Norton Sound Red King Crab SAFE2018

Jan 09 2018

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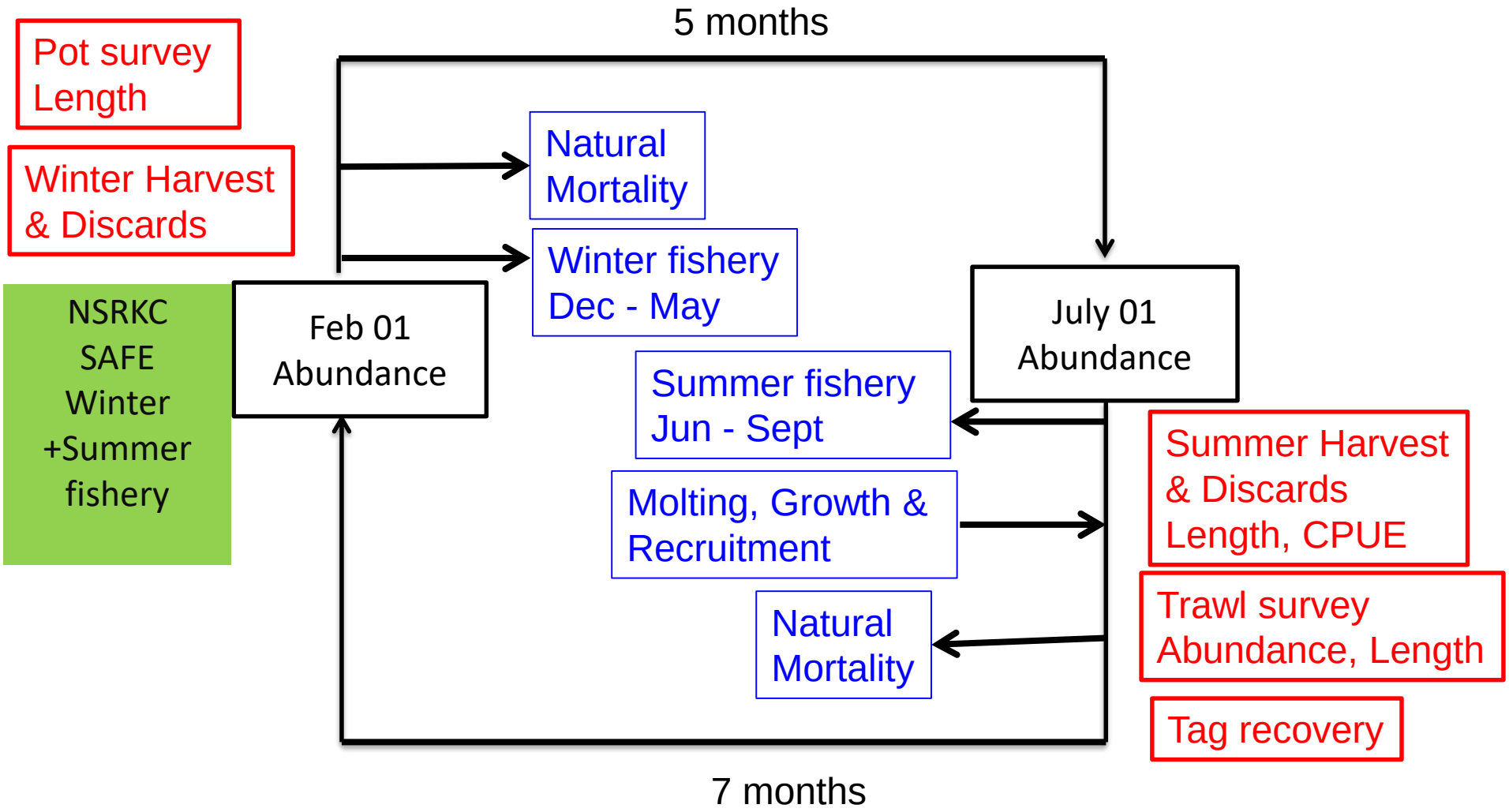
NSRKC Stock Assessment Model

Modeling process

Available Data & model fit



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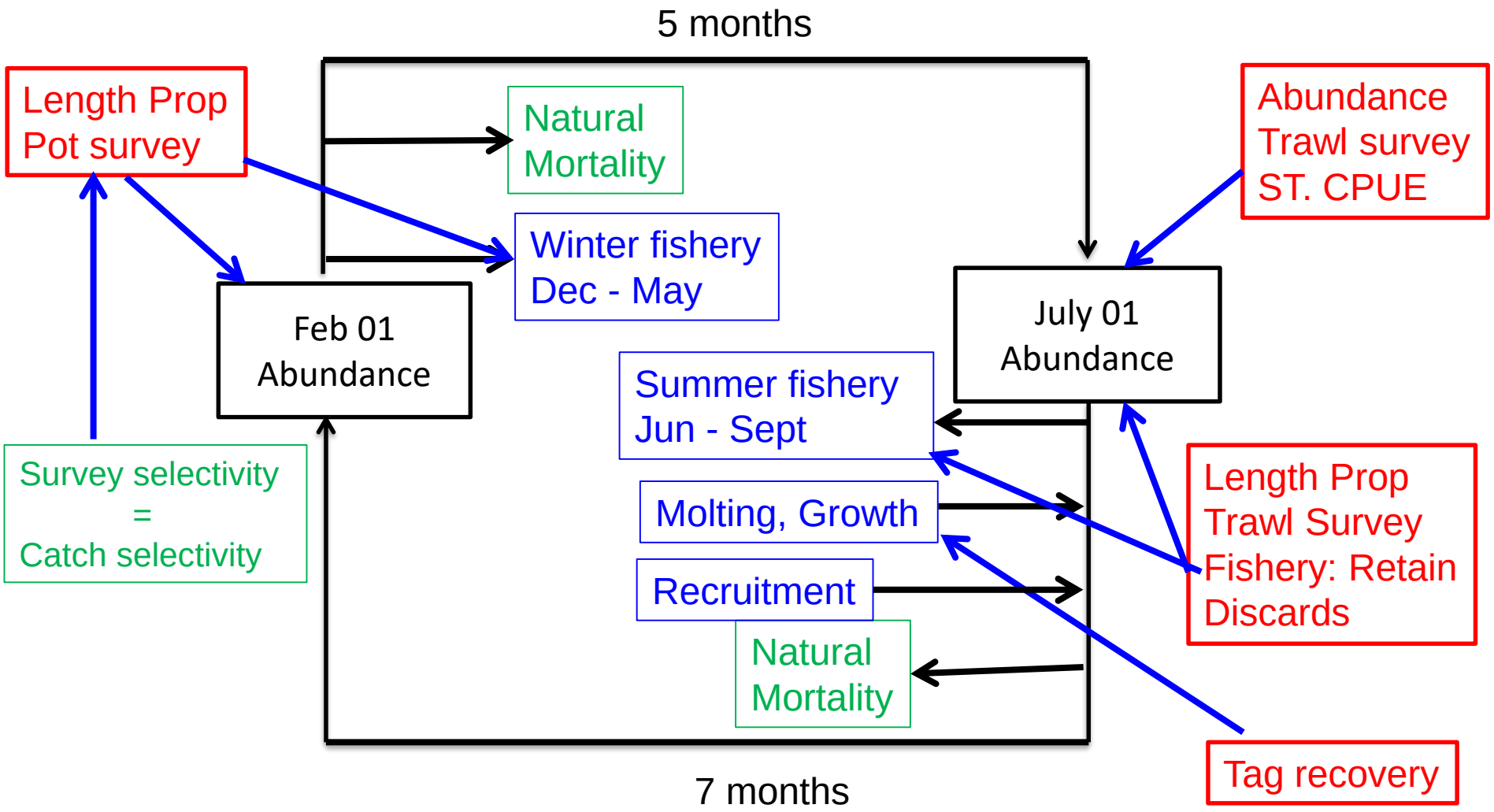
Available Data & model fit



Available Data

	Survey		Harvests			Tag	Data Not Used[3]				
	S. Trawl	W. Pot	S.Com	S.Com Discards	W. Com, Sub		S. Pot	Pre fish	Sp. Tag	F. Tag,	W. Com
N[1]	N		H, CPUE		H						
Length[2]	X	X	X	X		X	X	X	X	X	X
1976											
1977											
1978											
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2014											
2015											
2016											
2017											

Assumptions

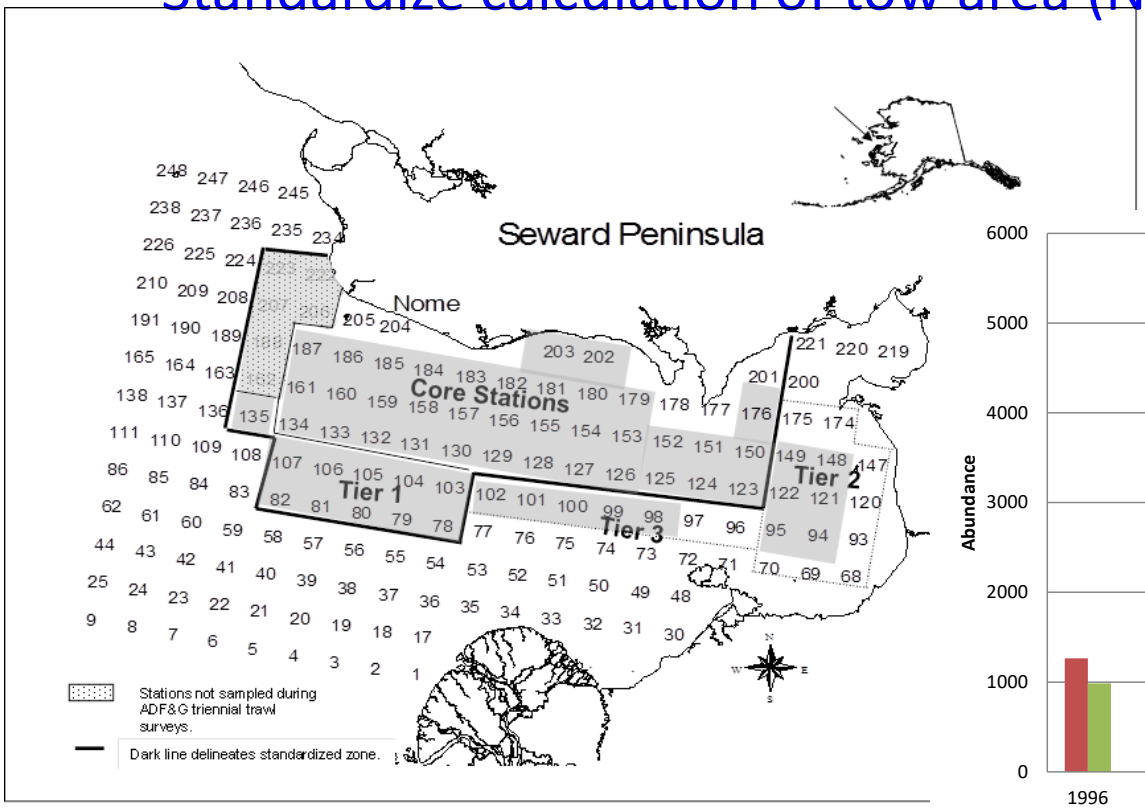
- M = 0.18 for length class 1-6, higher mortality of classes 7 and 8
- Same selectivity and catchability for New and Old Shells
- Discards mortality = 0.2
- Fishery harvests occur instantly:
  - Winter fishery: Feb 01: Nov – May
  - Summer fisher: July 01: Jun – Sept
- Winter catch selectivity = winter pot survey selectivity

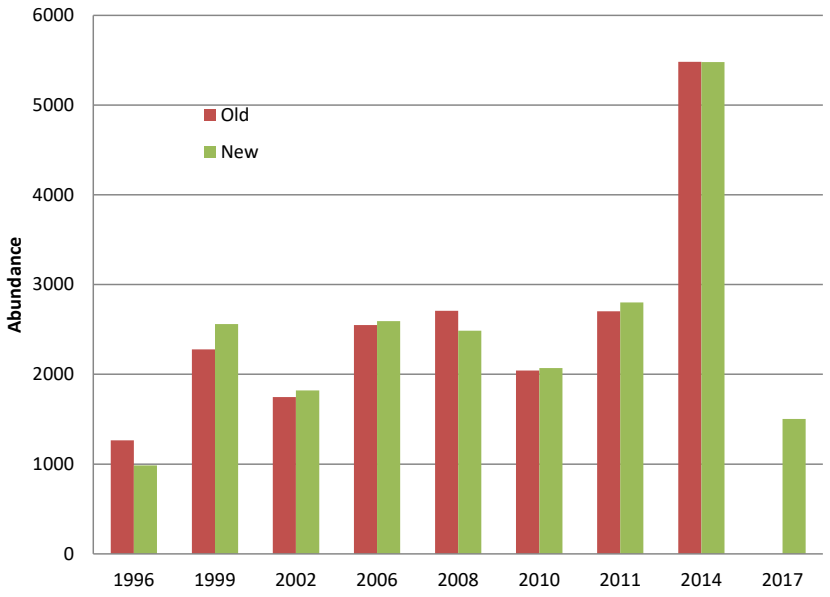
Changes Fishery & Data

- Winter fishery 2017
  - Commercial: 26,008 (77,843 lb.) The highest ever.
  - Subsistence: 6,039 (15,097 lb.). About average.
- Summer commercial fishery 2017
  - 6/26-7/25: 135,322 (411,736 lb.)
- Total retained harvest: 167,369 (0.50 mill. lb.) < ABC (0.54 mill. lb.)
- All harvest data finalized.
- Standardized CPUE update (Appendix B)
- ADF&G 2017 trawl survey
  - 7/28-8/08: 1762.1 k, CV =0.22
- NOAA 2017 trawl survey :
  - 8/18-8/29: 1035.8 k, CV = 0.40
- Recalculation ADFG trawl survey abundance
- Changes in fishery regulation: None

