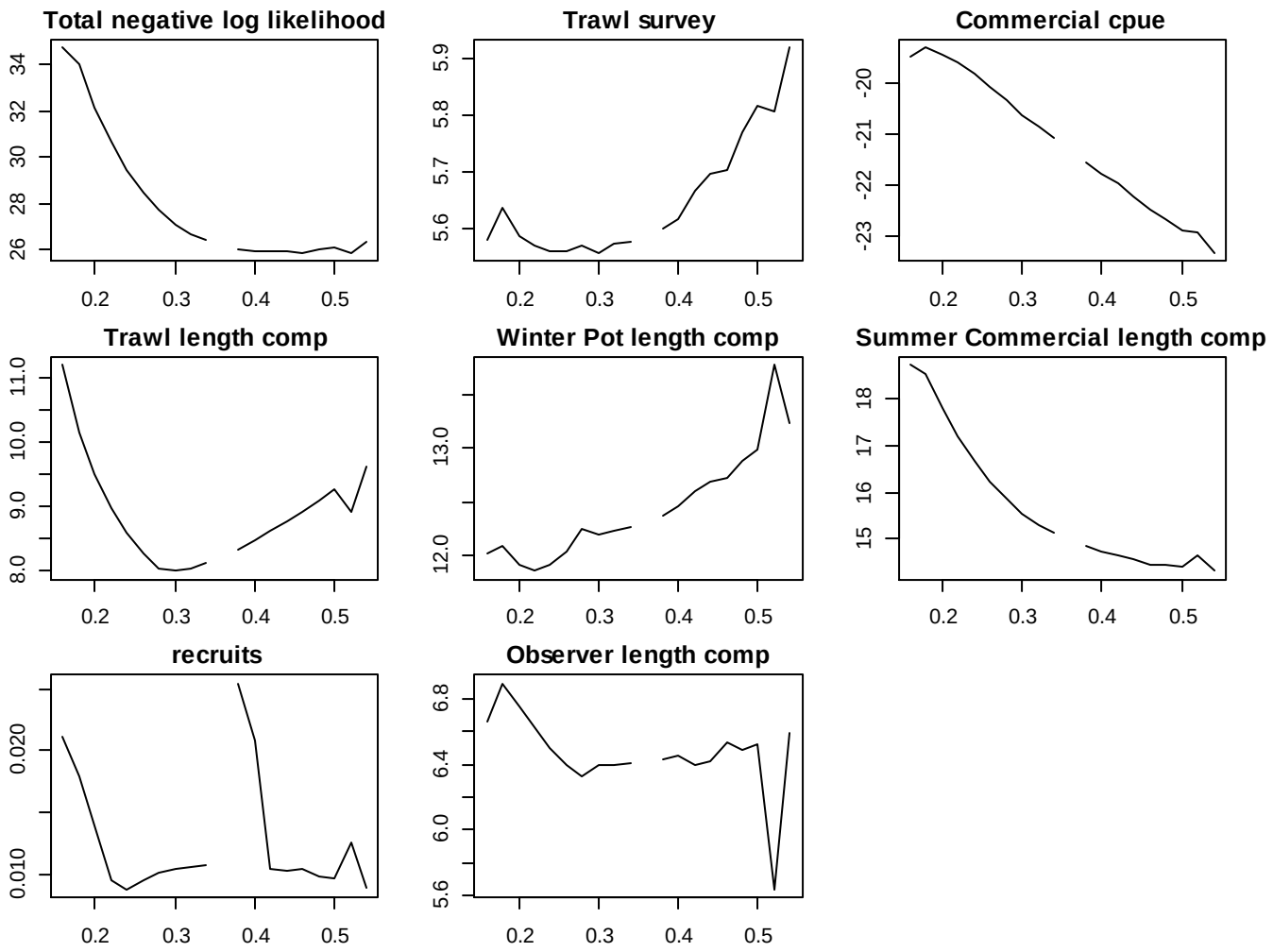
Total likelihood is lowest around M = 0.4.
Higher M ➔ Low molting probability
Higher M ➔ Higher crab abundance in 1970-1980 (lower q for NOAA survey)
Crab population projection: Crab population is increasing since late 1990s: **Tier 4a** ☺

2. Likelihood profile for SDR

By changing weights, comparison of total likelihood is meaningless
Higher SDR ➔ for all other likelihood components. Became stable after SDR > 10.
Higher SDR ➔ More noticeable ups and downs since 1980s.
Crab population projection:
SDR < 2: Crab population declined since 2010: **Tier 4b** ☹
SDR > 2: Crab population is increasing since late 1990s: **Tier 4a** ☺

Modeling attempt 1:
Change M from 0.1 to 0.5: constant all length classes
Recruitment SD (SDR) = 0.5
Separate NOAA and ADFG survey selectivity (Implemented)

Likelihood profile


Total negative log likelihood
Trawl survey
Commercial cpue
Trawl length comp
Winter Pot length comp
Summer Commercial length comp
recruits
Observer length comp

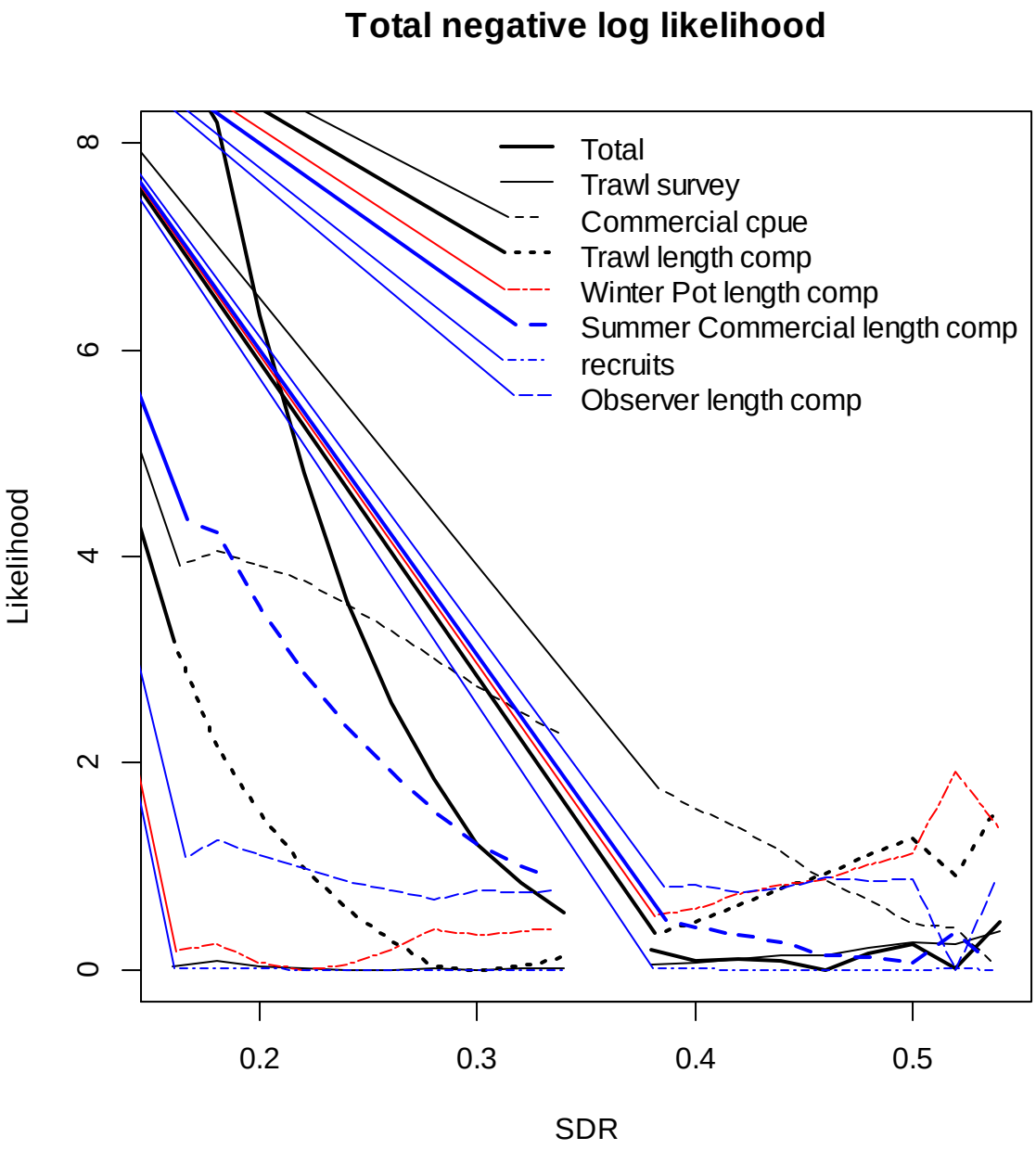


Figure 4a: Likelihood profile for total and each likelihood against M

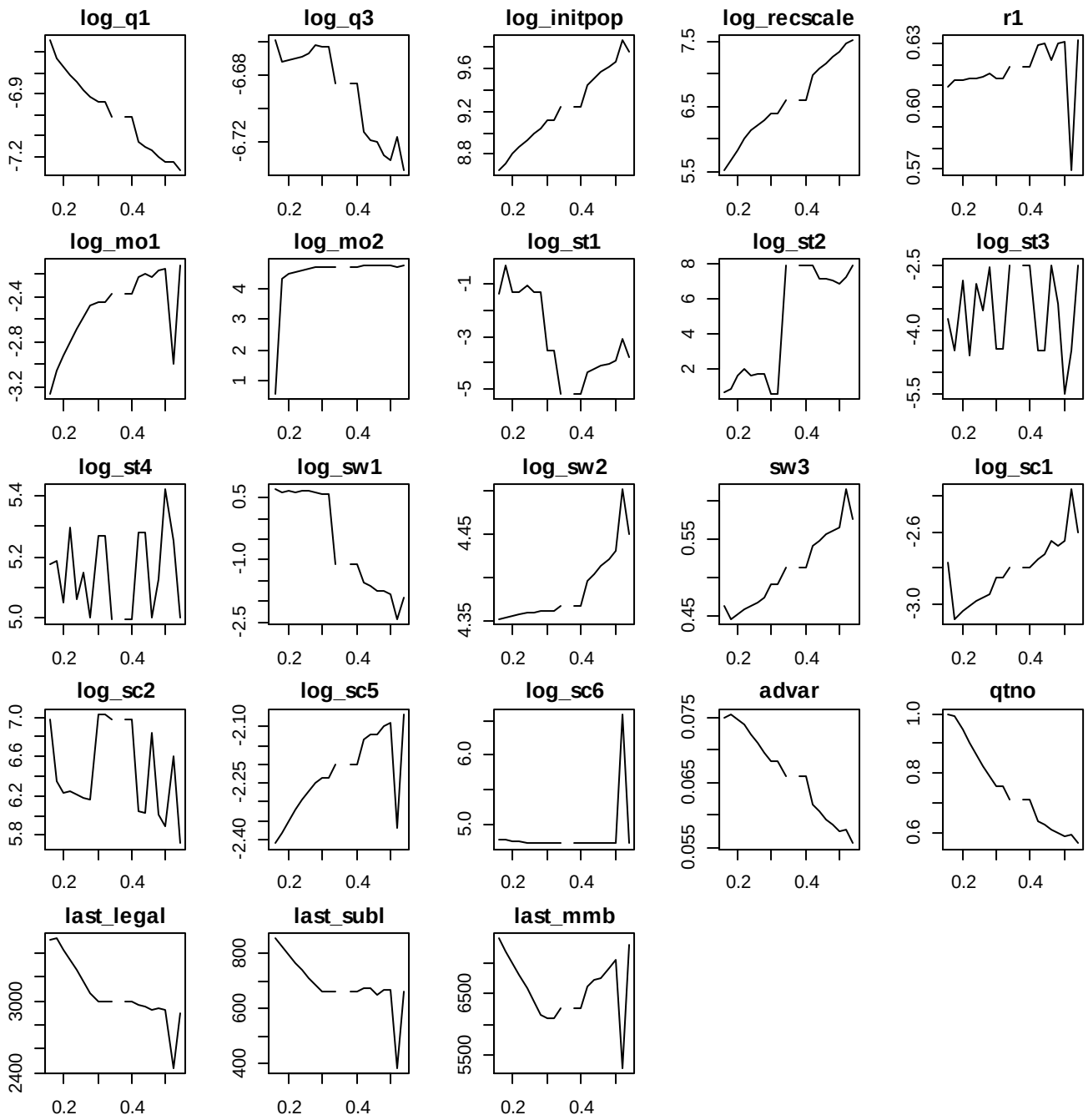


Figure 4b: Estimates of each model parameters for various M.