Changes Fishery & Data

- Recalculation of ADFG trawl abundance update
  - Standardize survey stations
  - Assume zero crab in unsurveyed stations (All unmonitored stations are corners) (See Appendix E).
  - Remove re-towed survey data (original: take average)
  - Standardize calculation of tow area (NM, NM^2)





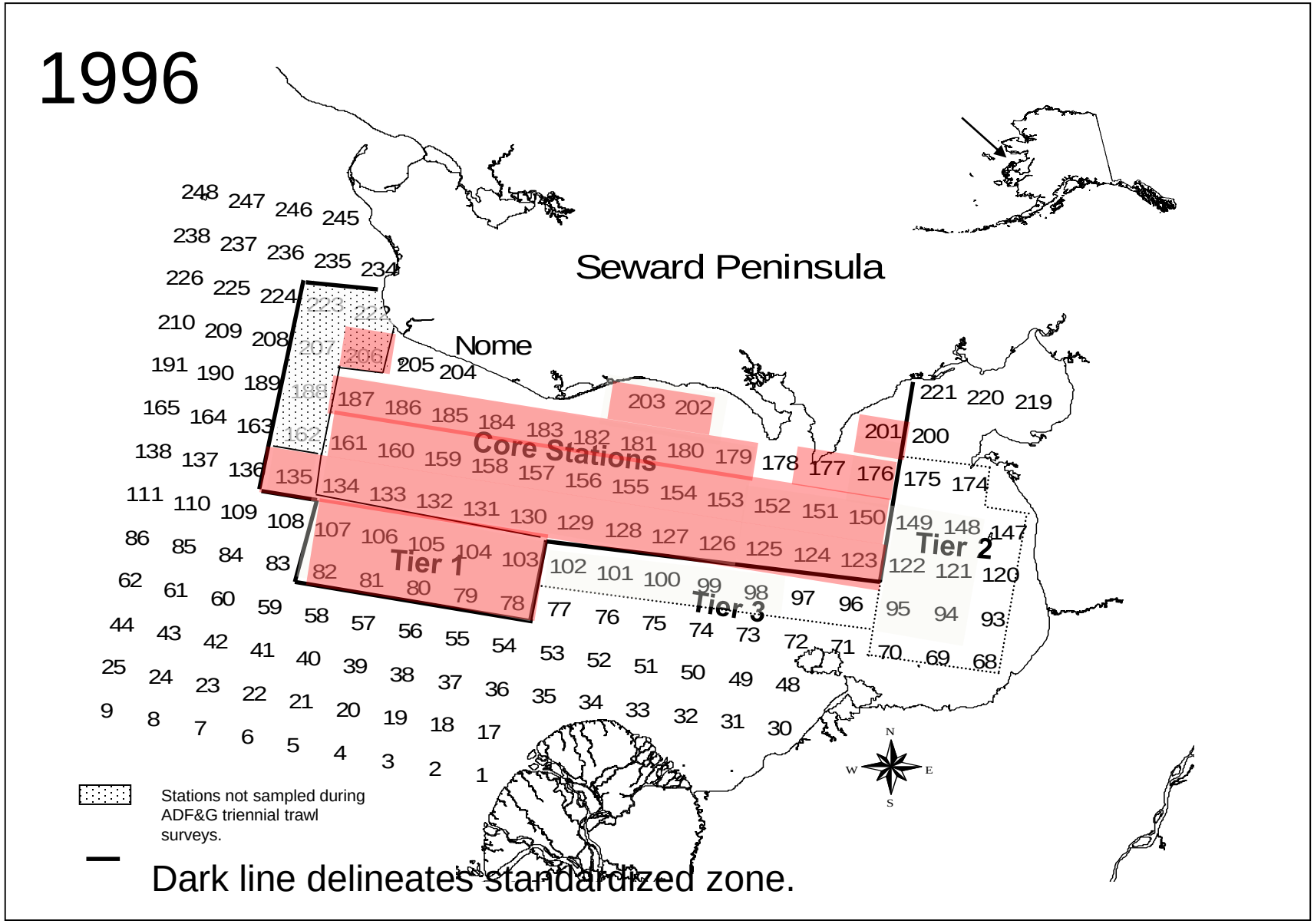
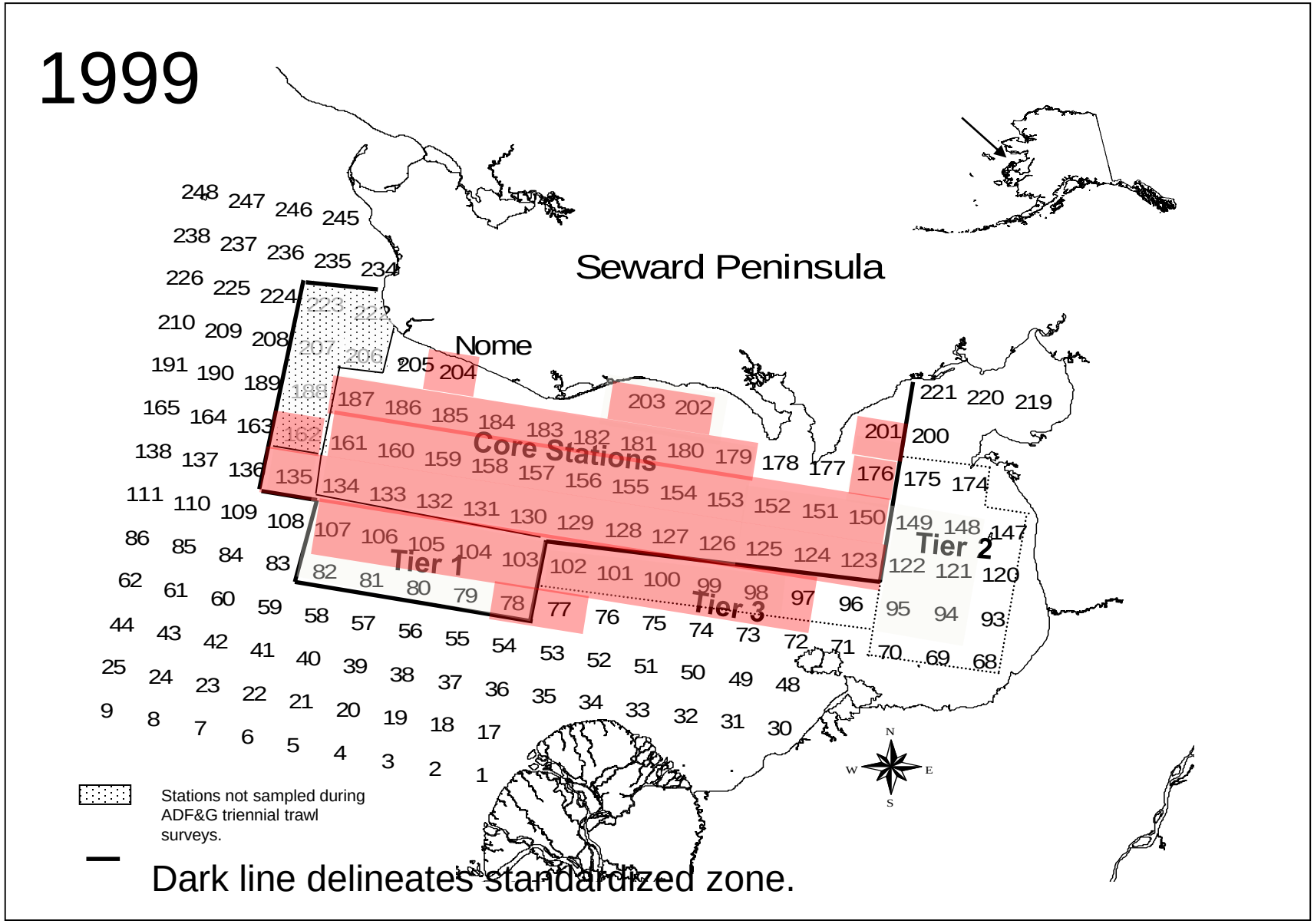


Figure 2- Station Map



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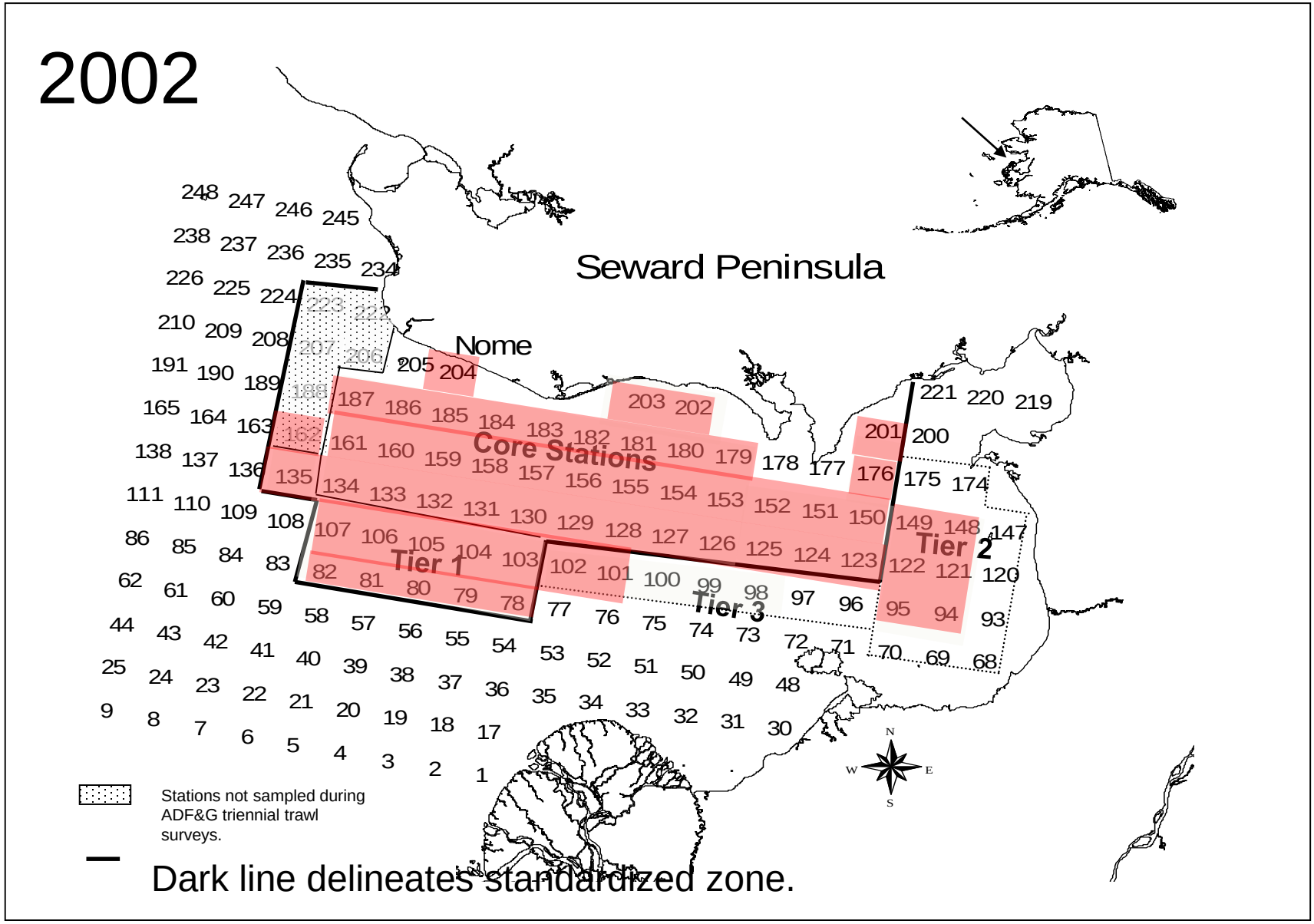

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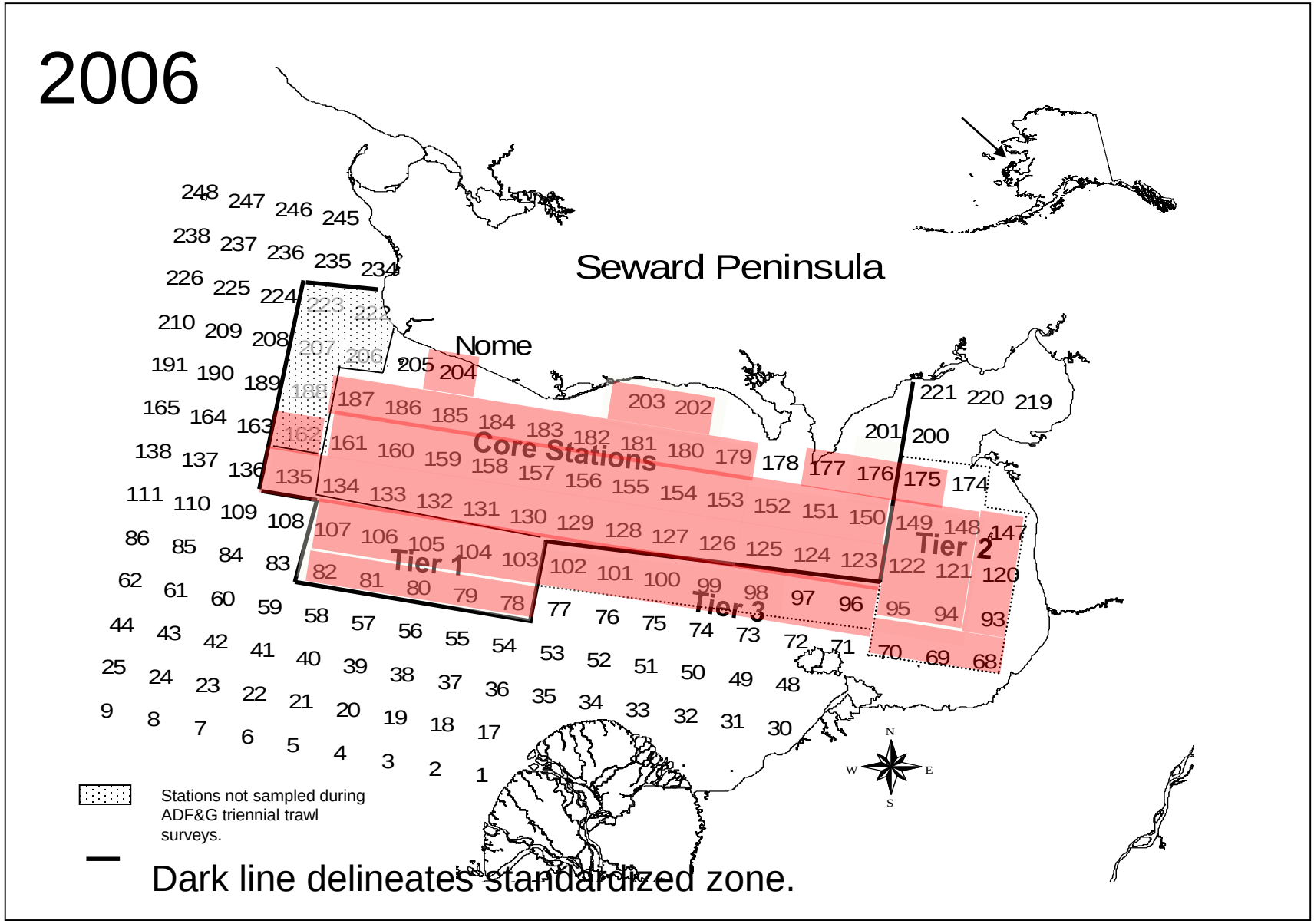

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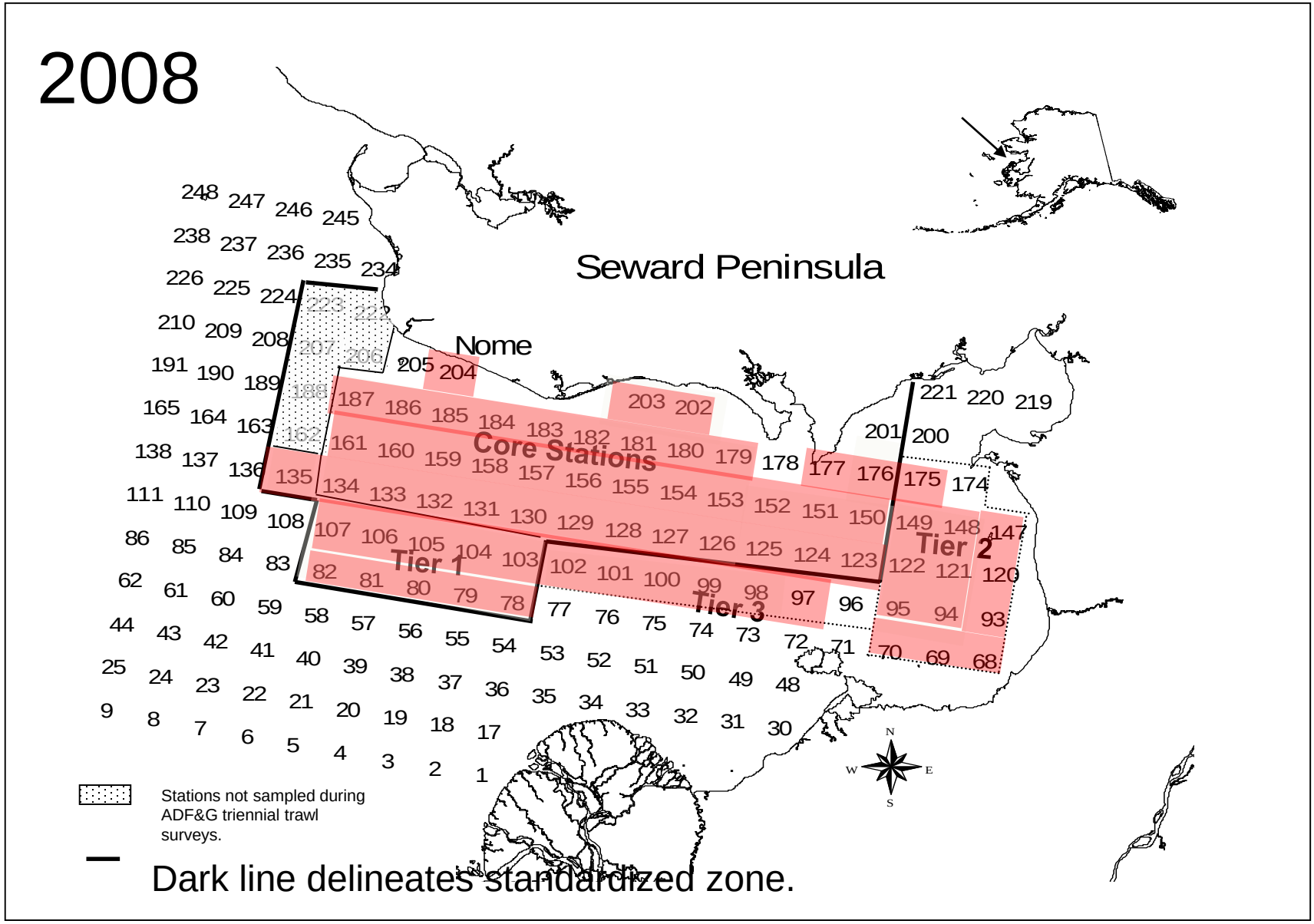

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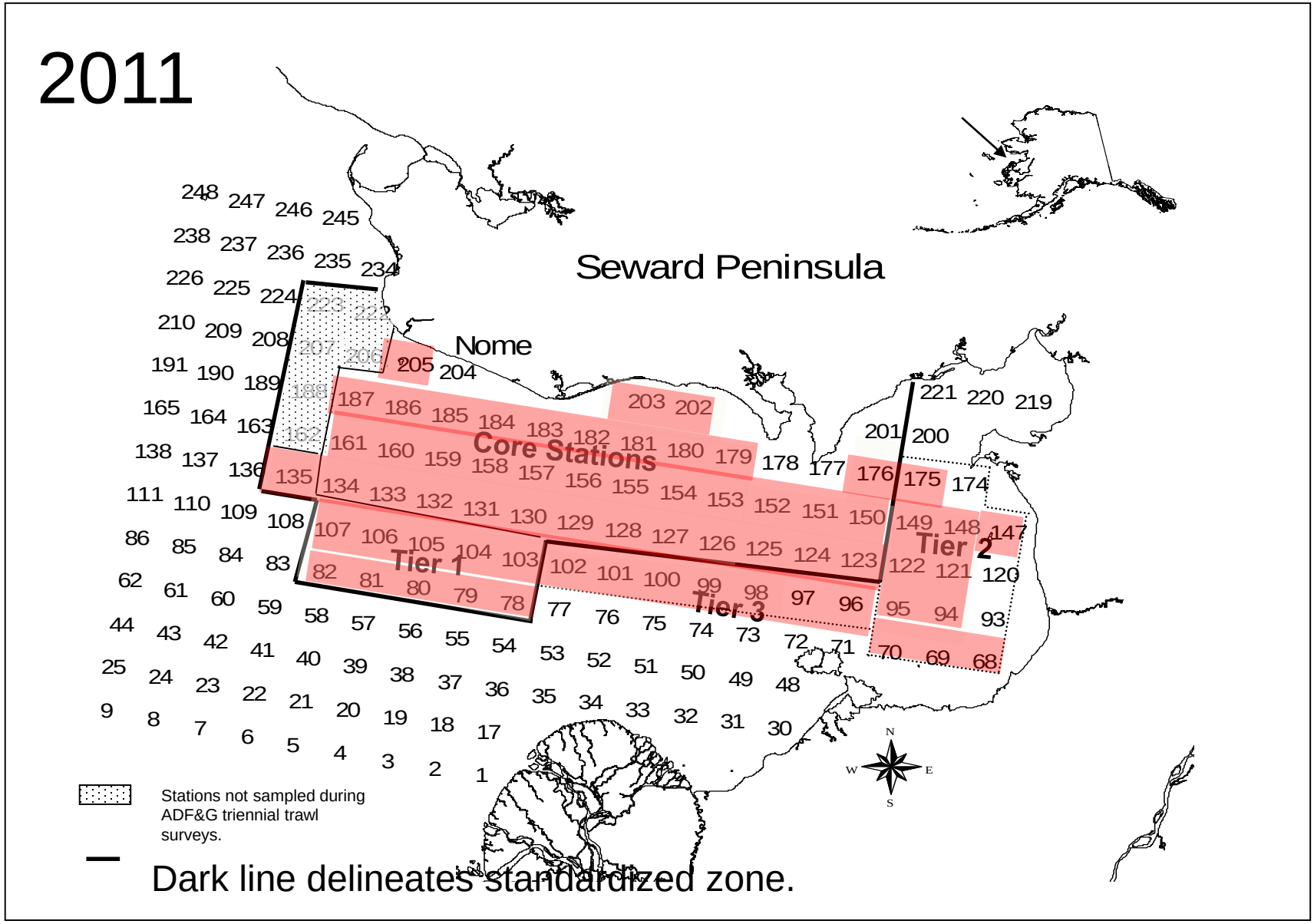

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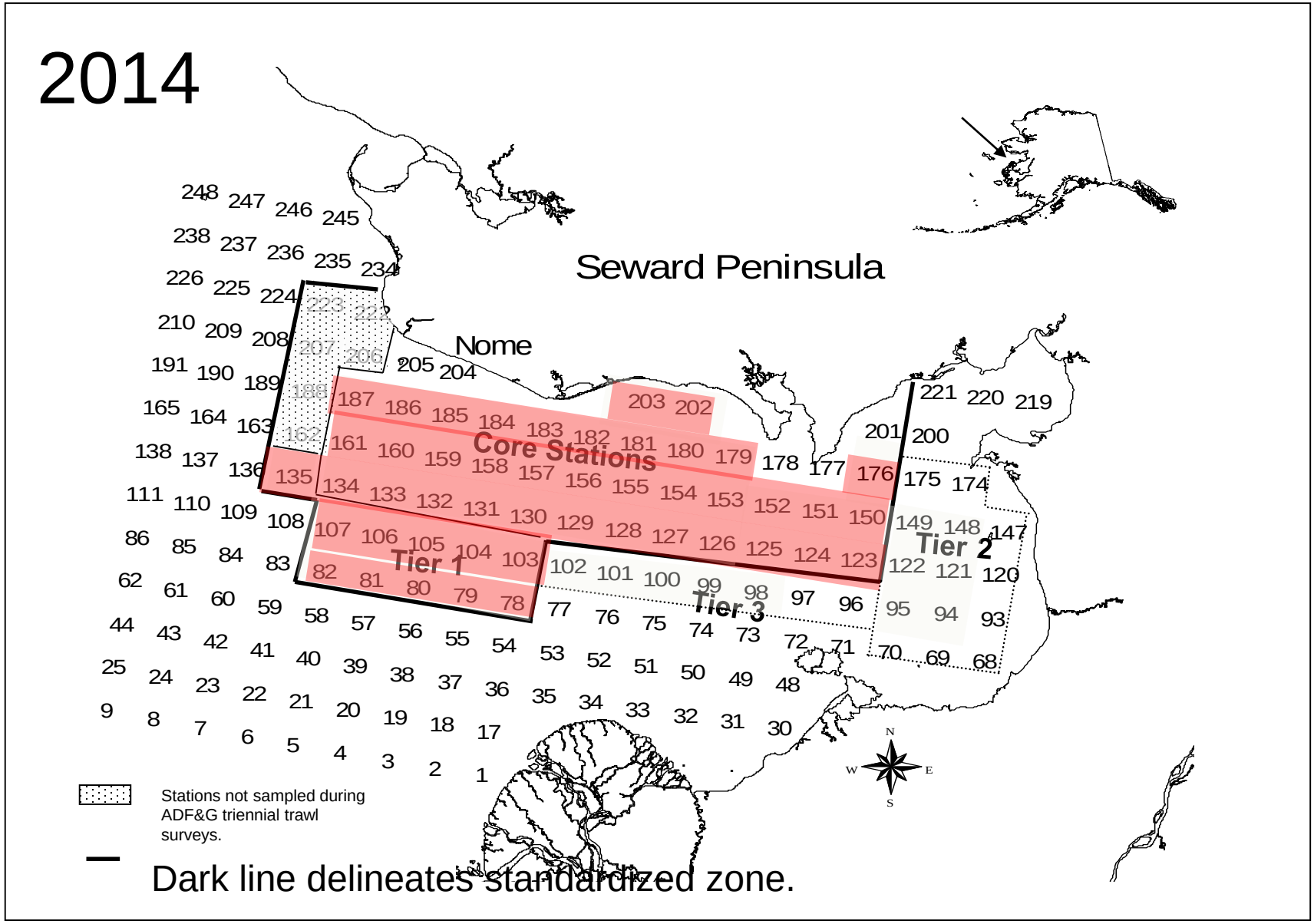