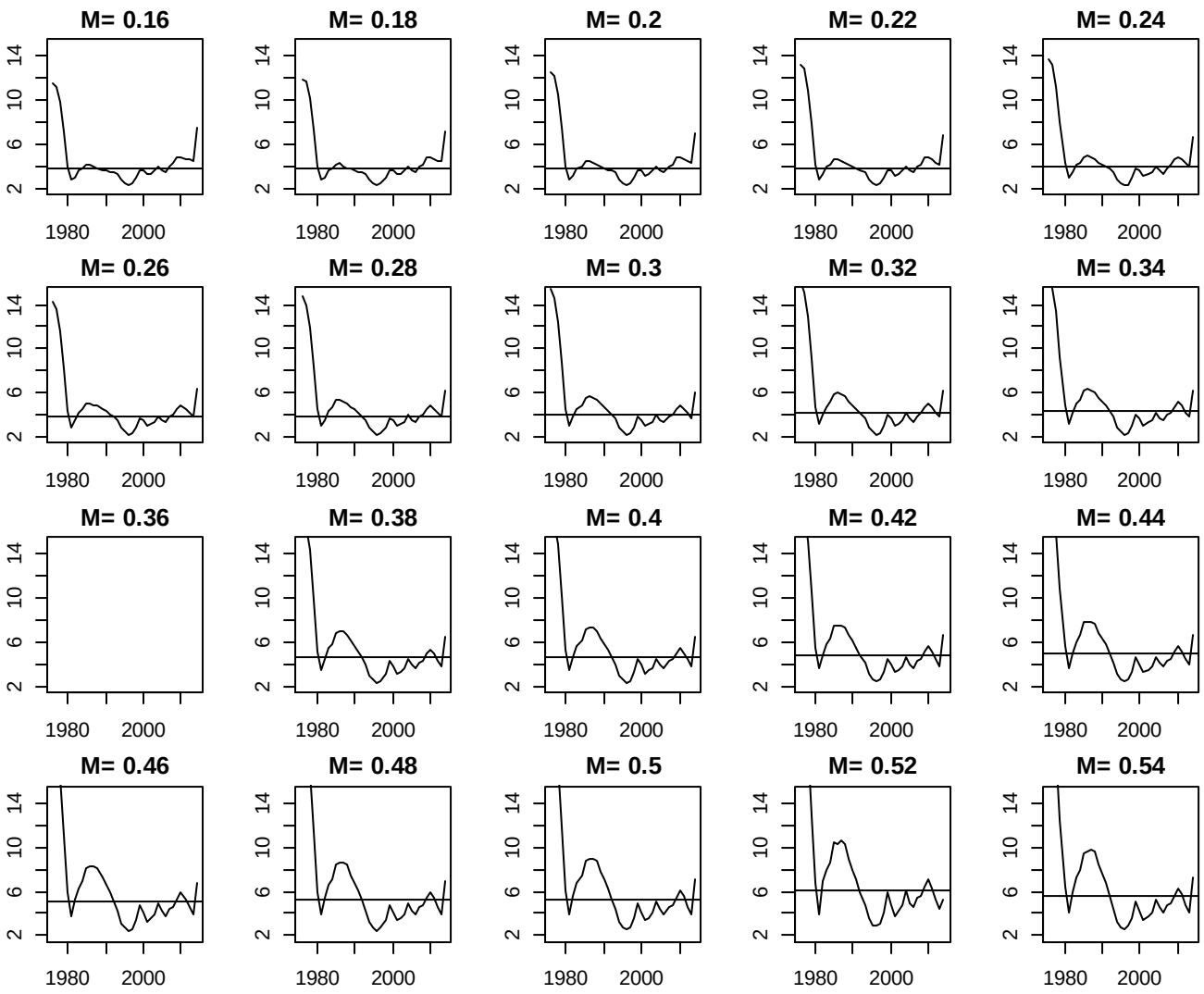
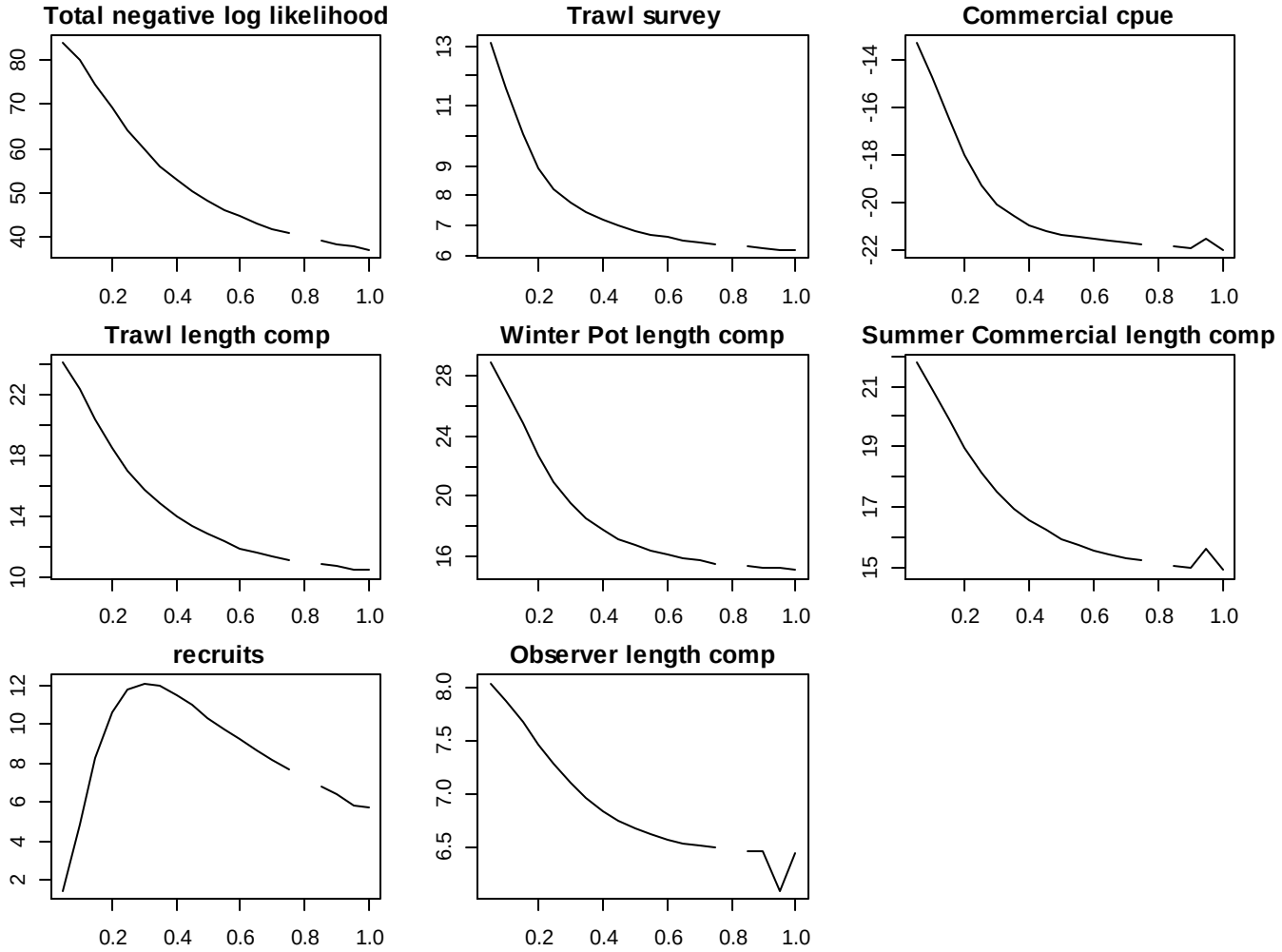
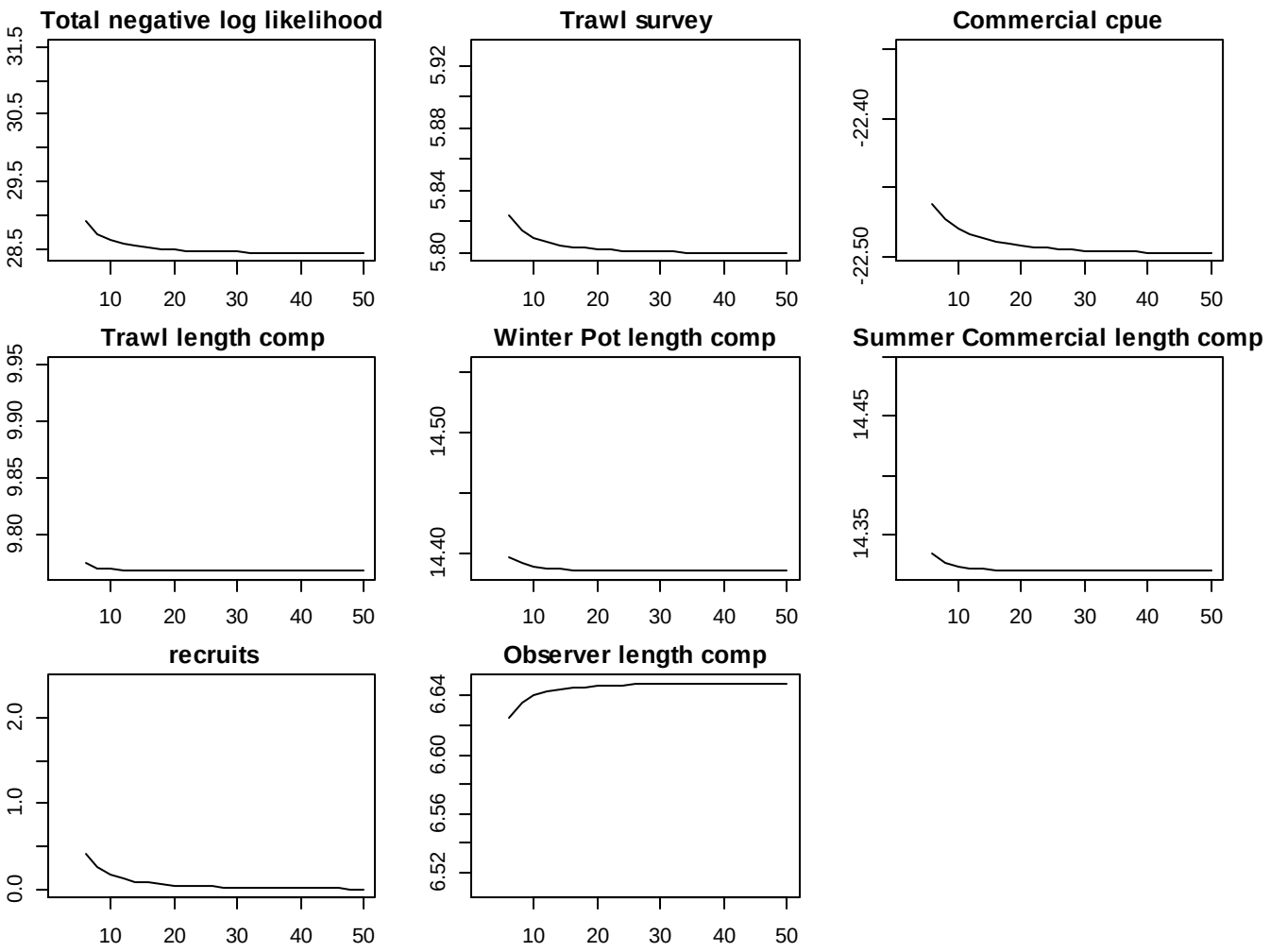
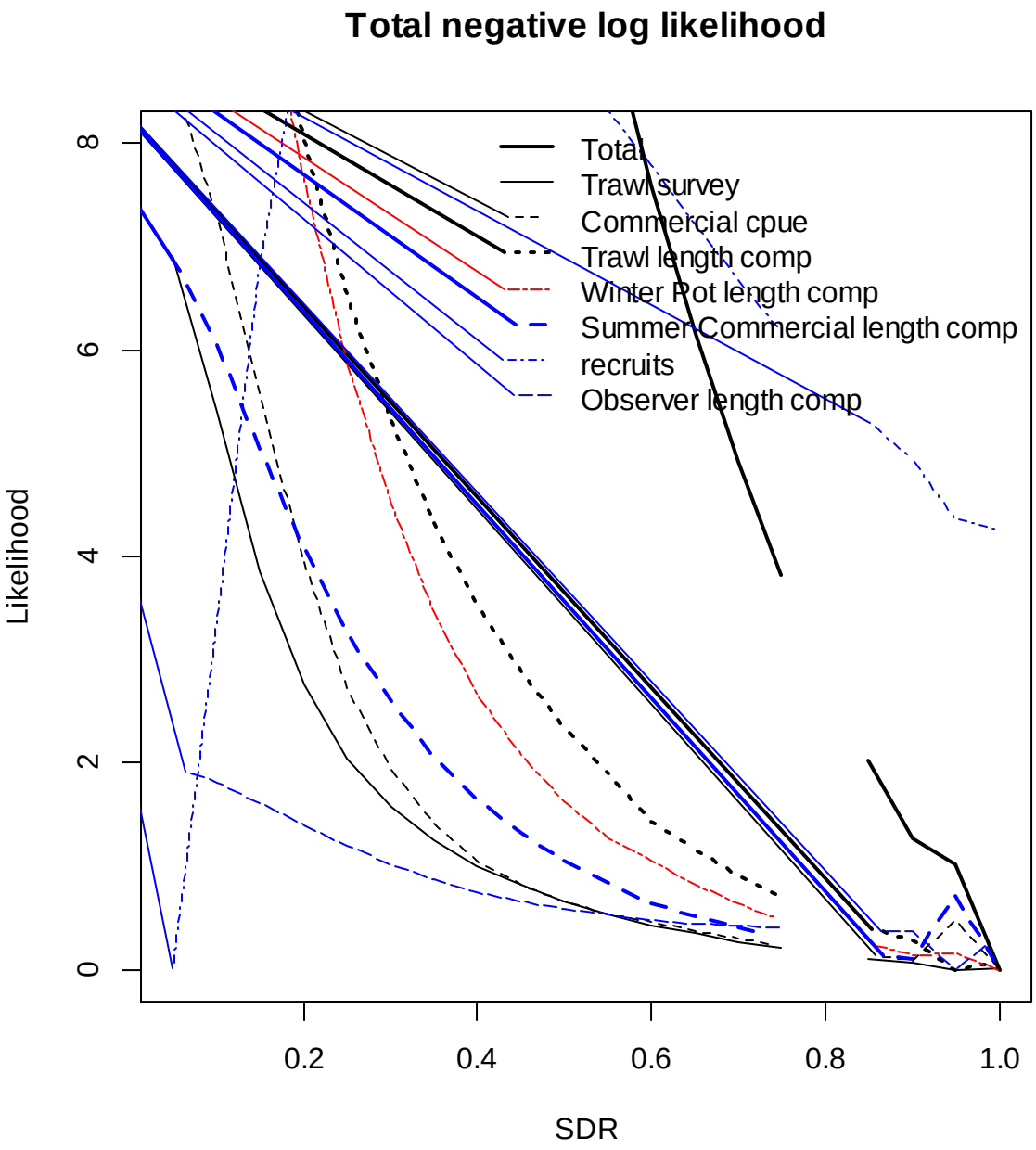