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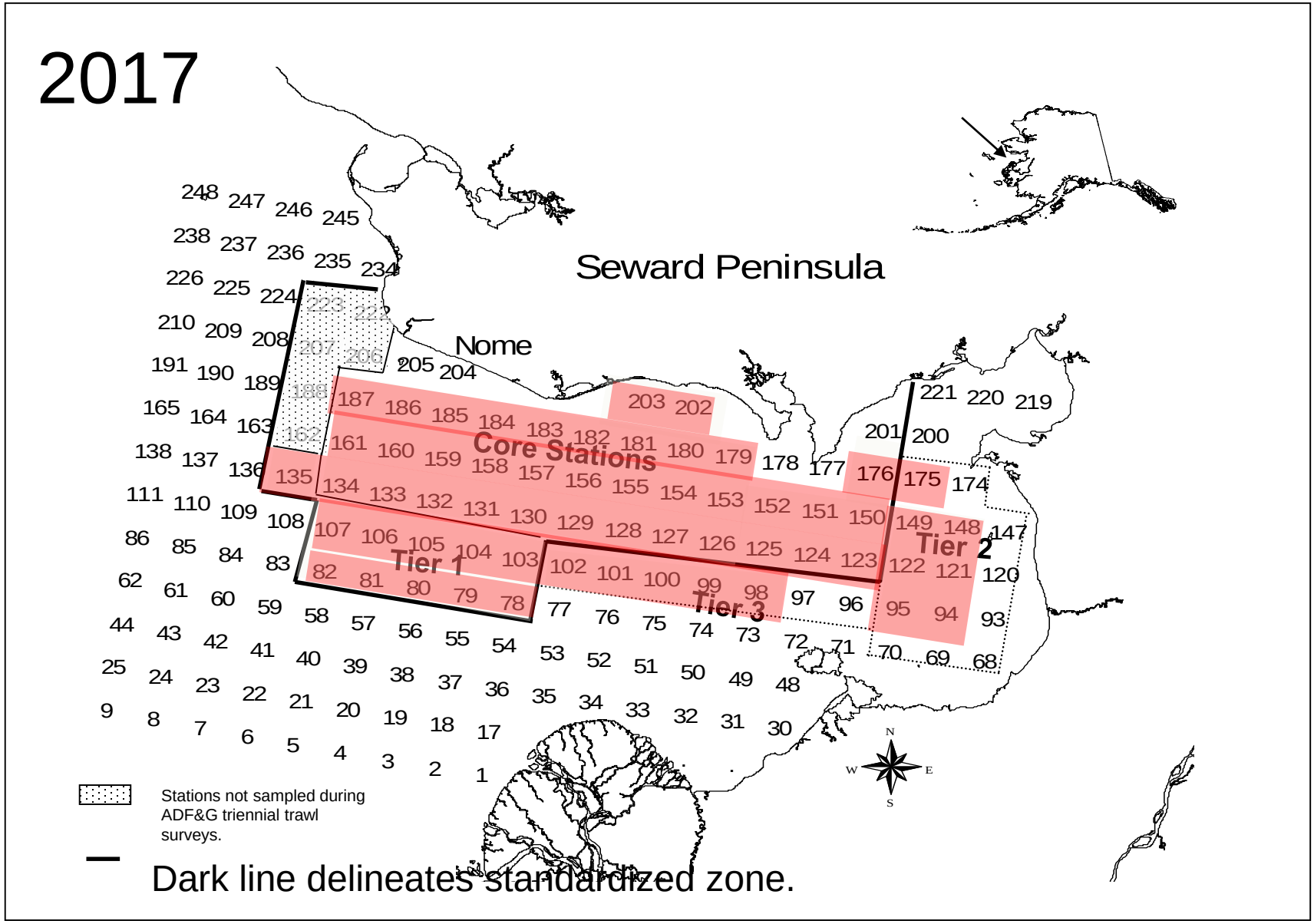

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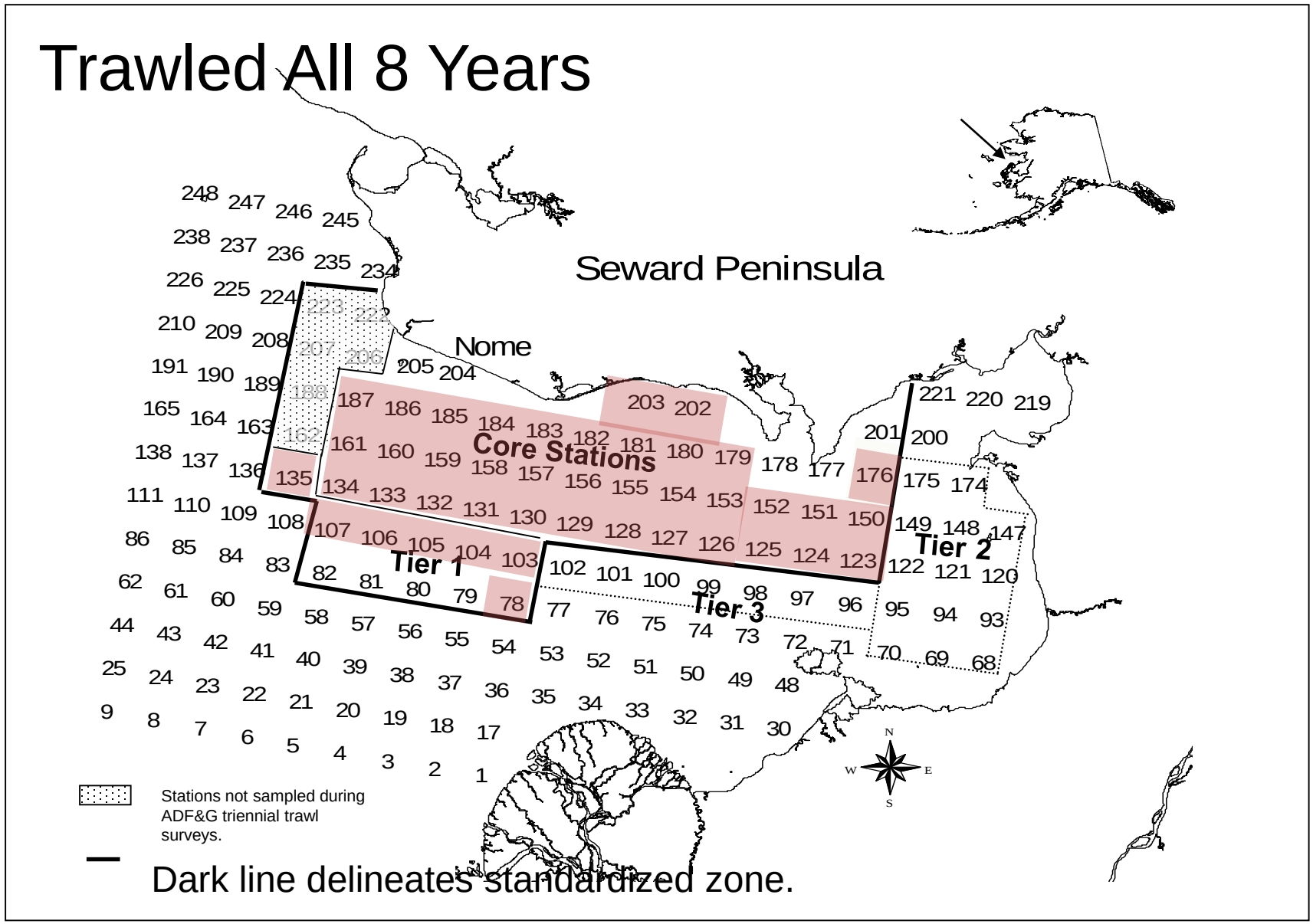

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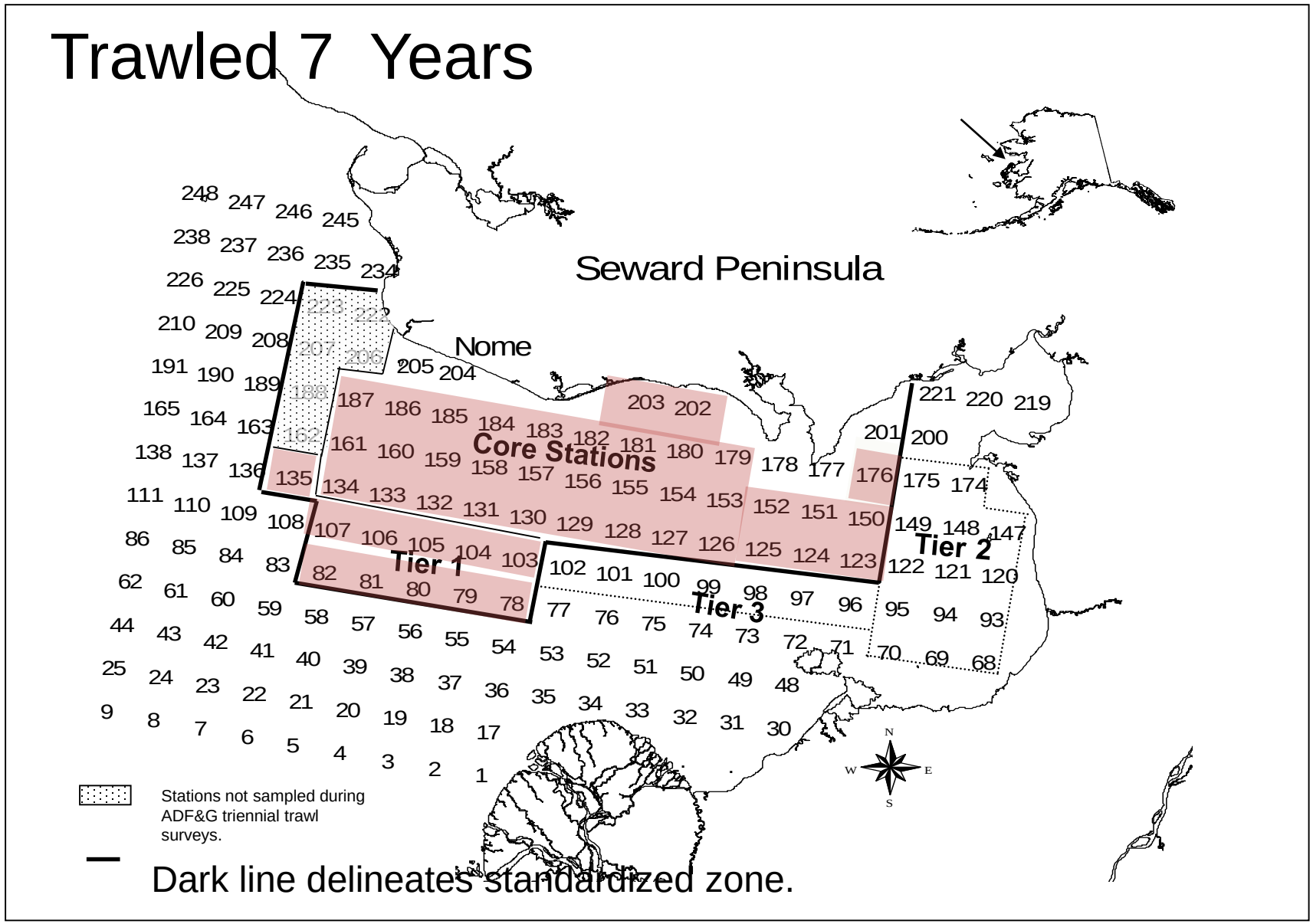

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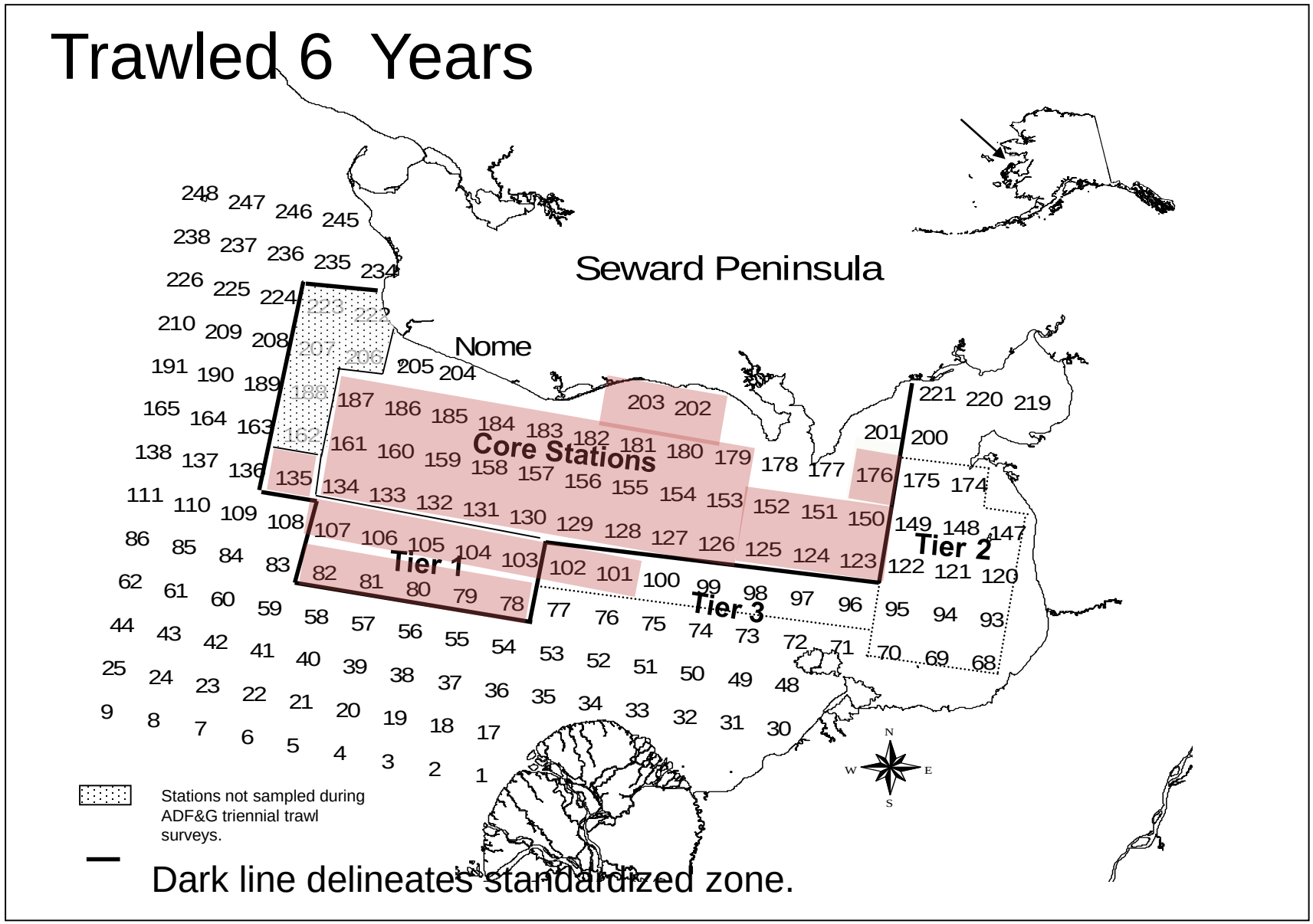