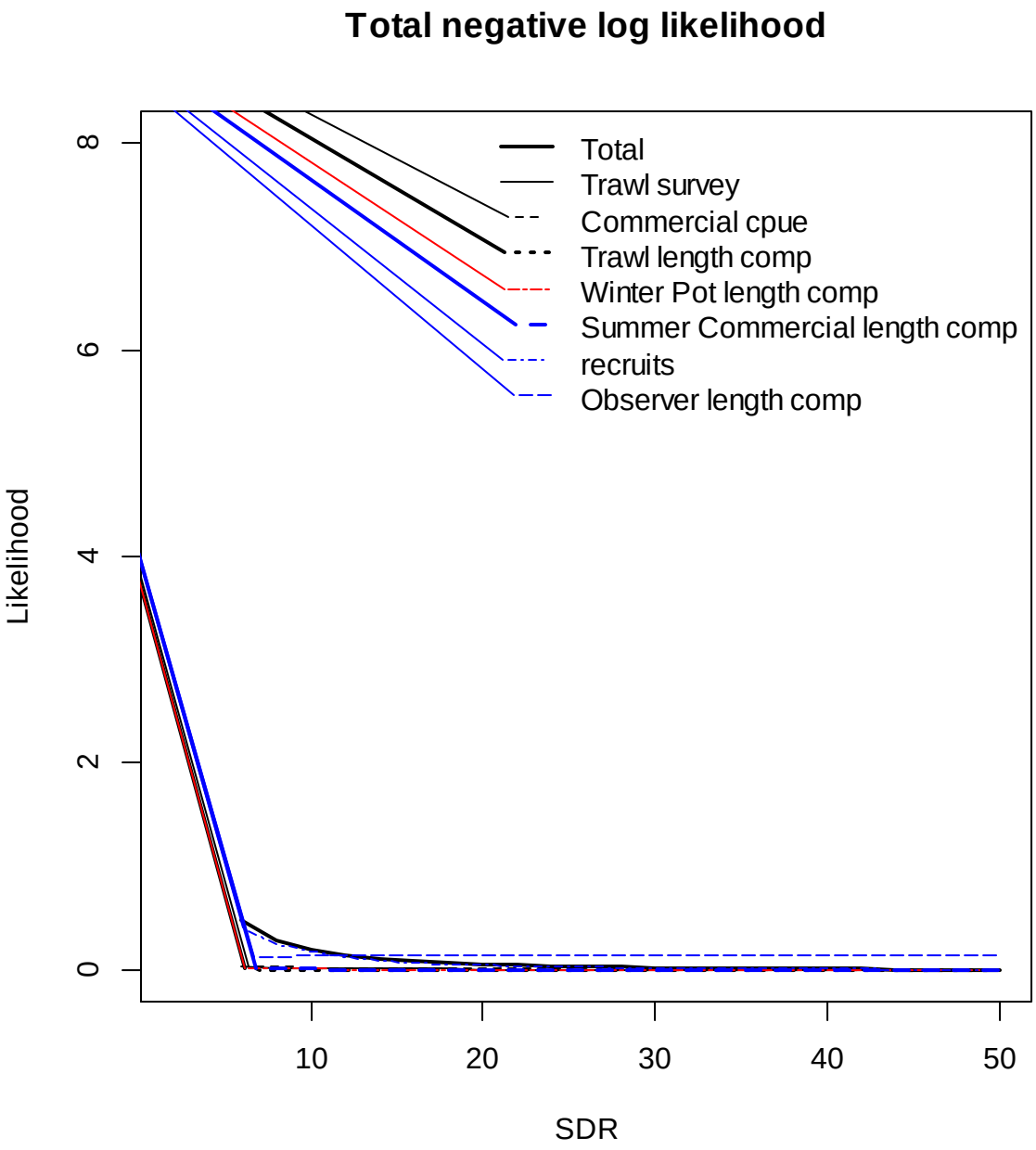
Figure 4c: Trajectory of MMB (million lbs) in various M . Trajectory for M=0.18 was not shown because of non-convergence.

Attempt 2: increase recruitment weight from 0.1 to 50. CPT recommended sd = 0.5, sd corresponding to W_R = 0.01 is sd = 43.6
M = 0.18, M6 = 0.648
Separate NOAA and ADFG survey selectivity (Implemented)




Total negative log likelihood
28.5
29.5
30.5
31.5
Trawl survey
5.80
5.84
5.88
5.92
Commercial cpue
-22.50
-22.40
Trawl length comp
9.80
9.85
9.90
9.95
Winter Pot length comp
14.40
14.50
Summer Commercial length comp
14.35
14.45
recruits
0.0
1.0
2.0
Observer length comp
6.52
6.56
6.60
6.64
10
20
30
40
50


Total negative log likelihood
Total
Trawl survey
Commercial cpue
Trawl length comp
Winter Pot length comp
Summer Commercial length comp
recruits
Observer length comp
Likelihood
0
2
4
6
8
0.2
0.4
0.6
0.8
1.0
SDR


Total negative log likelihood
Total
Trawl survey
Commercial cpue
Trawl length comp
Winter Pot length comp
Summer Commercial length comp
recruits
Observer length comp
Likelihood
0
2
4
6
8
10
20
30
40
50
SDR

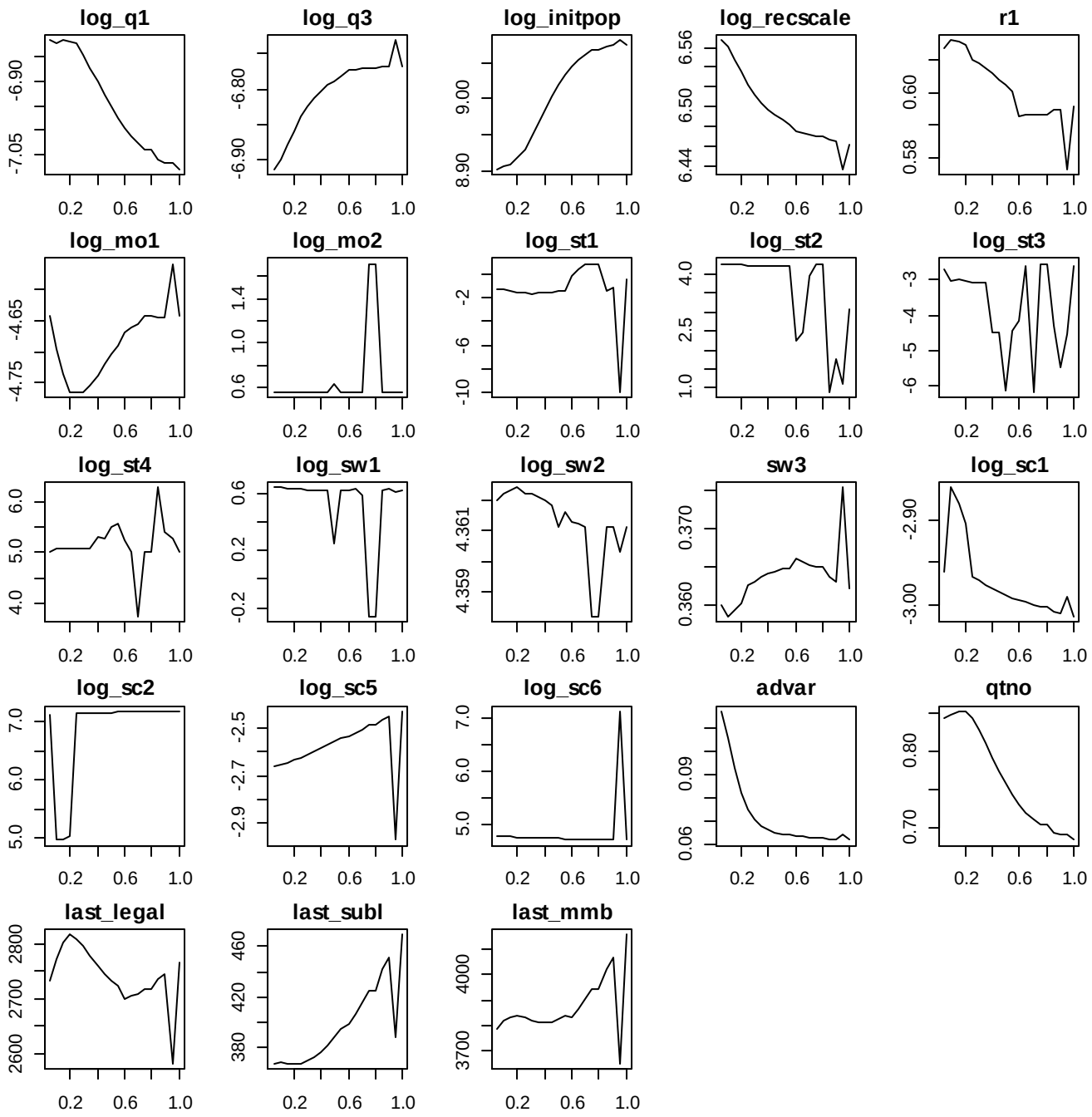
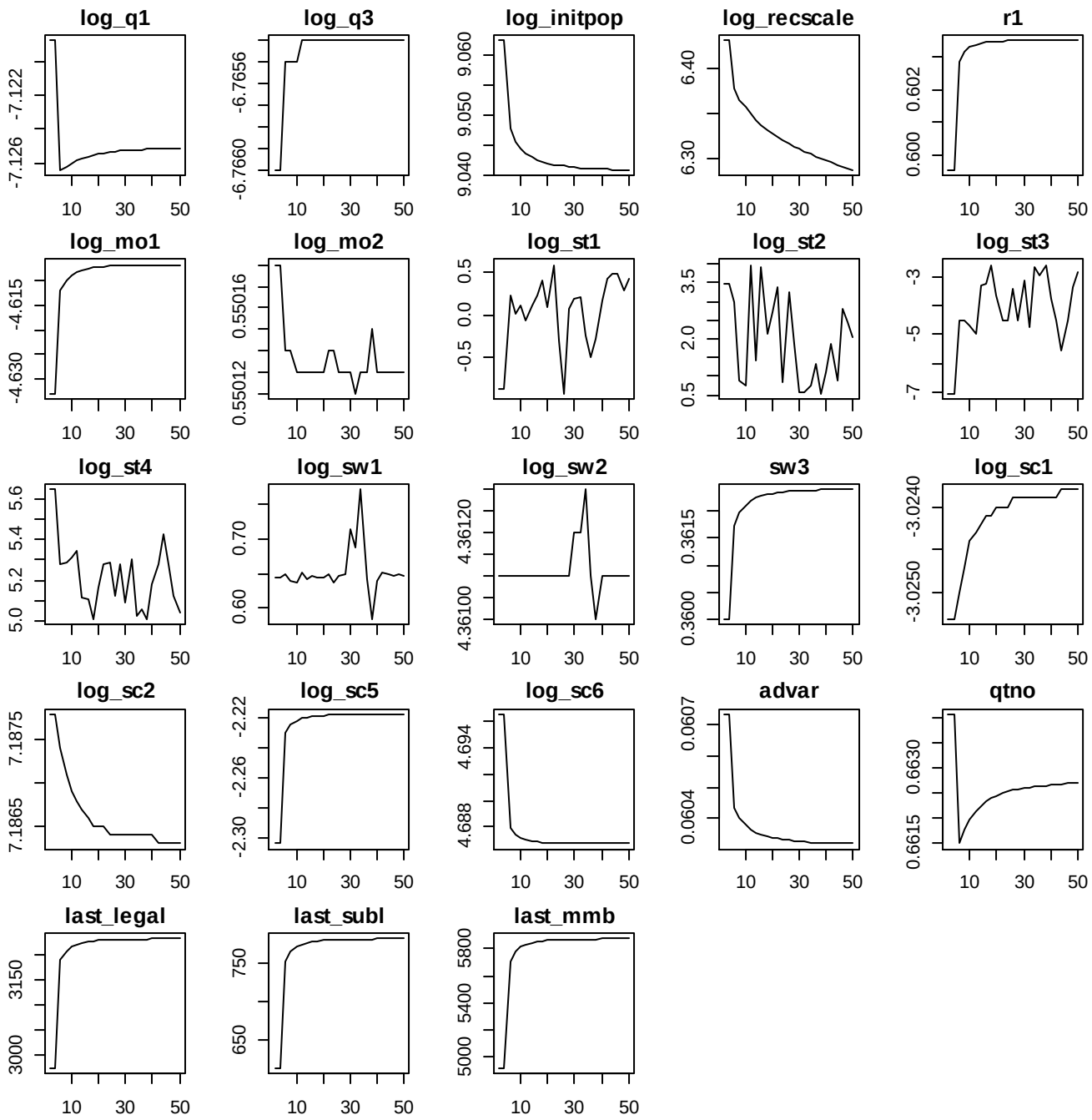


Figure 5a: Estimates of each model parameters for various SDR


log_q1
log_q3
log_initpop
log_recscale
r1
log_mo1
log_mo2
log_st1
log_st2
log_st3
log_st4
log_sw1
log_sw2
sw3
log_sc1
log_sc2
log_sc5
log_sc6
advar
qtno
last_legal
last_subl
last_mmb

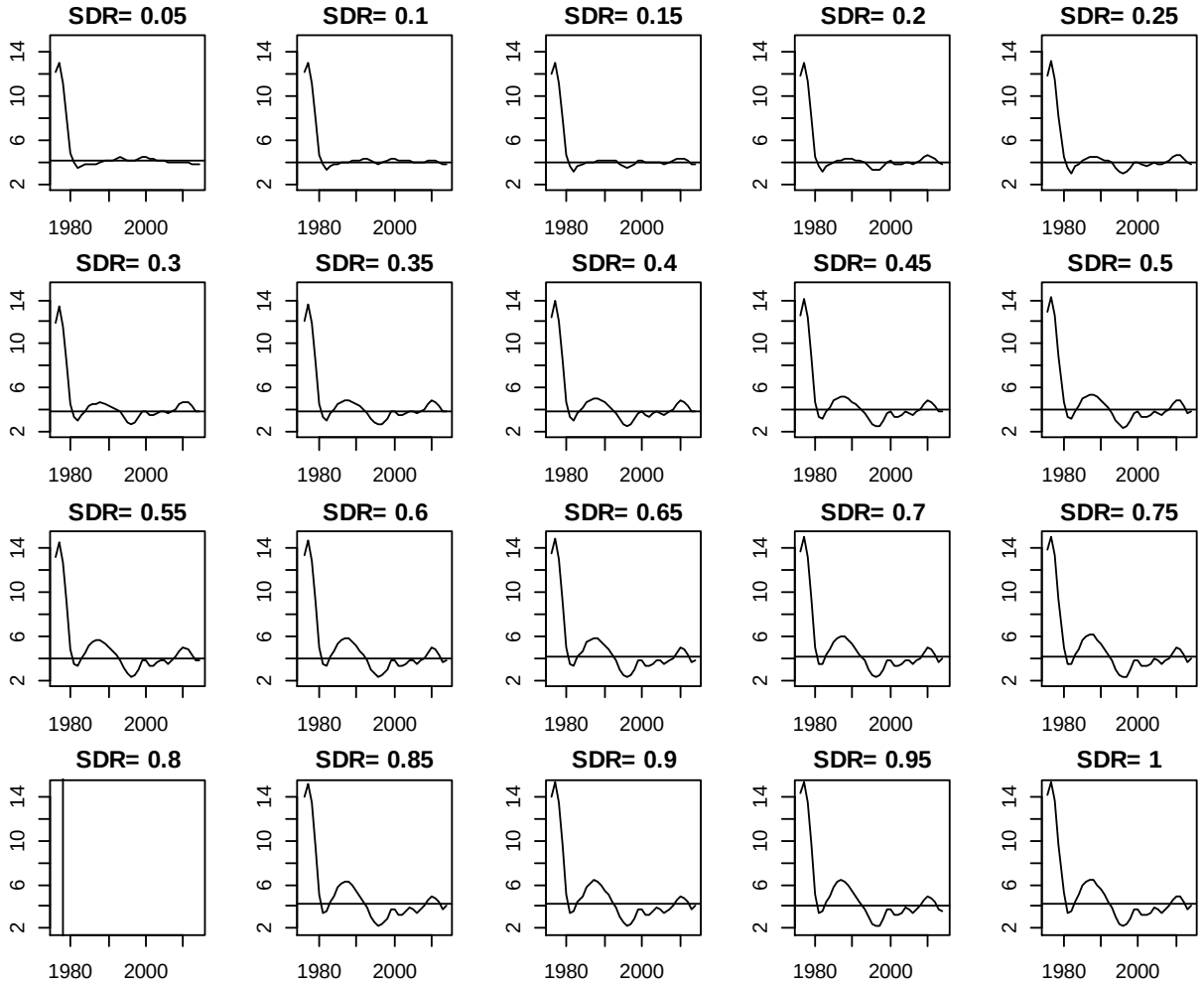
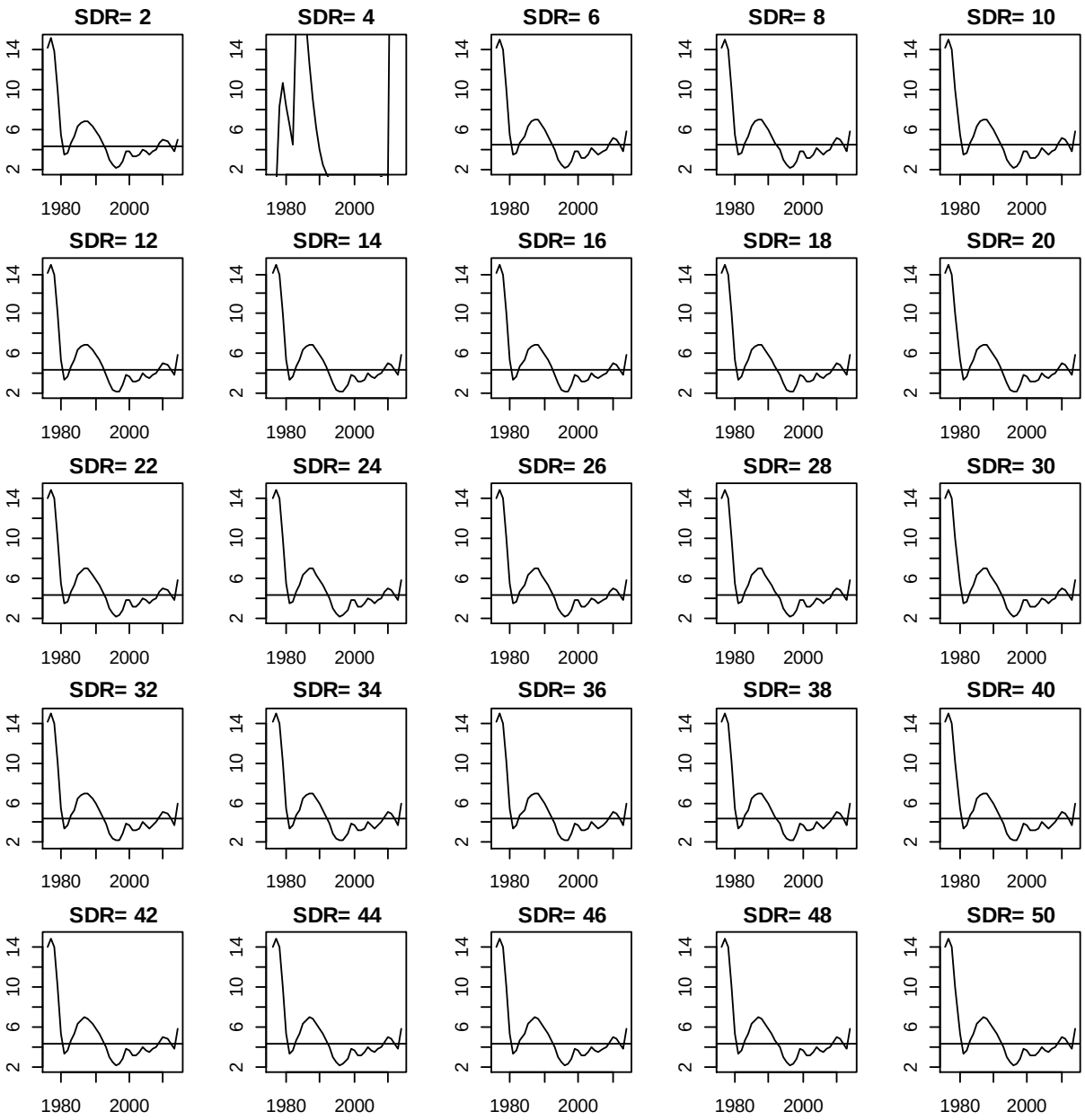


Figure 5b: Trajectory of MMB (million lbs) in various SDR values.


SDR= 2
SDR= 4
SDR= 6
SDR= 8
SDR= 10
SDR= 12
SDR= 14
SDR= 16
SDR= 18
SDR= 20
SDR= 22
SDR= 24
SDR= 26
SDR= 28
SDR= 30
SDR= 32
SDR= 34
SDR= 36
SDR= 38
SDR= 40
SDR= 42
SDR= 44
SDR= 46
SDR= 48
SDR= 50
2
6
10
14
1980
2000

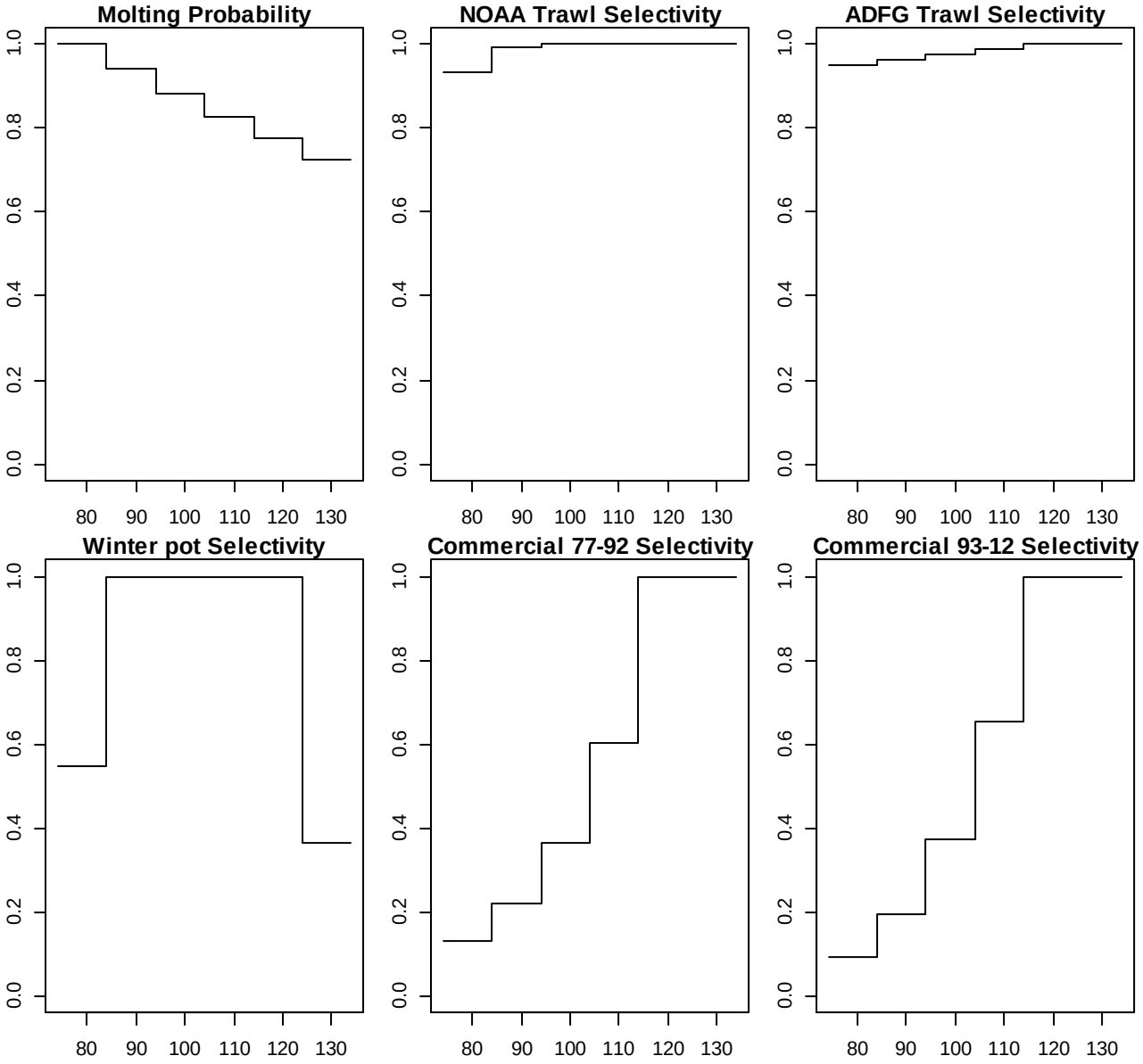


Figure 5b. Molting probability and trawl/pot selectivity

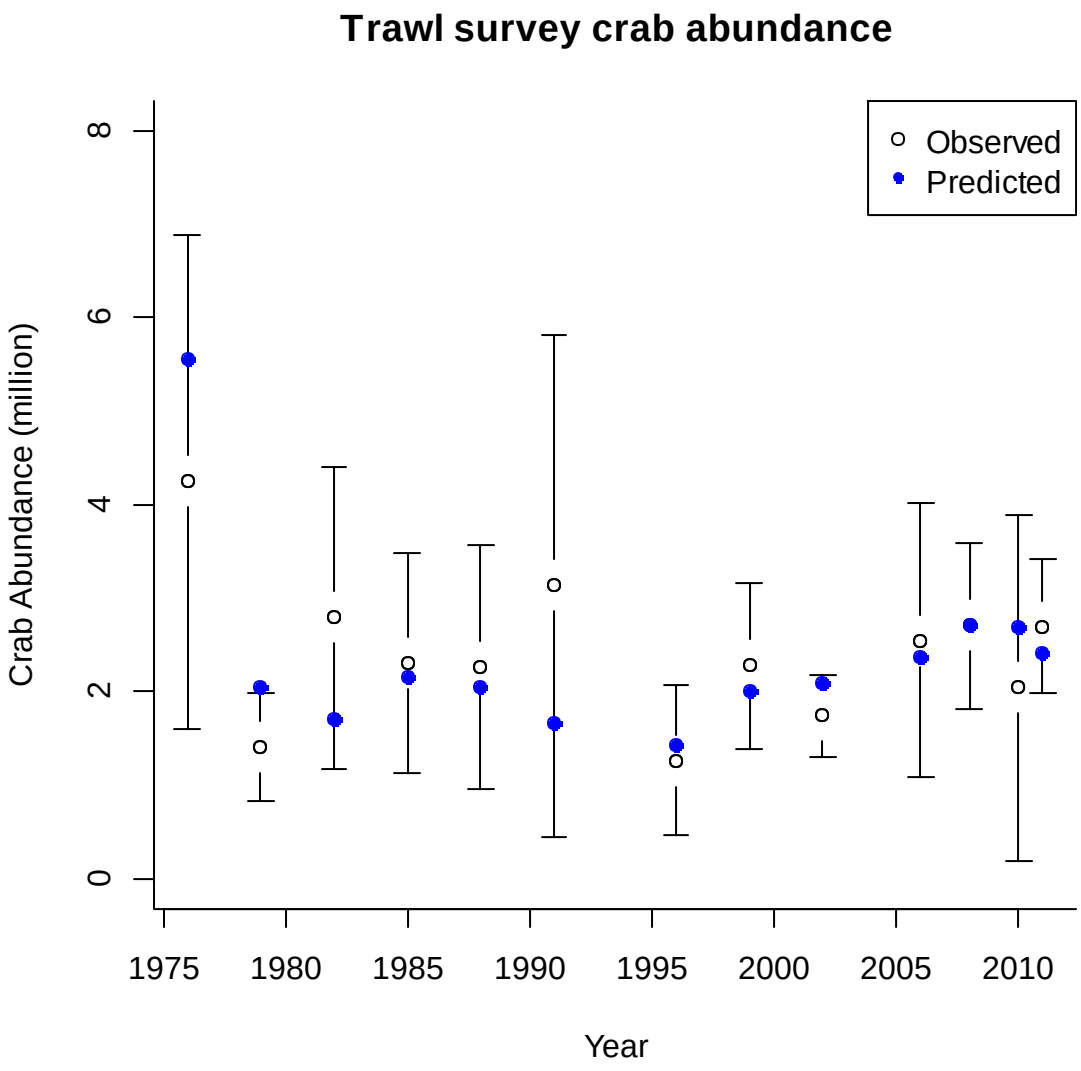


Figure 6. Estimated trawl survey abundance (crabs ≥ 74 mm CL) male.