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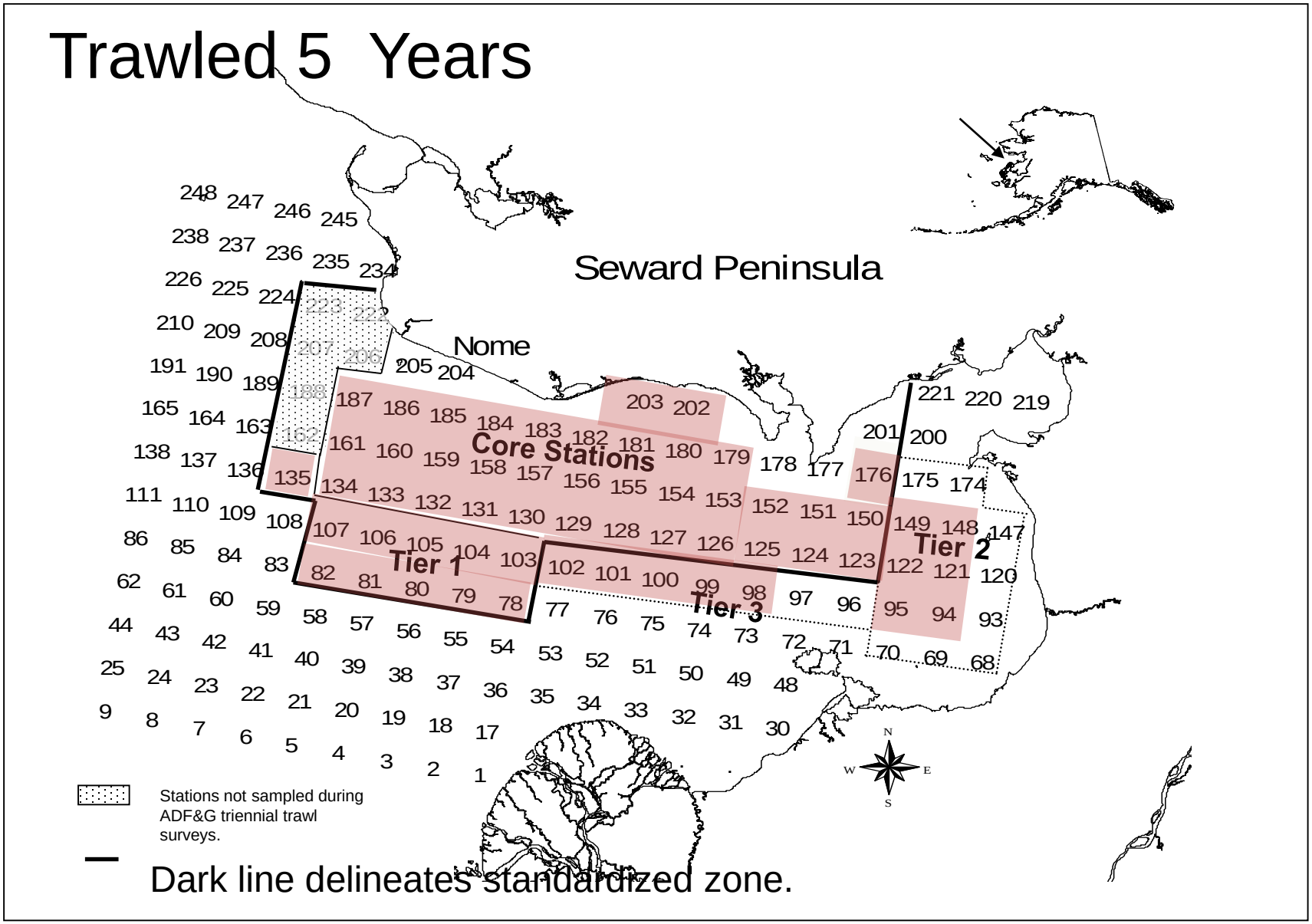
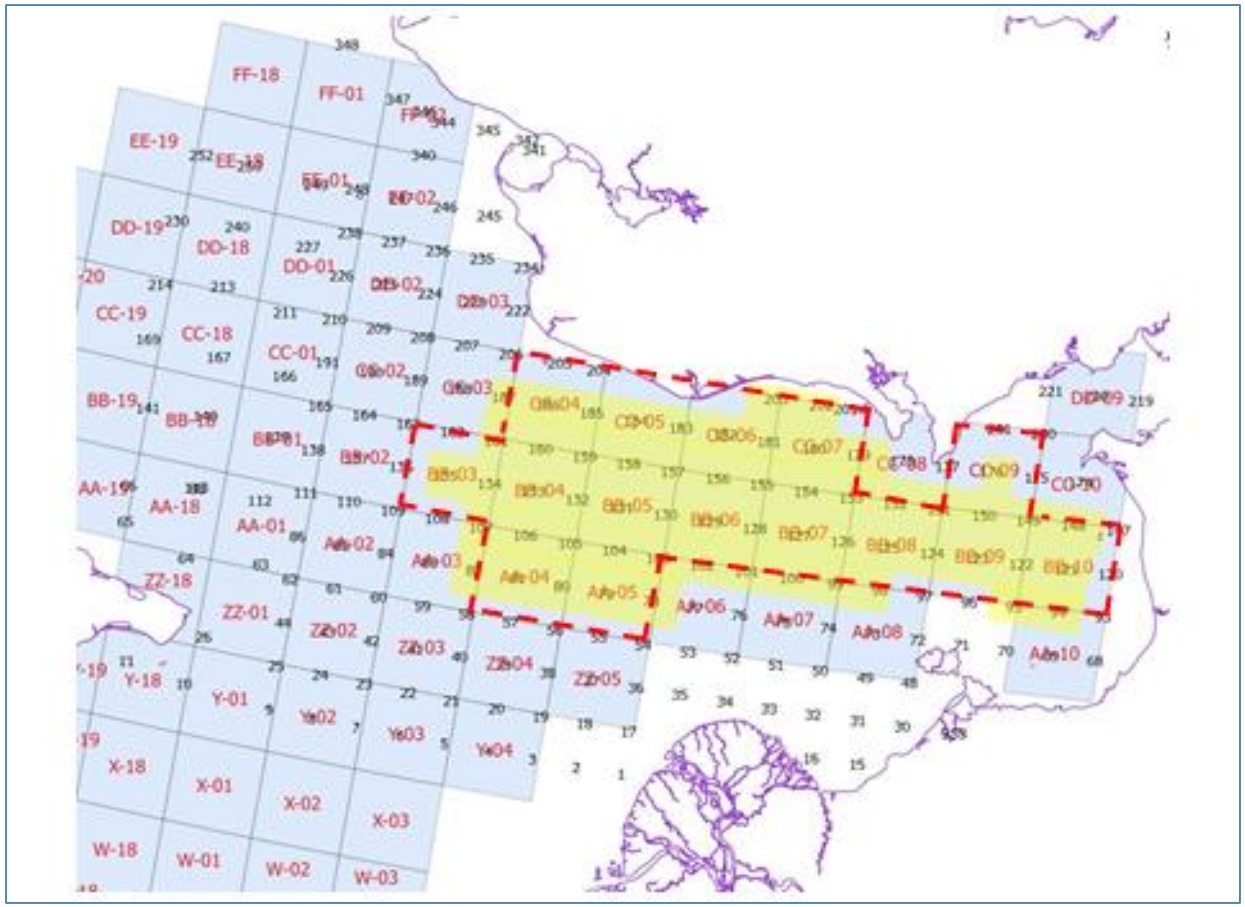


Figure 2- Station Map

Trawl Survey: ADFG vs. NMFS

- Survey Stations: ADFG 59: 100 nm^2, NMFS 18: 400 nm^2
- Total area: ADFG 5868 nm^2, NMFS 6972 nm^2



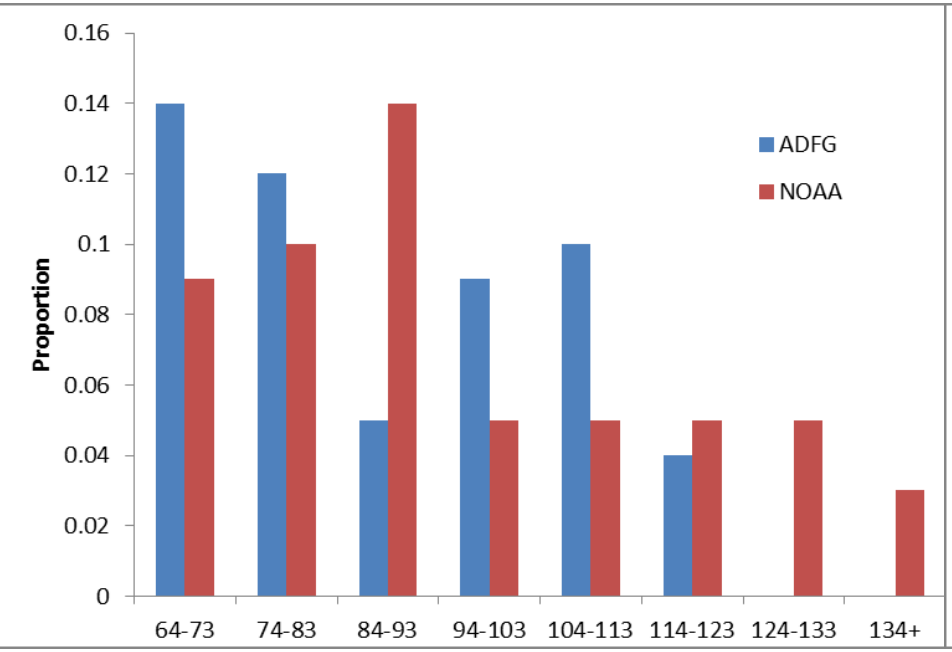
ADF&G 2017 trawl survey: 7/28-8/08: 1762.1 k, CV =0.22

NOAA 2017 trawl survey : 8/18-8/29: 1035.8 k, CV = 0.40

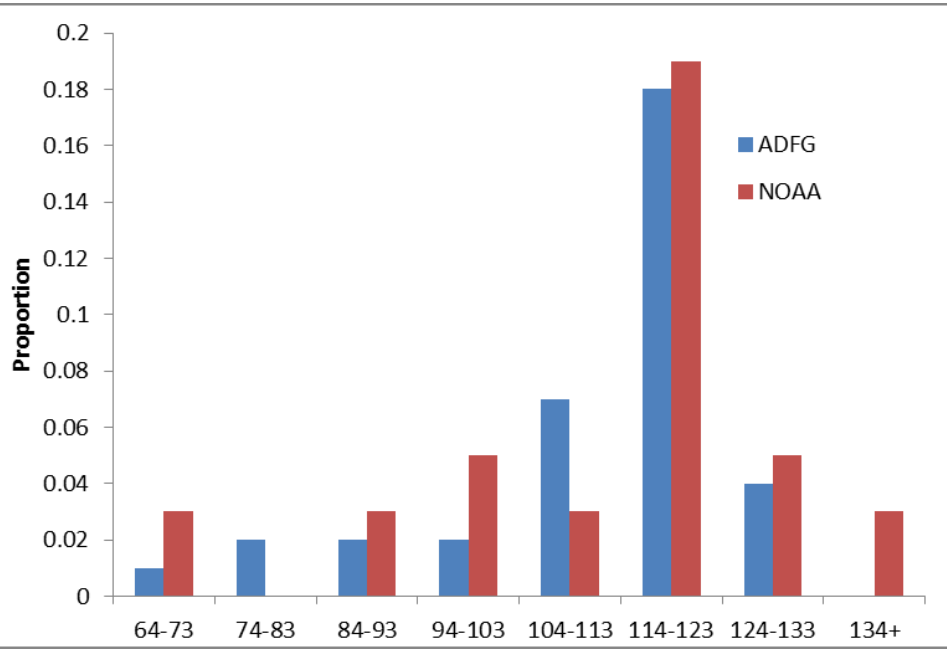
Trawl Survey: ADFG vs. NMFS

- Number of crabs sampled: ADFG 116, NMFS 58

New shell



Old shell



ADF&G 2017 trawl survey

7/28-8/08: 1762.1 k, CV =0.22

NOAA 2017 trawl survey :

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NSRKC Major Modeling Issues

- Under the size invariant M, the model overestimate abundance/proportion of large sized (> 123mm) crab.
  - Current Assumption: Higher M for large sized (> 123mm) crab
    - Pro: Model fits data better
    - Con: Biologically implausible
  - Alternative Assumptions
    - Faster-slower molting (model did not support: SAFE 2016)
    - Large crabs move out (implausible: SAFE 2017)
    - Higher M across all length (too high: M ~ 0.44: SAFE 2017)
    - Gradual mortality increase (SSC requests: Feb 2017, Alternative models)

Responses to CPT and SSC (Sept – Oct 2017)

- Include a graphic on where pot-pulls have been observed
  - Appendix D
- Conduct likelihood profile on the *M*
  - Appendix F
- Bring forward default model, model 3-5. Include results for 2014-2016 pot survey data
  - See alternative models.

Responses to CPT

- Breaking out natural mortality by size class for future model evaluation.