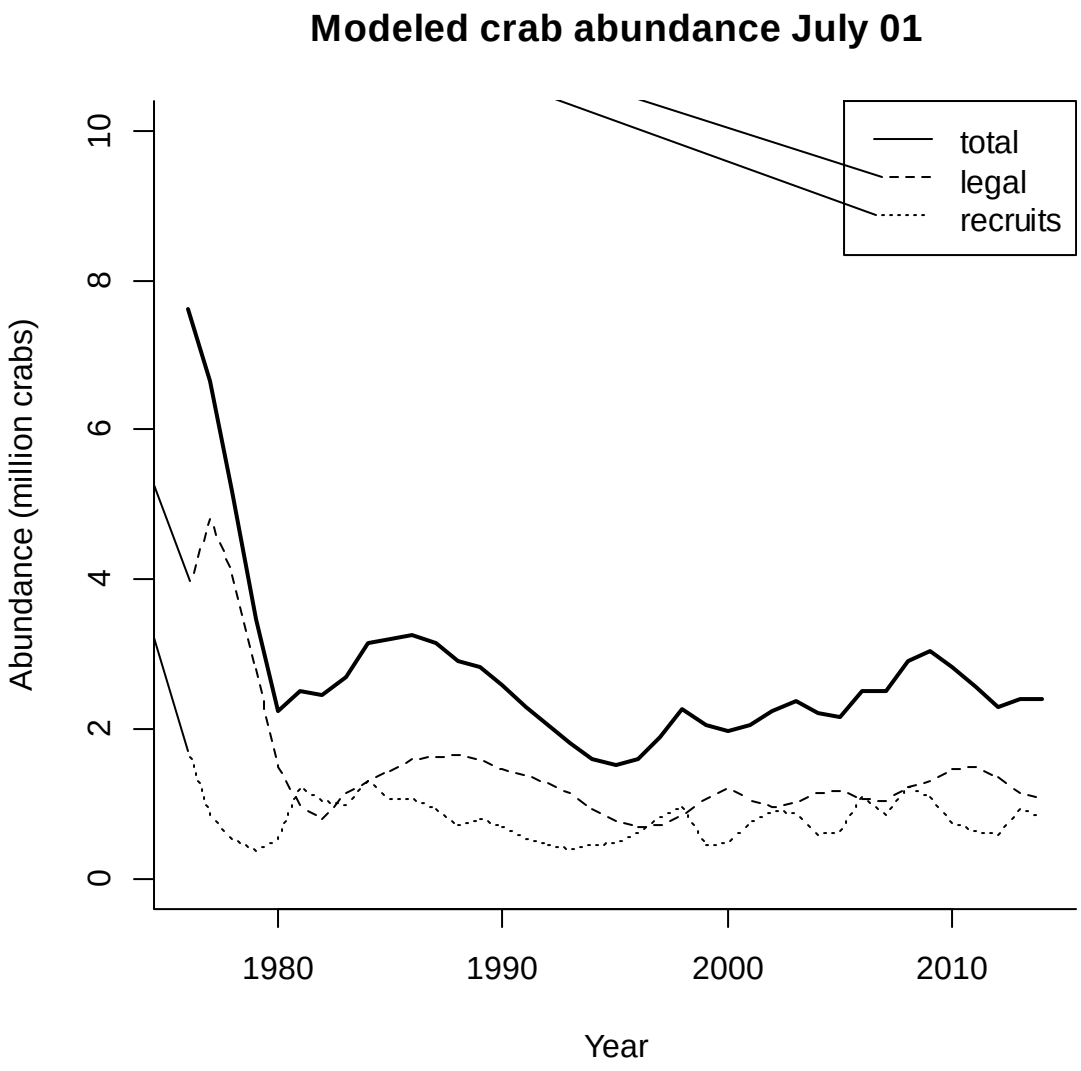


Figure 7a. Estimated abundance of legal male from 1976-2013

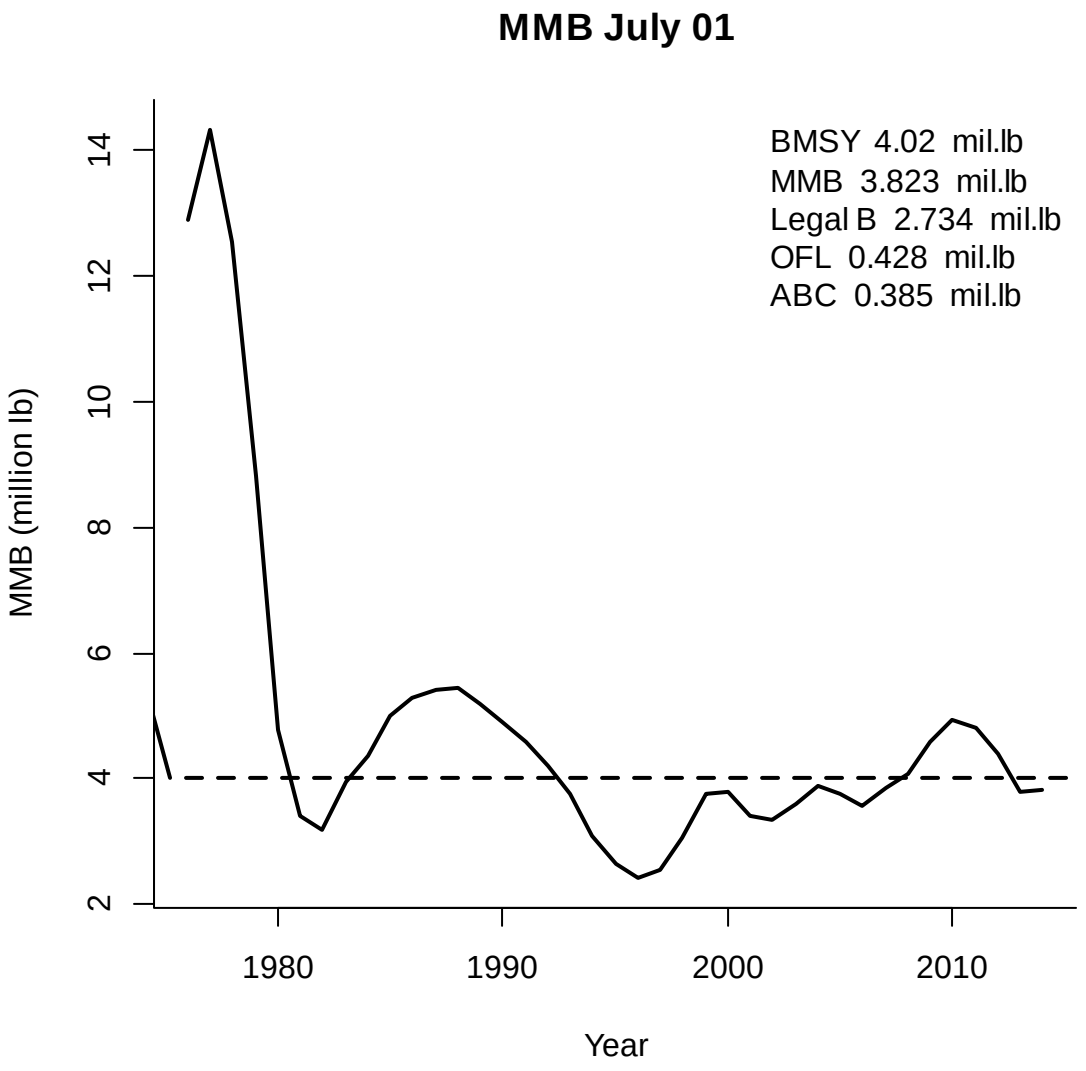


Figure 8a. Estimated abundance of leg recruits from 1976-2014 (Full data). Dash line shows Bmsy (Average MMB of 1980-2014)

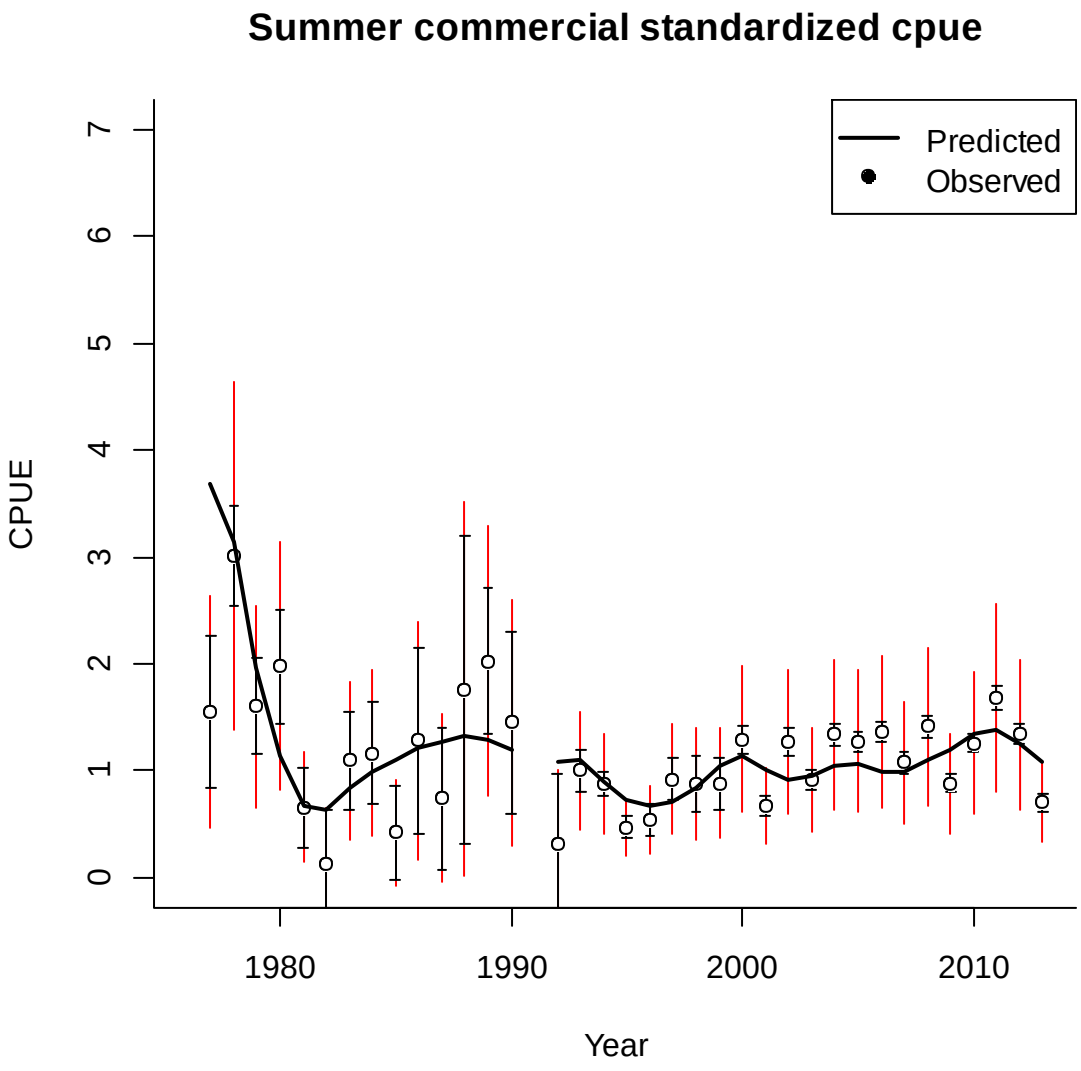


Figure 9a. Summer commercial standardized cpue (95% CI) (1977-2013). Red line shows 95% CI with additional estimated variance.

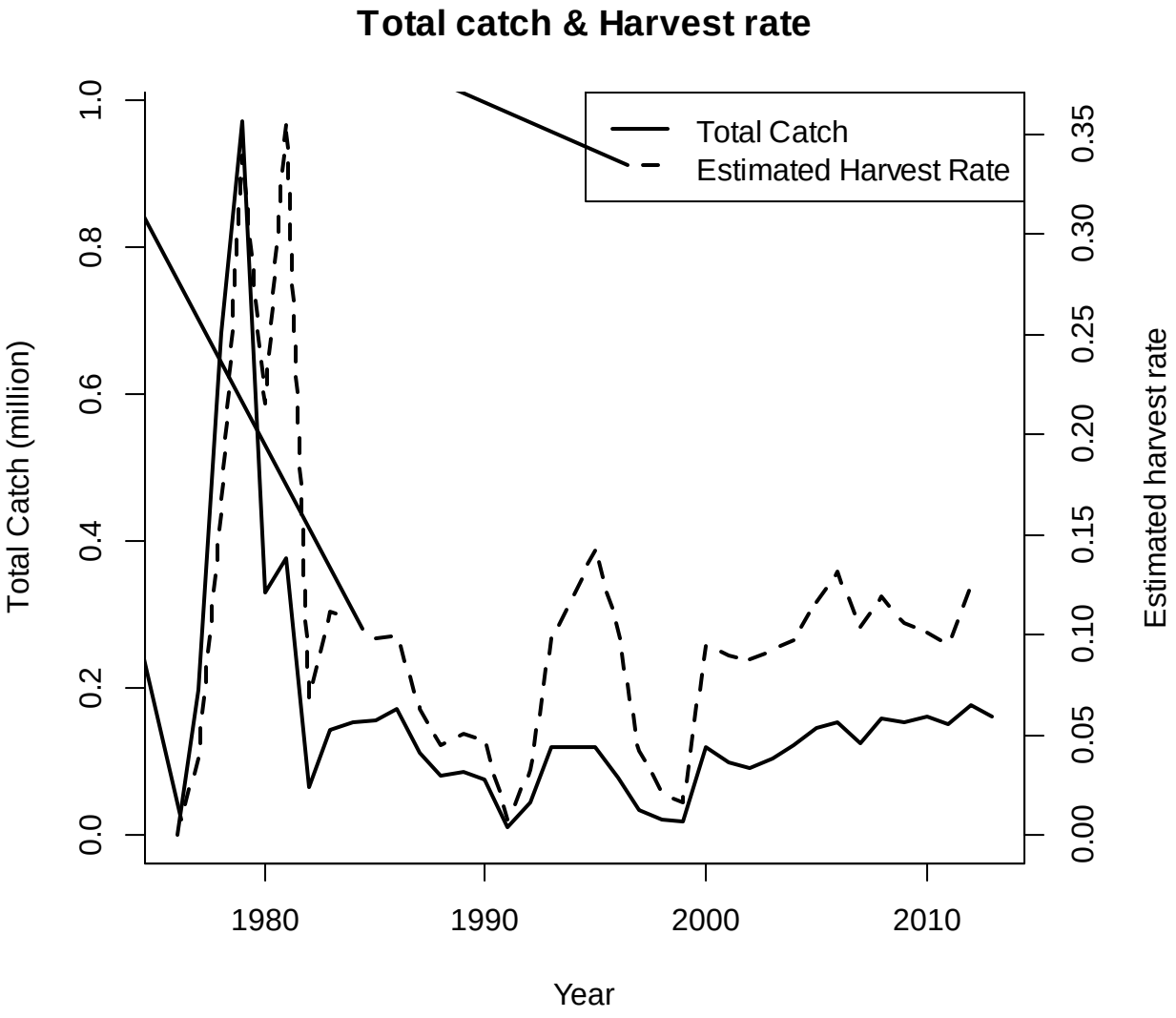


Figure 10a: Total catch and estimated harvest rate 1976-2013

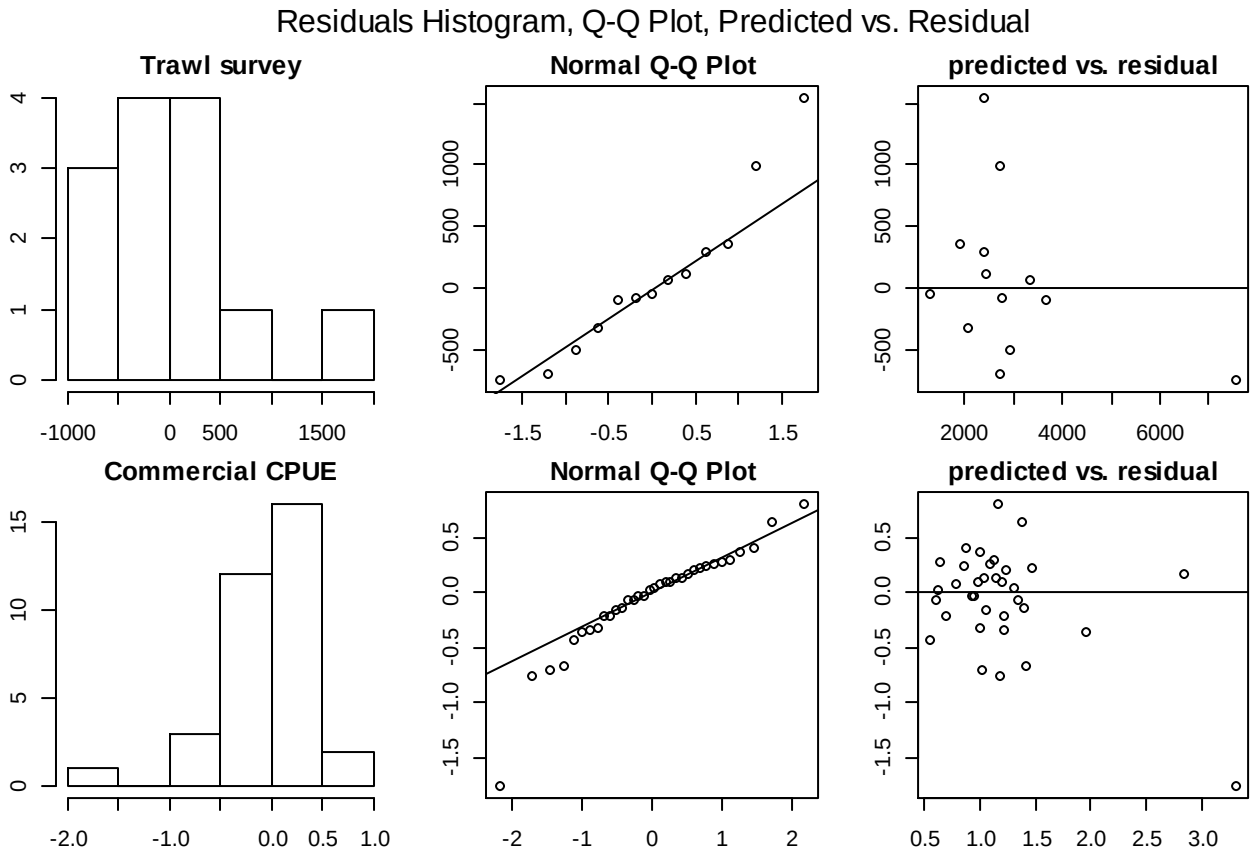


Figure 11a: Residual and QQ plot (Full data)