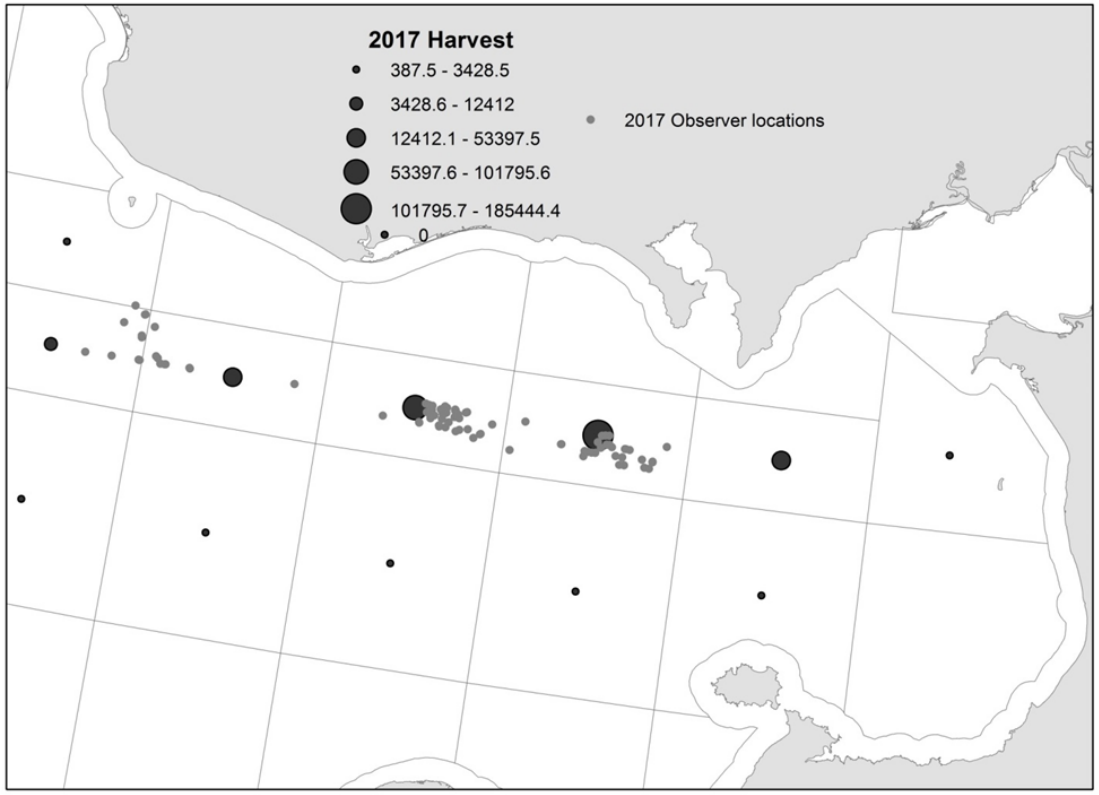
$$OFL = \sum_{l} \left[Legal\_B_{w,l} \left(1 - e^{-(F_{OFL} + 0.42M_l)} - (1 - e^{-0.42M_l}) \left(\frac{1 - p(1 - e^{-(F_{OFL} + 0.42M_l)})}{1 - p(1 - e^{-0.42M_l})} \right) \right) \right]$$

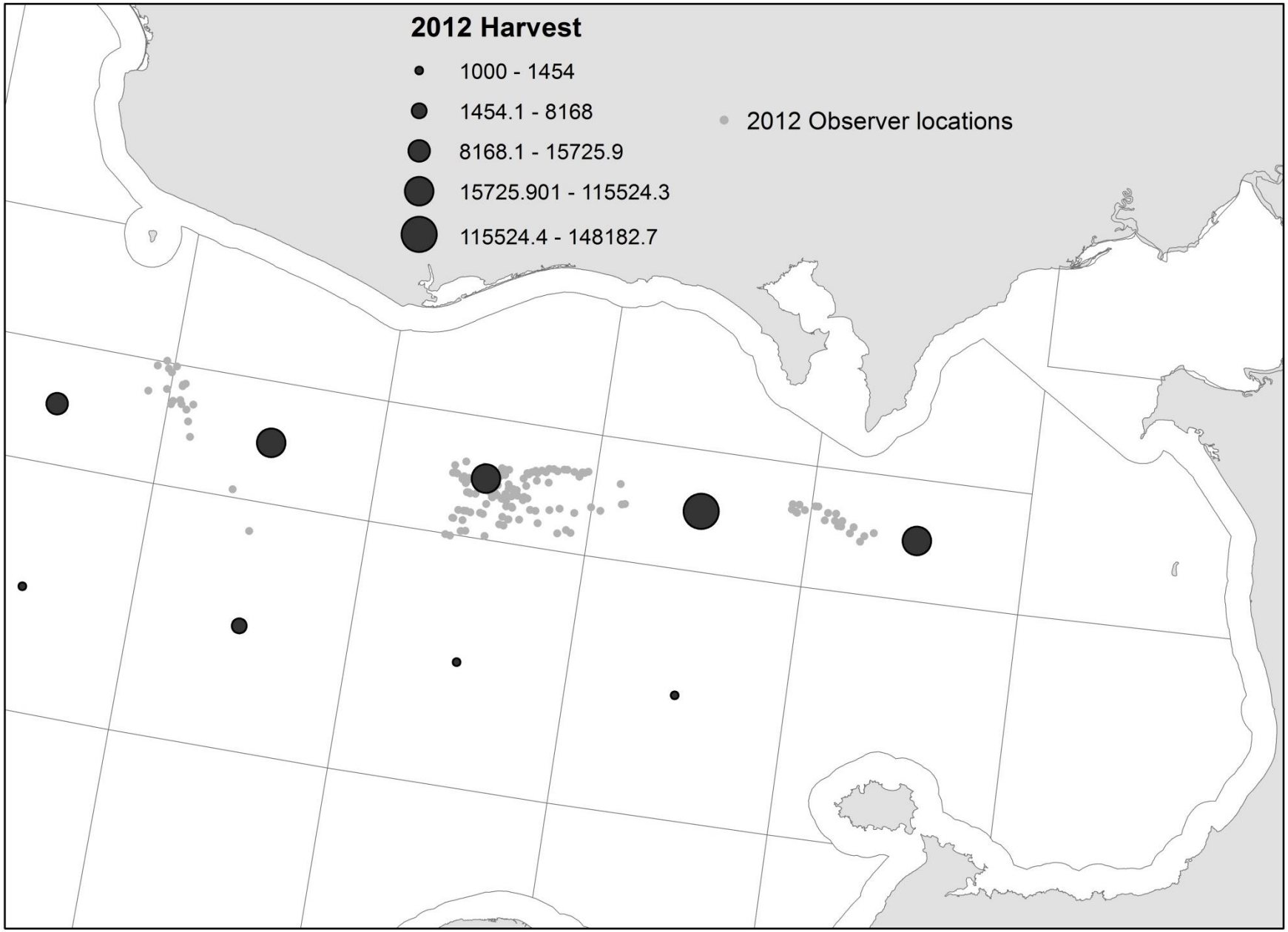
Responses to CPT and SSC

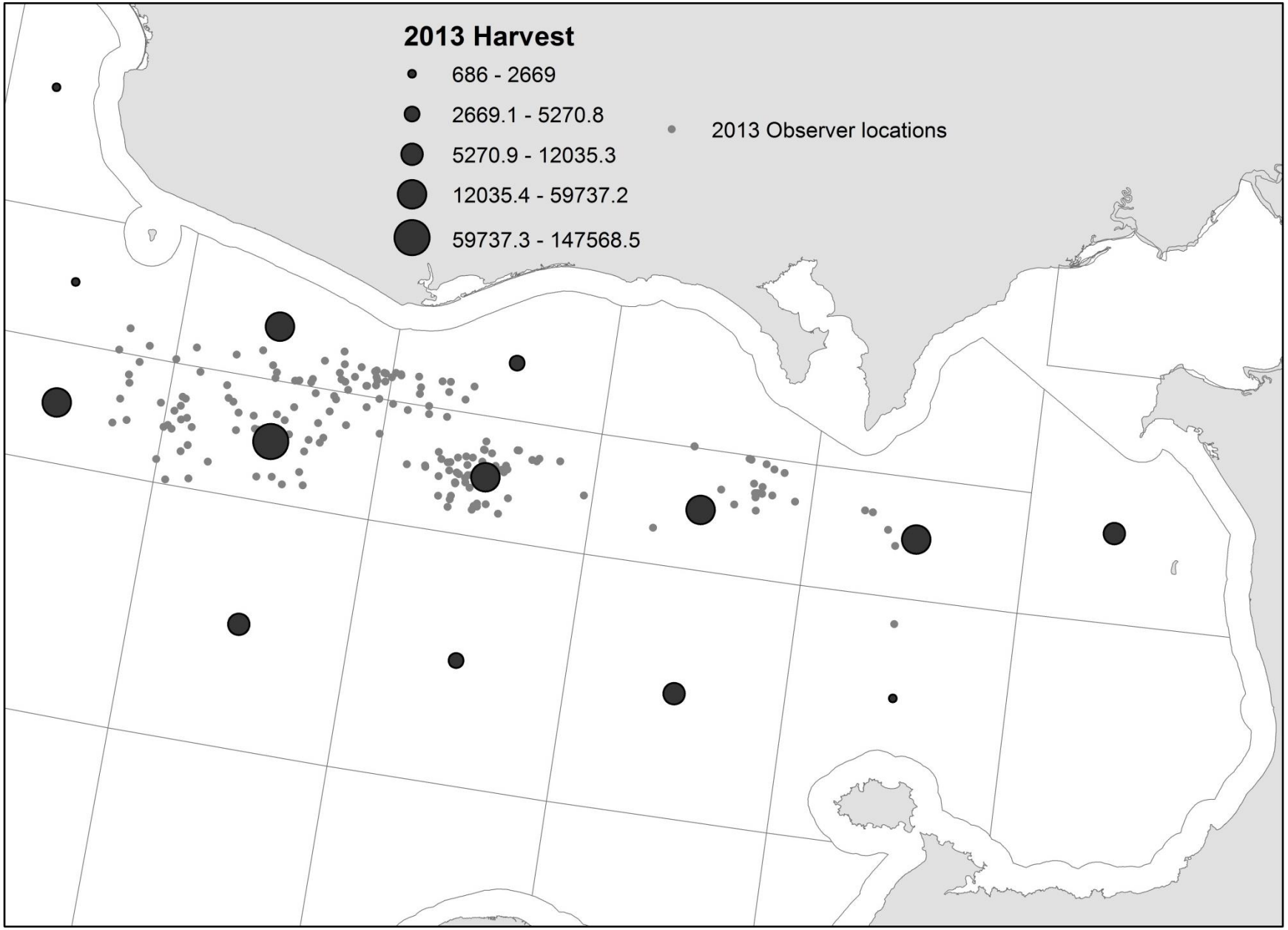
- NSRKC observer program:
  - Ship on an available boat (by generosity of crabber)
  - Same crabbers every year.
  - Measure length-shell-sex of every catch (legal retain, legal discards, sublegal discards, female discards) from sampled pots
  - Data obtained
    - The number of sampled crab by length-shell-sex
    - CPUE (may be)
  - Data location
    - ADFG NS shared hard drive. EXCEL files….