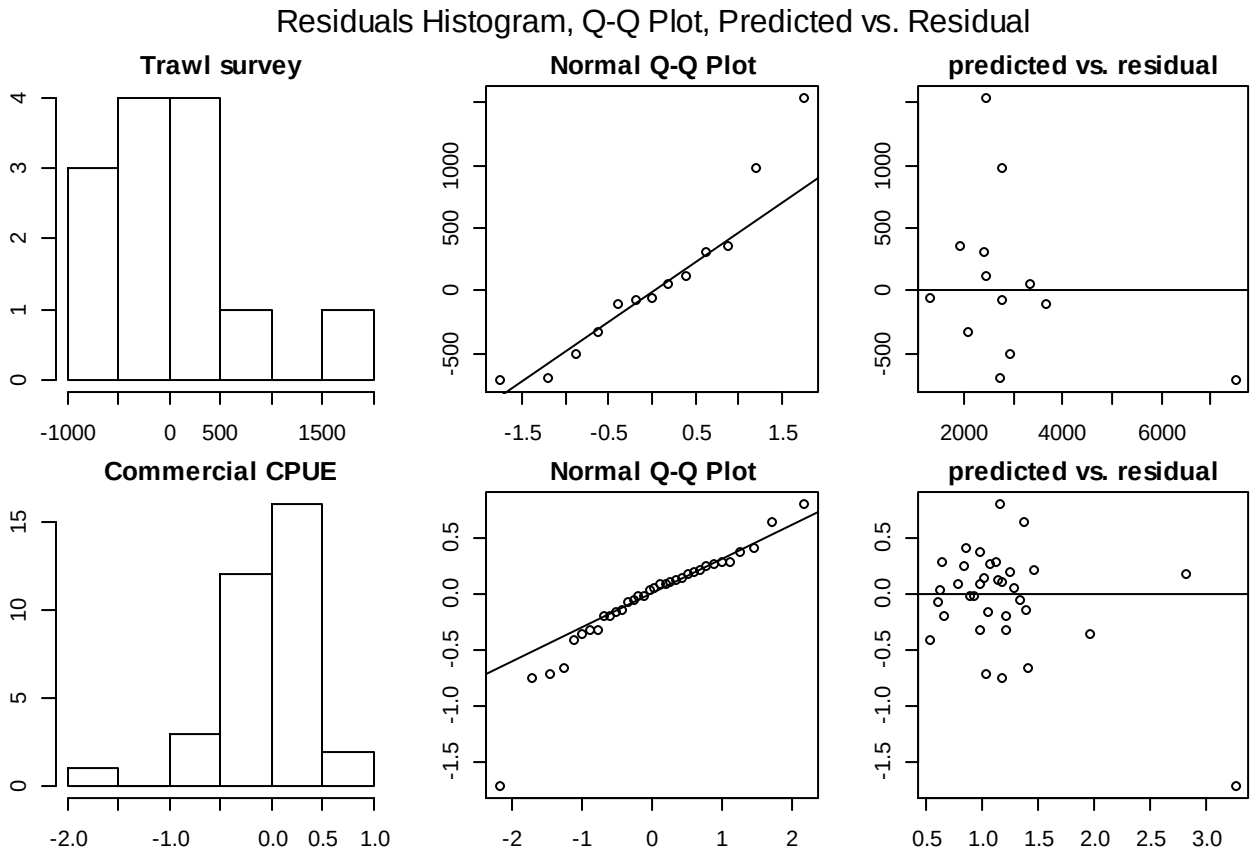
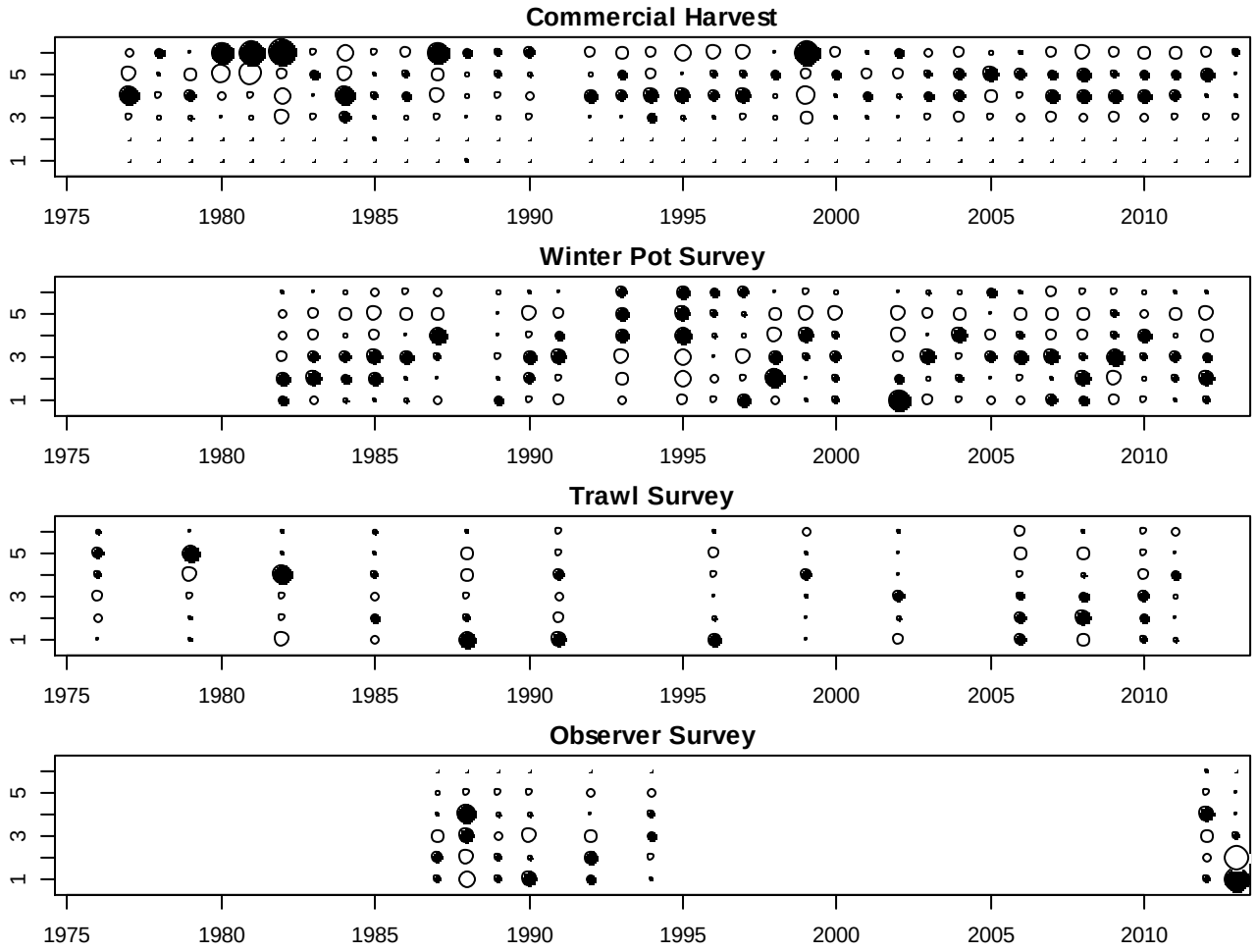
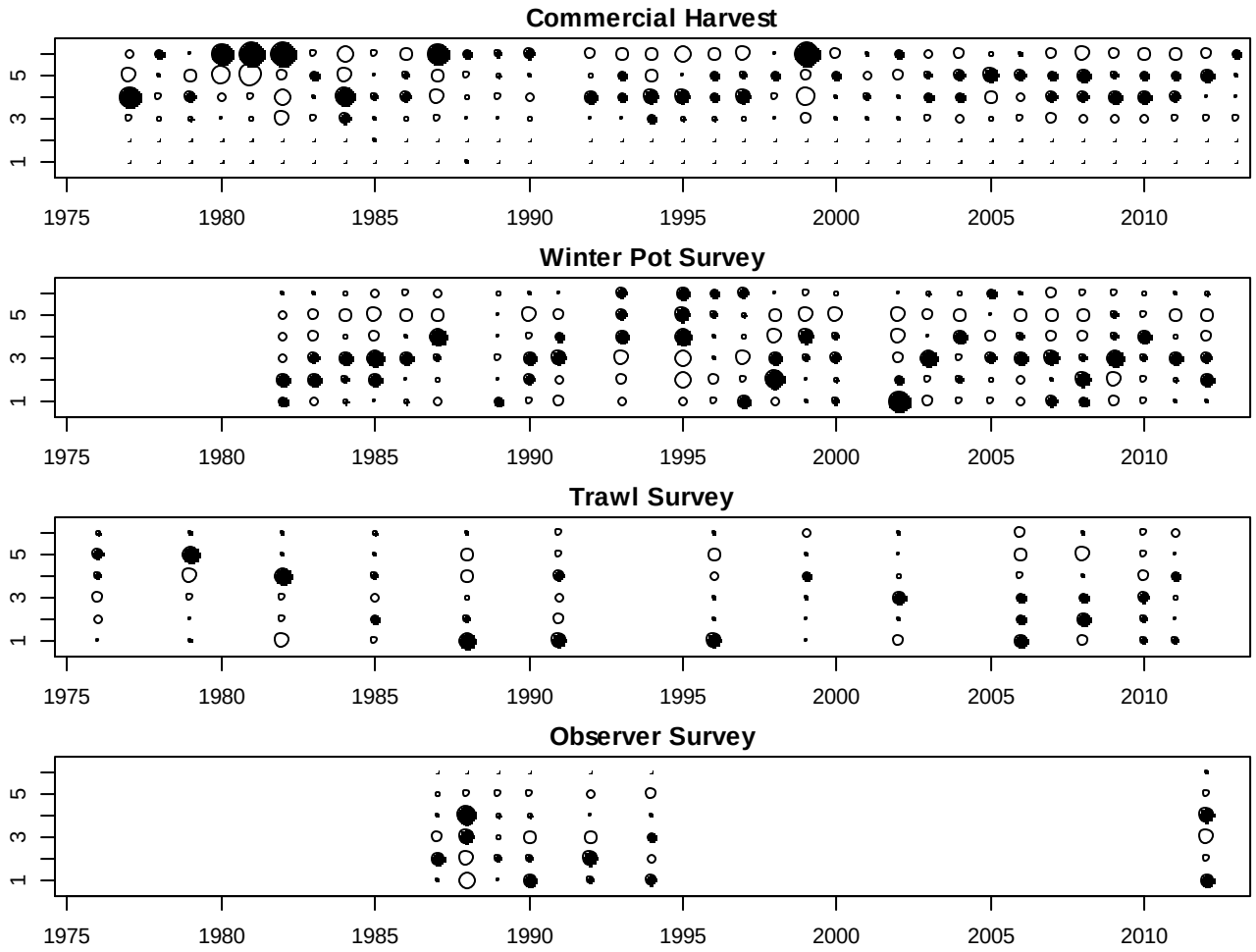


Figure 11b: Residual and QQ plot (without 2013 Observer data)



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 12a: Bubble plot of predicted and observed length proportion (Full data).



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 12b: Bubble plot of predicted and observed length proportion (without 2013 Observer data).

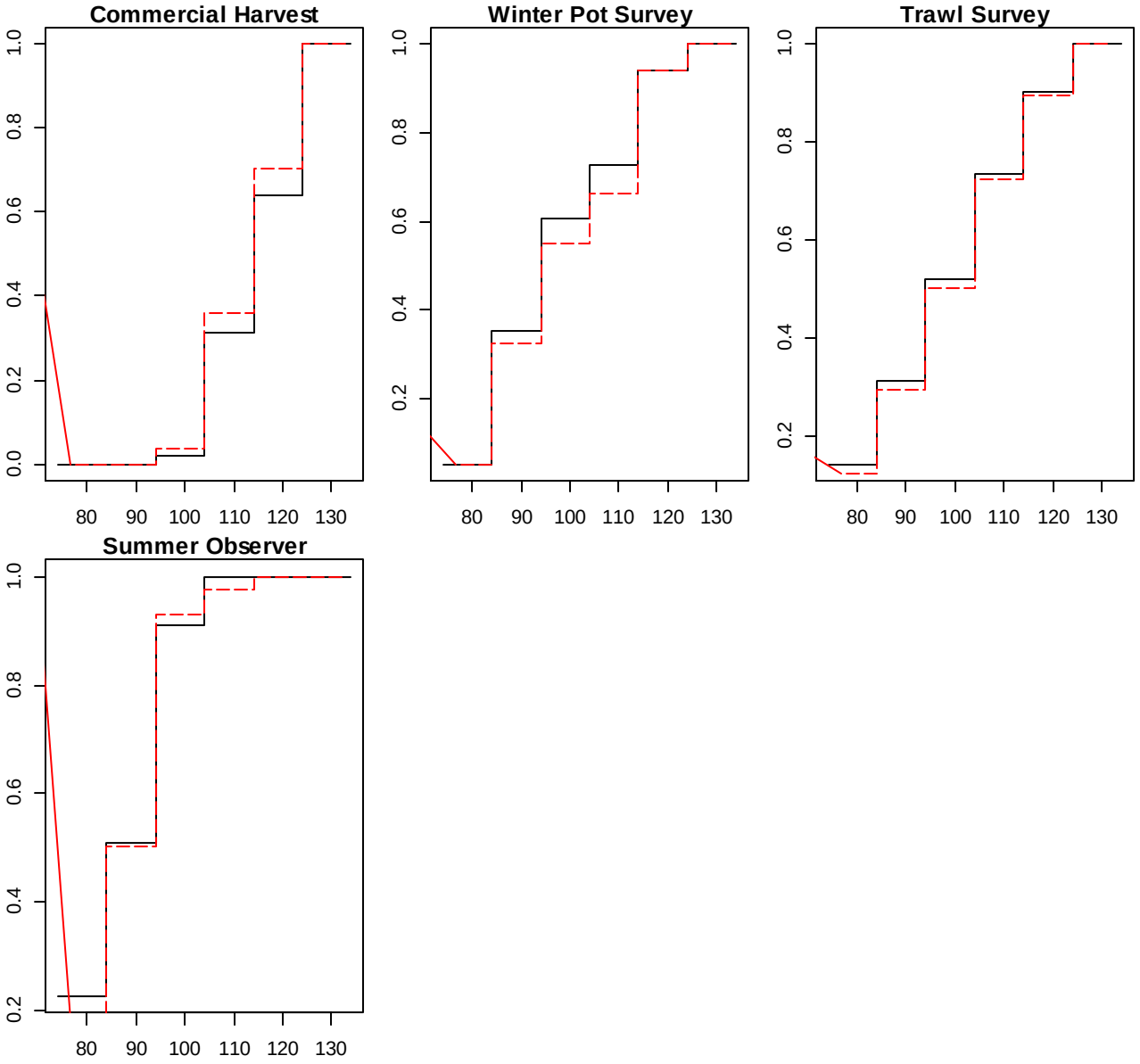


Figure 13a:. Cumulative frequency of length classes between observed and modeled (Full data)

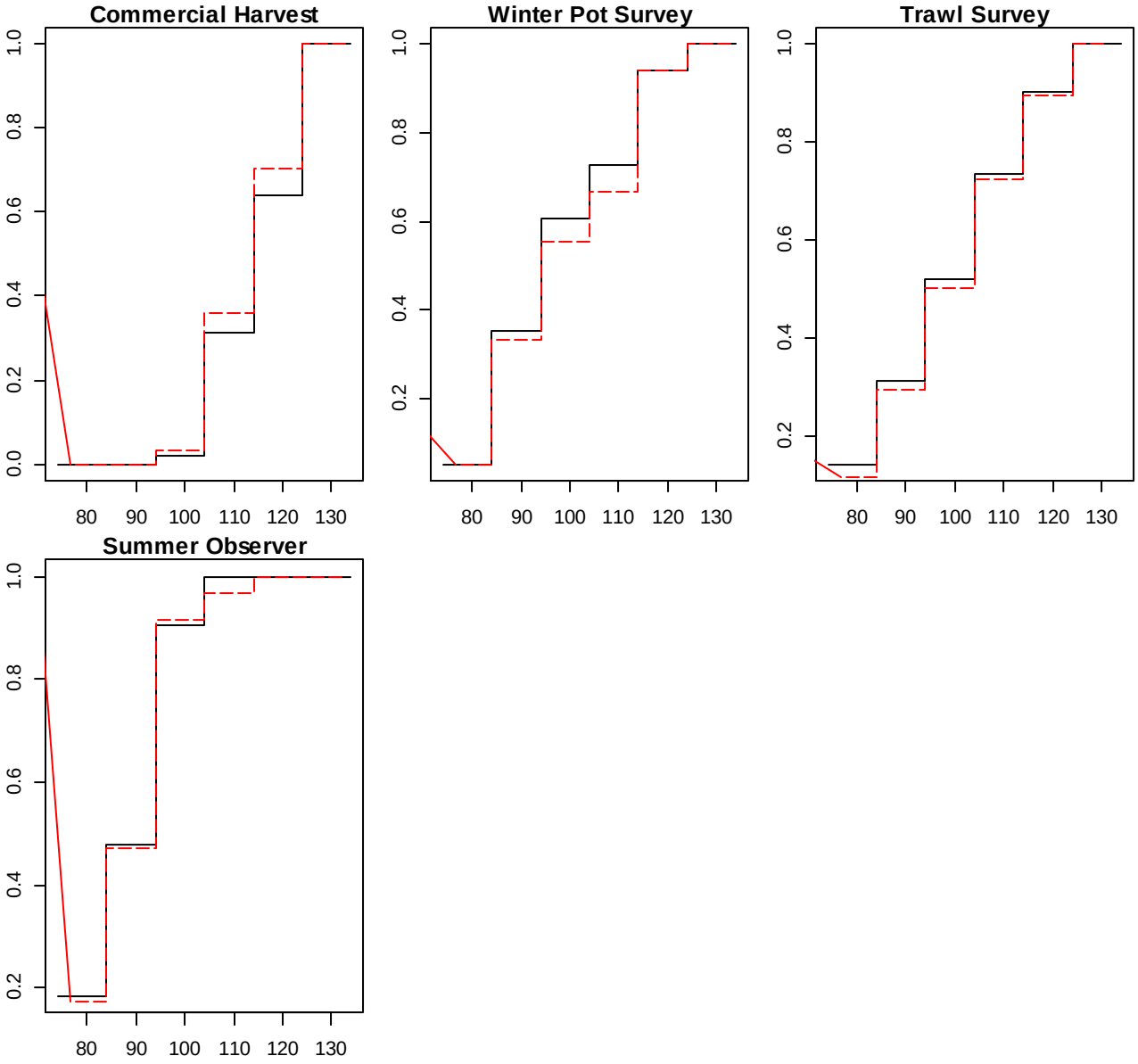


Figure 13b: Cumulative frequency of length classes between observed and modeled (without 2013 Observer data)

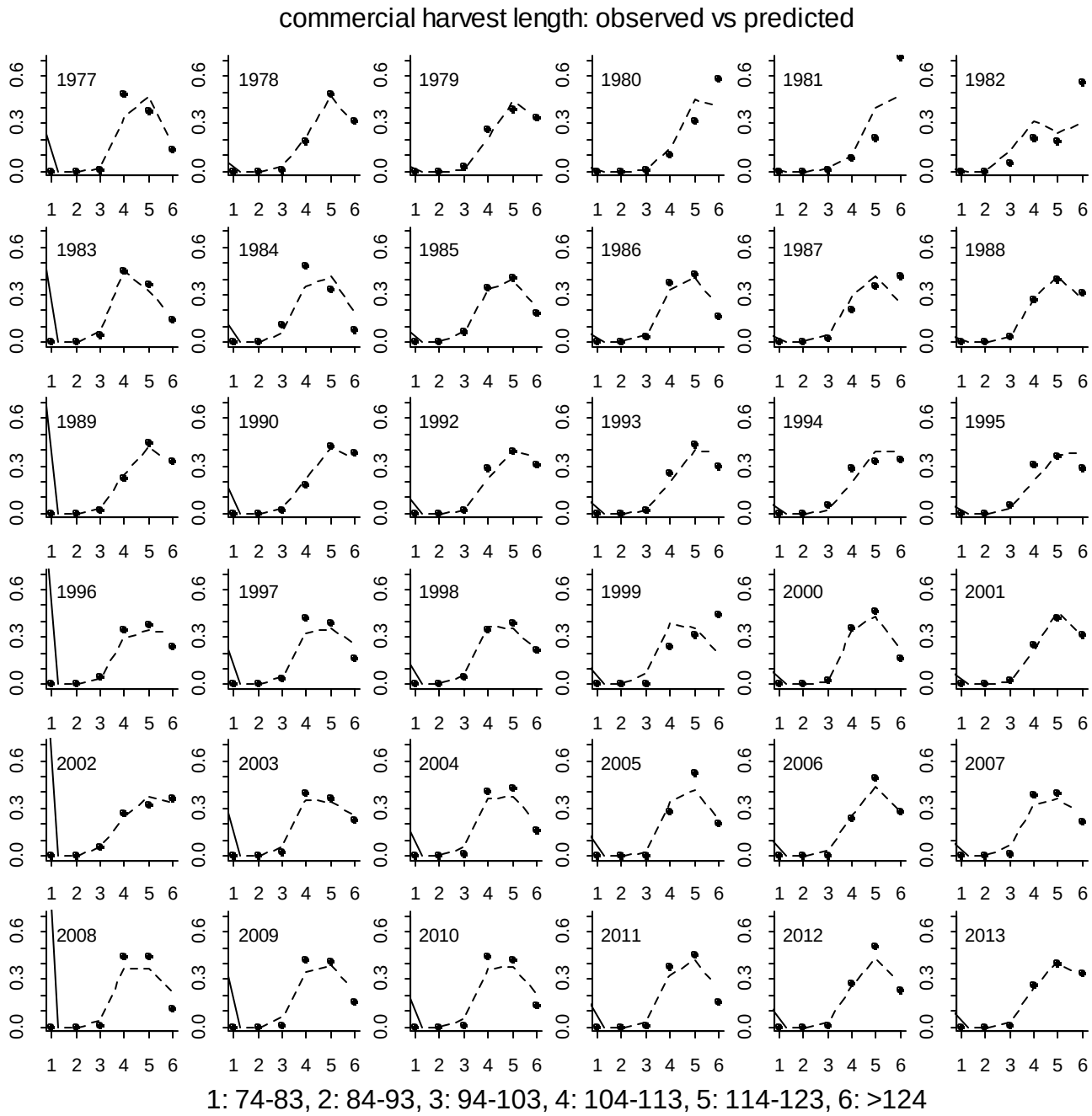


Figure 14a: Predicted vs. observed length class proportion for commercial catch (Full data)