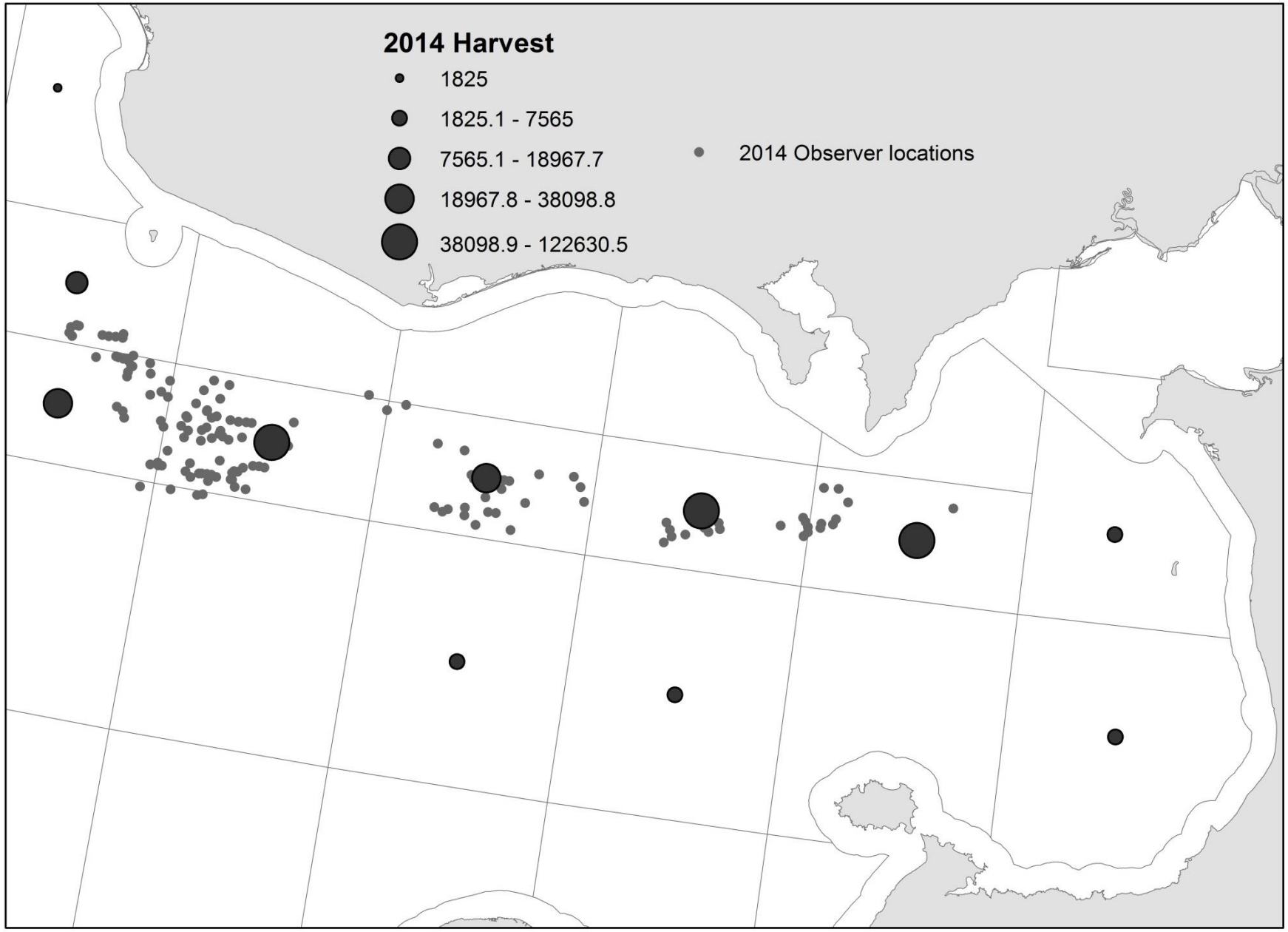
Discards Observer coverage

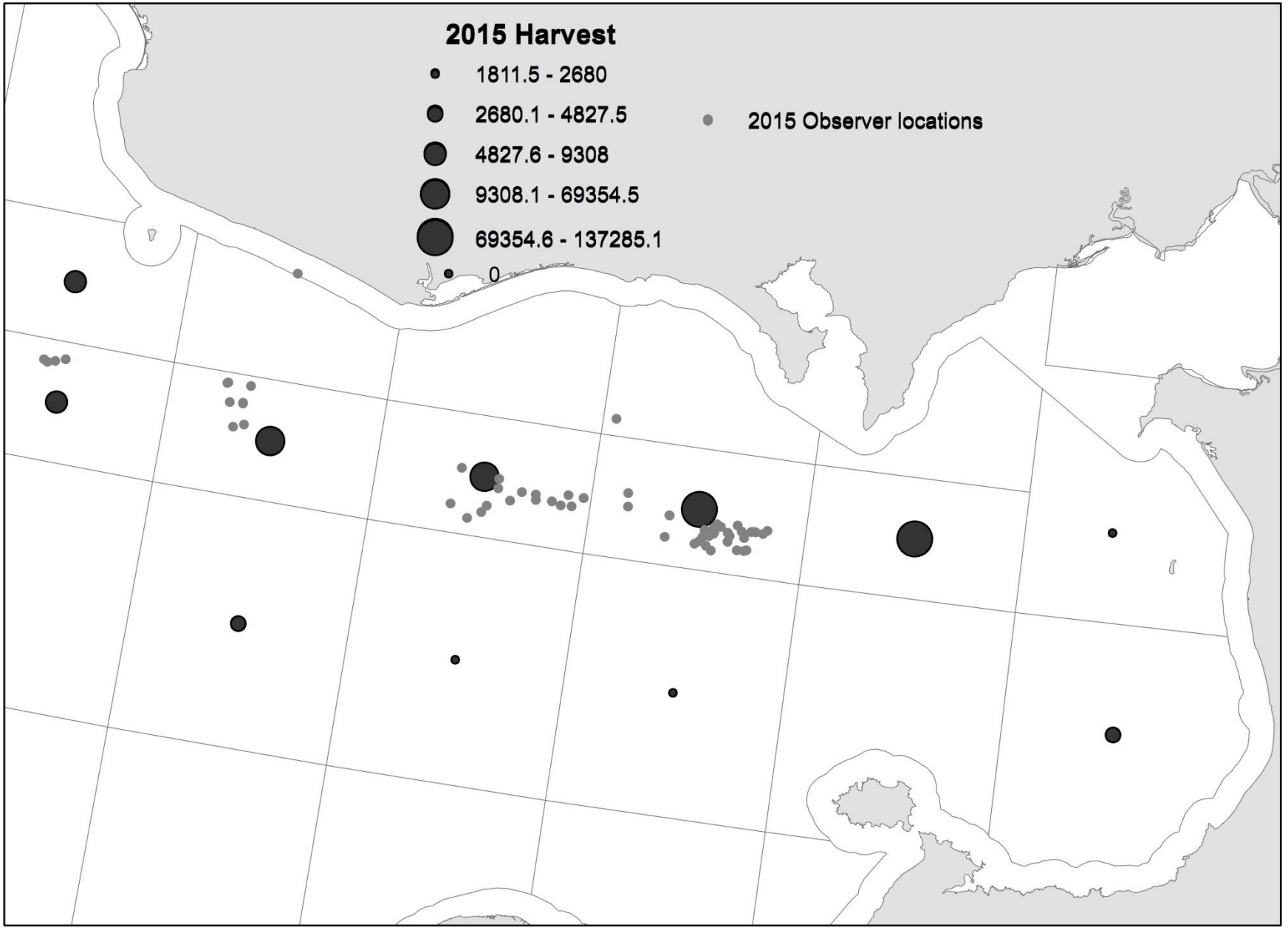
- Majority of observer coverage occurred where the majority of fisheries occurred. (Appendix D)
  - But coverage of ships are small: usually 4-5 /36-37 boats.