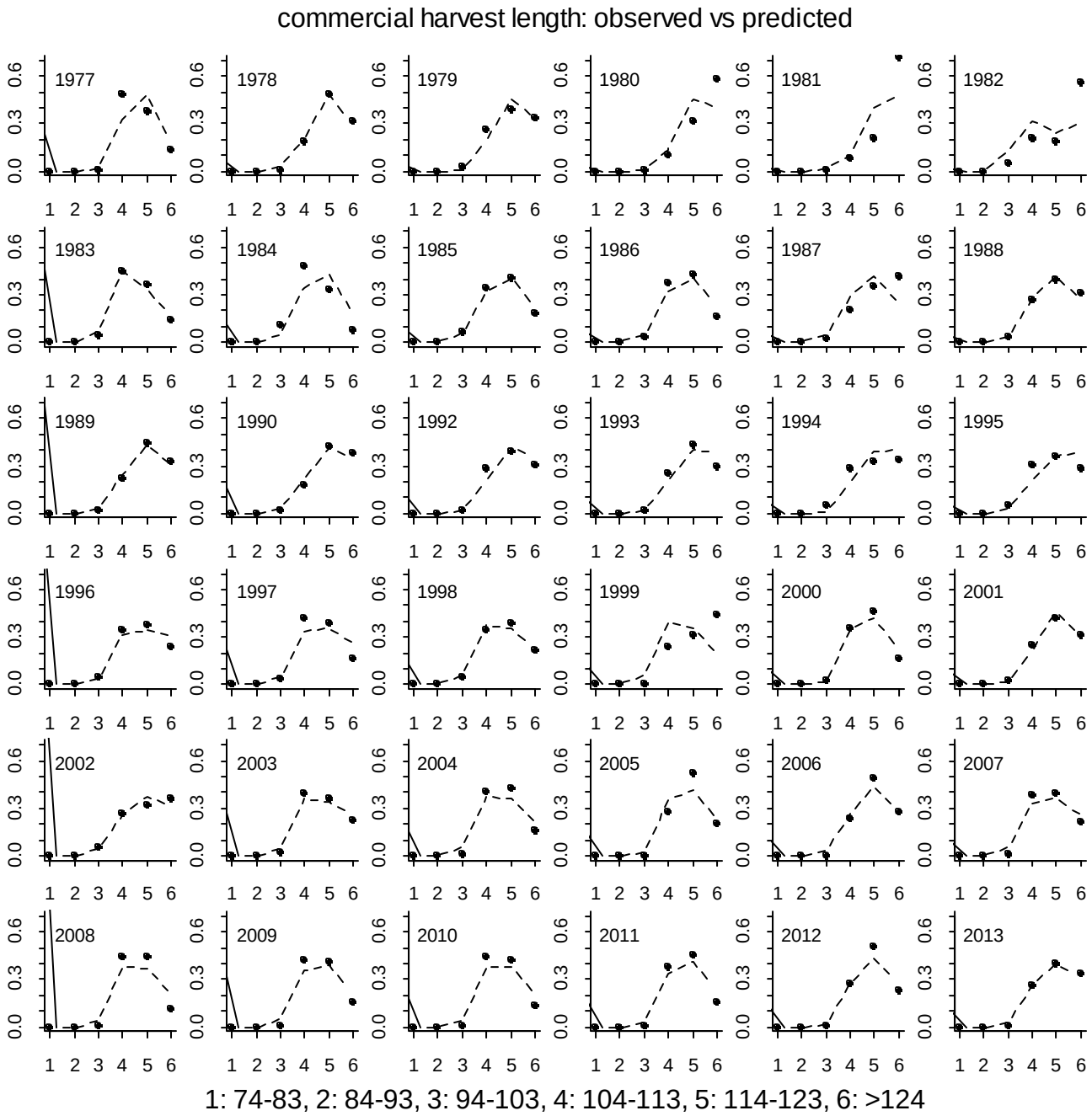
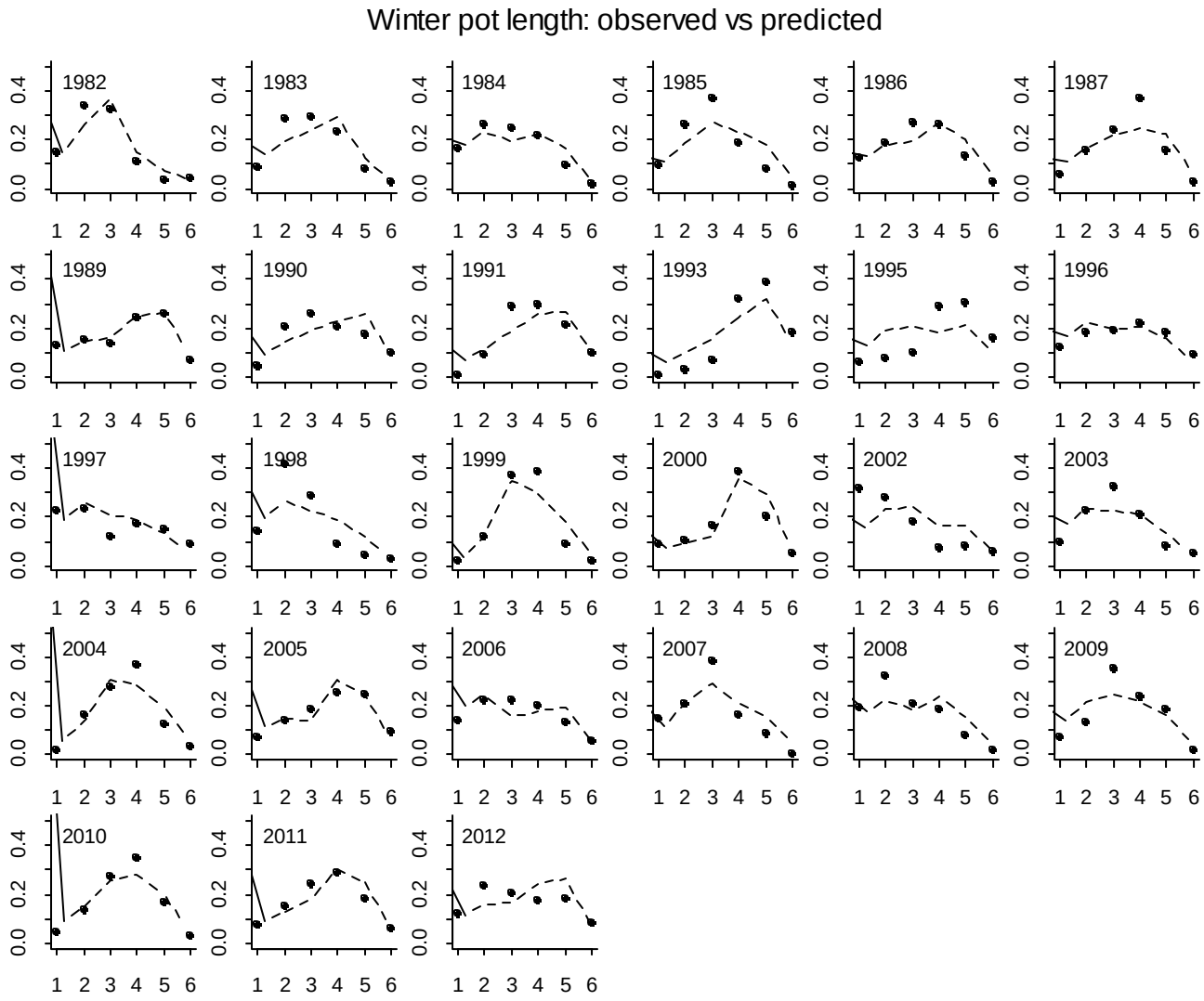
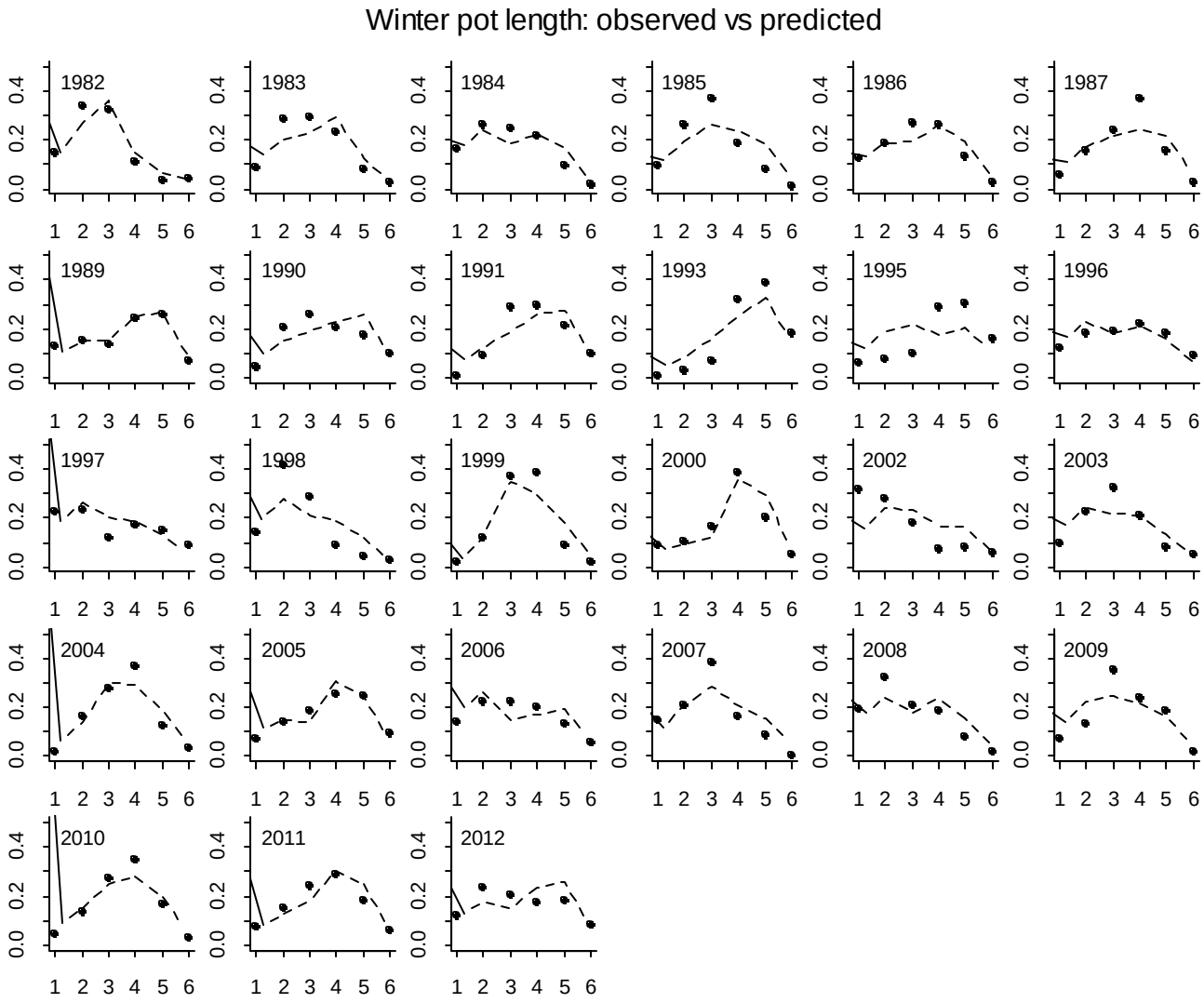


Figure 14b: Predicted vs. observed length class proportion for commercial catch (without 2013 Observer data)



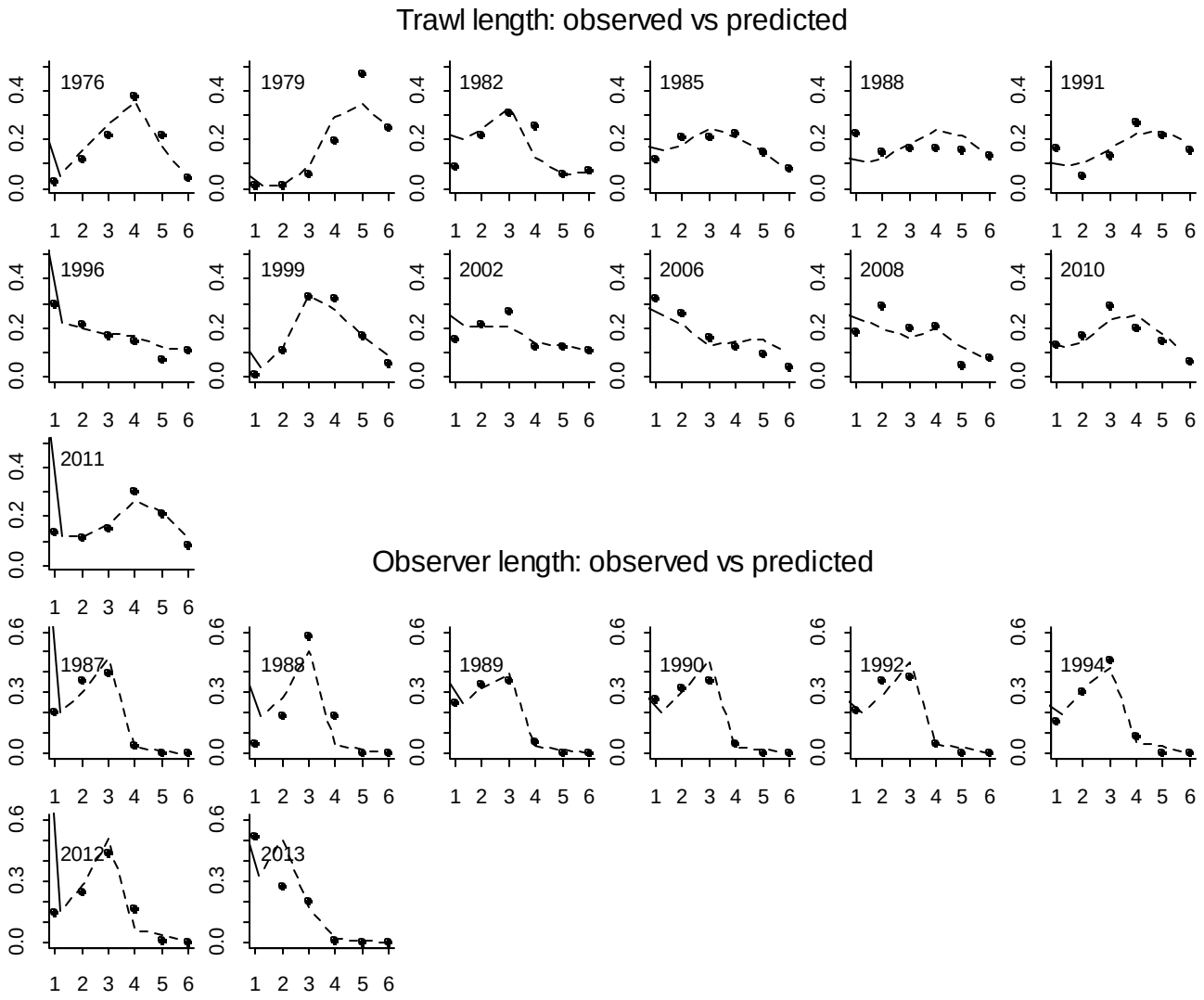
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 15a: Predicted vs. observed length class proportion for winter pot survey (Full data)



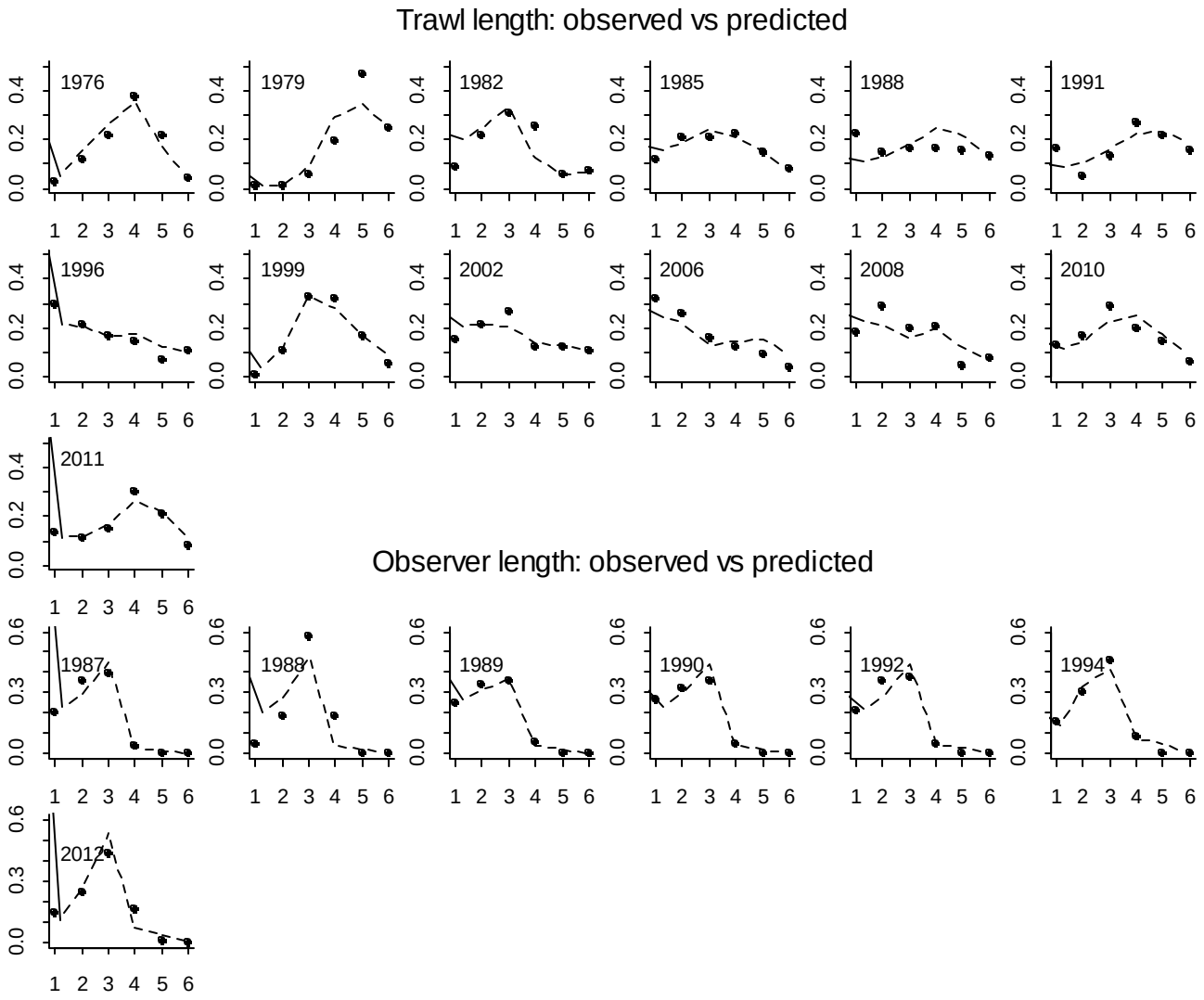
1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 15b: Predicted vs. observed length class proportion for winter pot survey (without 2013 Observer data)



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 16a: Predicted vs. observed length class proportion for trawl survey and commercial observer (Full data).



1: 74-83, 2: 84-93, 3: 94-103, 4: 104-113, 5: 114-123, 6: >124

Figure 16b: Predicted vs. observed length class proportion for trawl survey and commercial observer. (without 2013 Observer data)