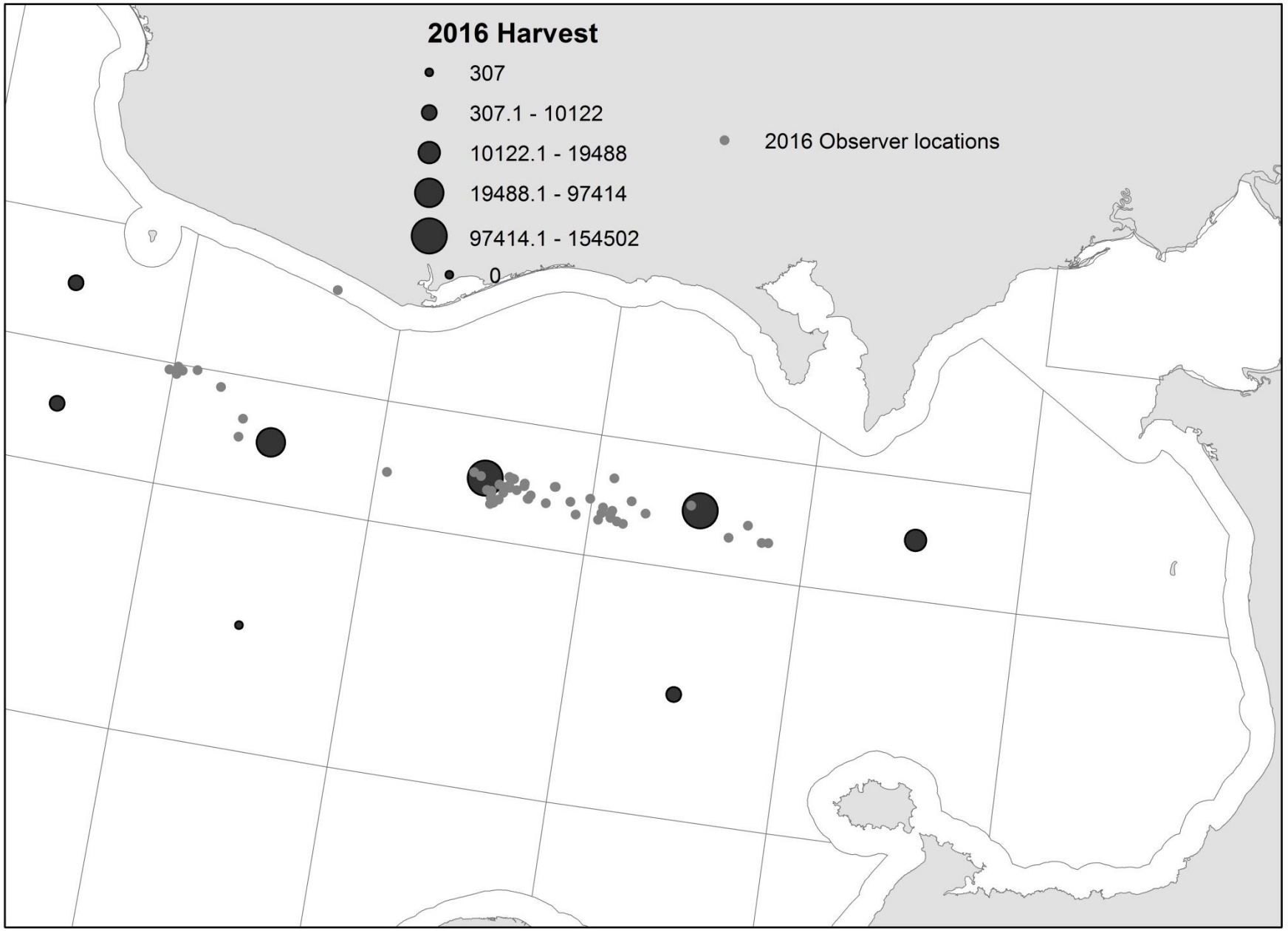


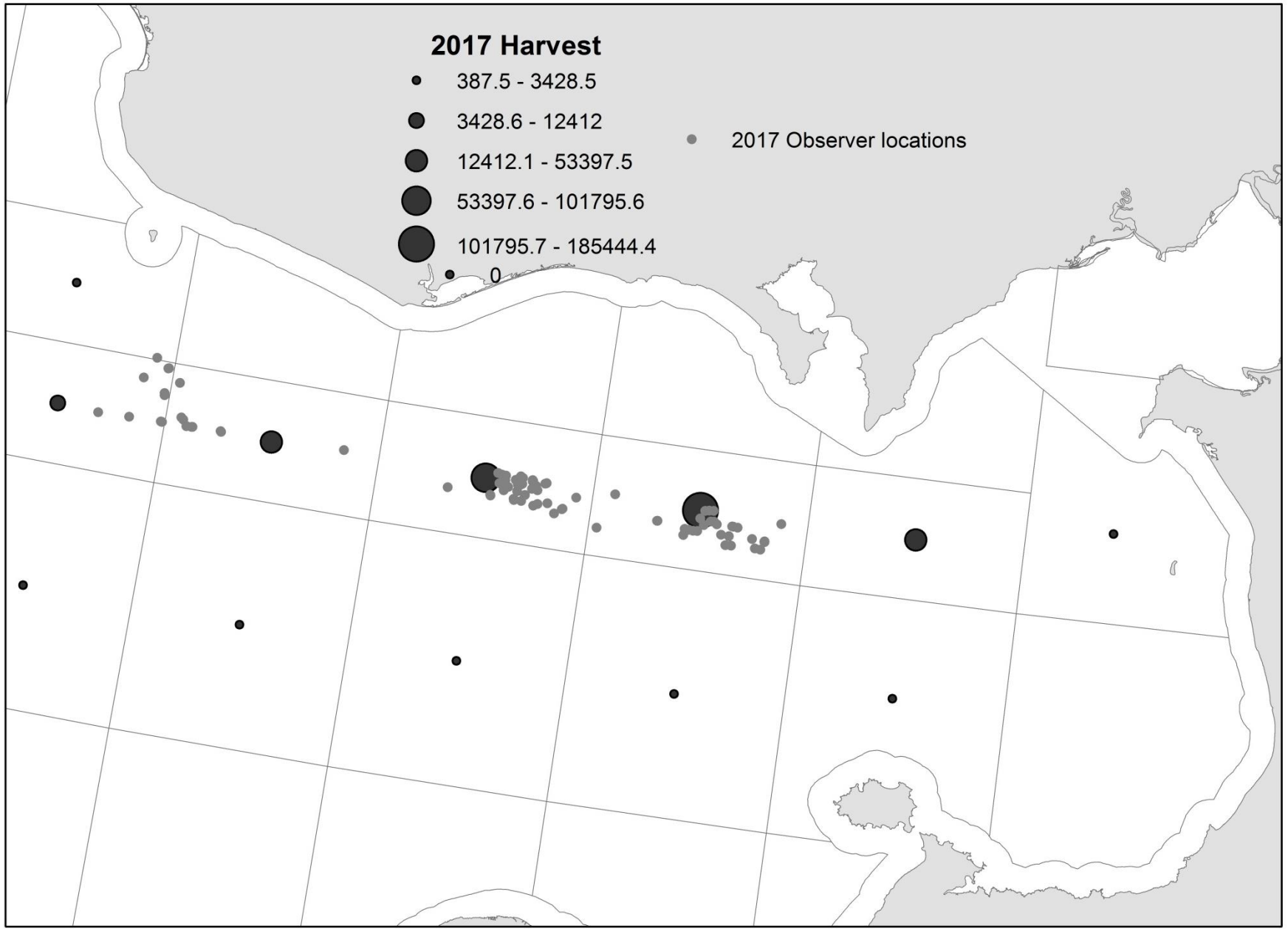

2012 Harvest
1000 - 1454
1454.1 - 8168
8168.1 - 15725.9
15725.901 - 115524.3
115524.4 - 148182.7
2012 Observer locations


2013 Harvest
686 - 2669
2669.1 - 5270.8
5270.9 - 12035.3
12035.4 - 59737.2
59737.3 - 147568.5
2013 Observer locations


2014 Harvest
1825
1825.1 - 7565
7565.1 - 18967.7
18967.8 - 38098.8
38098.9 - 122630.5
2014 Observer locations

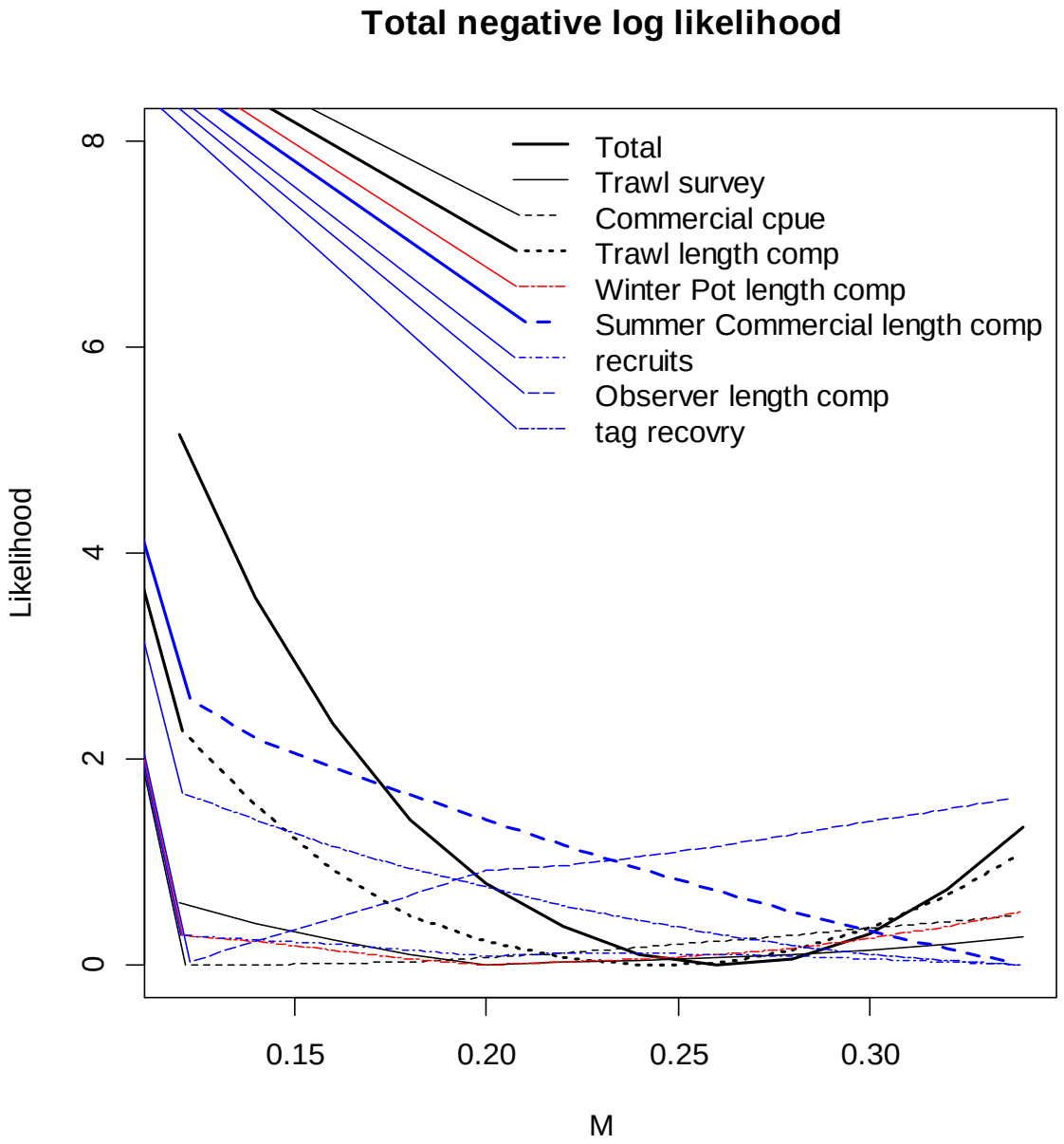

2015 Harvest
1811.5 - 2680
2680.1 - 4827.5
4827.6 - 9308
9308.1 - 69354.5
69354.6 - 137285.1
0
2015 Observer locations


2016 Harvest
307
307.1 - 10122
10122.1 - 19488
19488.1 - 97414
97414.1 - 154502
0
2016 Observer locations


2017 Harvest
387.5 - 3428.5
3428.6 - 12412
12412.1 - 53397.5
53397.6 - 101795.6
101795.7 - 185444.4
0
2017 Observer locations

Responses to CPT

- Model still wants to go higher *M*.



Responses to CPT and SSC

- Alternative models 3,4,5,6

	fishery	M1 64+	M2 74+	M3 84+	M4 94+	M5 104+	M6 114+	M7 124+	M8 134+
Default	1p	0.18	0.18	0.18	0.18	0.18	0.18	0.18*ms1	0.18*ms1
Alt 3	2p	0.18	0.18	0.18	0.18	0.18	0.18	0.18*ms1	0.18*ms1
Alt 4	2p	0.18	0.18	0.18	0.18	0.18	0.18	0.18*ms1	0.18*ms2
Alt 5	2p	0.18	0.18	0.18	0.18	0.18	0.18*ms1	0.18*ms2	0.18*ms3
Alt 6	2p+sp	0.18	0.18	0.18	0.18	0.18	0.18	0.18*ms1	0.18*ms1

- Fishery selectivity function 1 vs. 2 parameters model

$$S_l = \frac{1}{1 + e^{(\phi(L_{\max} - L) + \ln(1/0.999 - 1))}}$$

$$S_l = \frac{1}{1 + e^{\phi 1(L - \phi 2)}}$$

Alternative models

- Alternative model 3-6: NLL

Model	Model 0	Model 3	Model 4	Model 5	Model 6
No. Parameters	67	68	69	70	68
Total	281.1	269.2	269.1	265.44	286.01
TSA	9.1	9.1	9.1	9.36	9.24
St.CPUE	-30.6	-30.7	-30.7	-30.4	-30.6
TLP	95.1	90.6	90.6	89.8	90.8
WLP	38.7	39.1	39.1	38.5	39.3
CLP	50.8	51.4	51.2	49.2	51.3
OBS	25.2	23.2	23.2	23.1	23.0
REC	13.6	14.0	13.9	14.5	16.5
TAG	79.2	72.5	72.6	71.3	72.5
SP					14.0
MMB(mil.lb)	4.08	3.94	3.95	3.91	4.00

Responses to CPT and SSC

- Alternative models 3,4,5,6

	fishery	M1 64+	M2 74+	M3 84+	M4 94+	M5 104+	M6 114+	M7 124+	M8 134+
Default	1p	0.18	0.18	0.18	0.18	0.18	0.18	0.58	0.58
Alt 3	2p	0.18	0.18	0.18	0.18	0.18	0.18	0.60	0.60
Alt 4	2p	0.18	0.18	0.18	0.18	0.18	0.18	0.58	0.63
Alt 5	2p	0.18	0.18	0.18	0.18	0.18	0.34	0.55	0.59
Alt 6	2p+sp	0.18	0.18	0.18	0.18	0.18	0.18	0.59	0.59

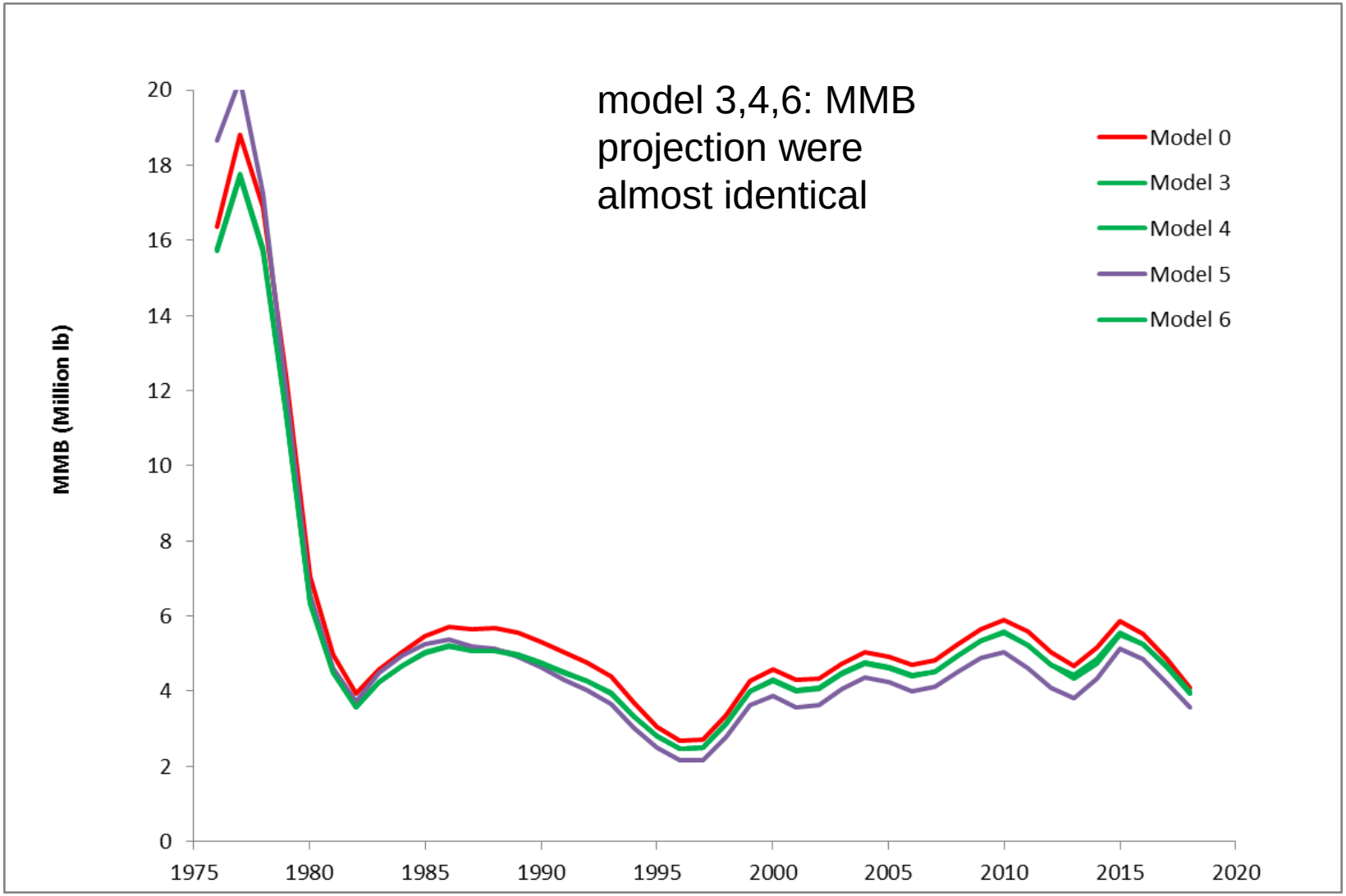
- Fishery selectivity function 1 vs. 2 parameters model

$$S_l = \frac{1}{1 + e^{(\phi(L_{\max} - L) + \ln(1/0.999 - 1))}}$$

$$S_l = \frac{1}{1 + e^{\phi 1(L - \phi 2)}}$$

Alternative models

- Alternative model 3-6: MMB projection



Search for balance

- Model 0 vs. Model 3
  - Major model fit improvement. (reduction 10 nll)
  - Slight decline in MMB projection and dynamics

- Model 3 vs. Model 4 vs. Model 6
  - No model fit improvement.
  - Identical MMB projection and dynamics
  - Probably more biologically realistic (model 4?)
  - Adding more data did not change anything (model 6)

- Model 3 vs. Model 5 (reduction 4 nll)
  - Slight model fit improvement.
  - Slight decline in MMB
  - More biologically realistic?

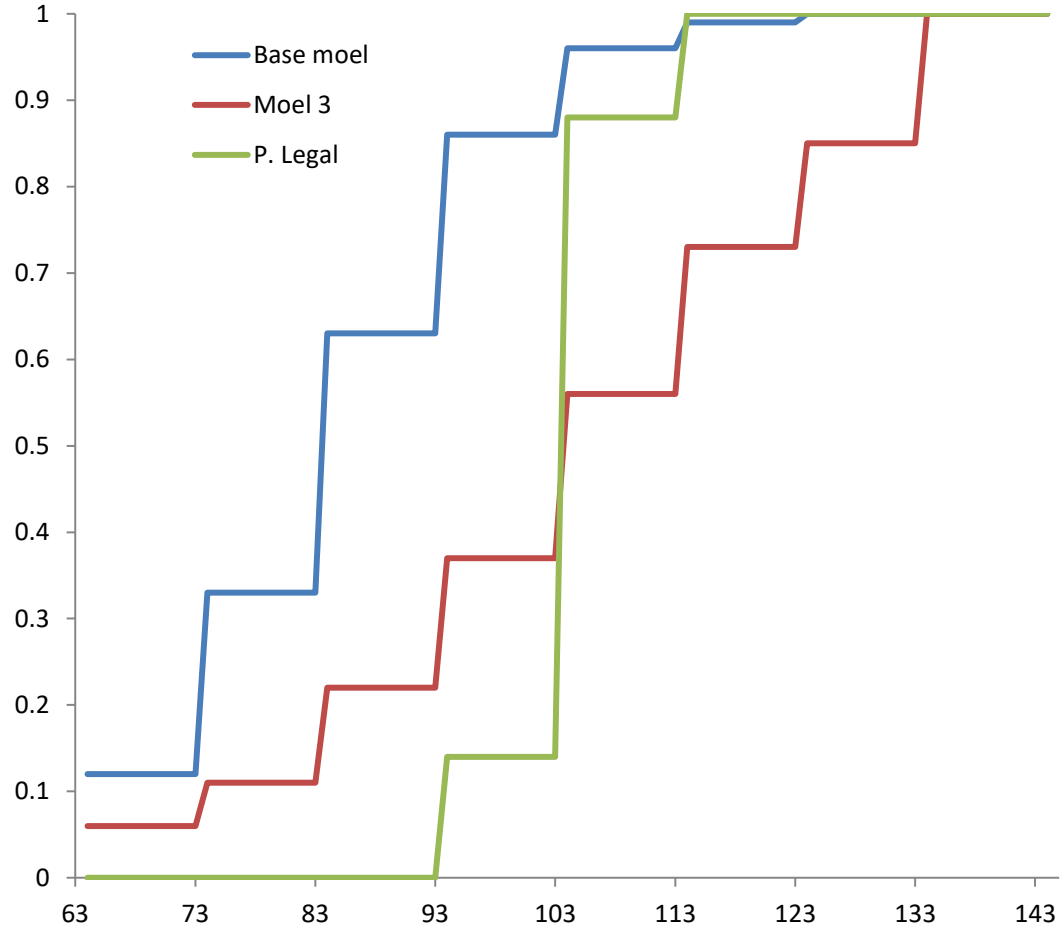
Alternative models

- Assessment model choice ~~Model 3~~ => Base Model

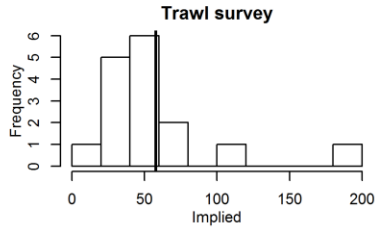
Model	Model 0	Model 3	Model 4	Model 5	Model 6
No. Parameters	67	68	69	70	68
Total	281.1	269.2	269.1	265.44	286.01
TSA	9.1	9.1	9.1	9.36	9.24
St.CPUE	-30.6	-30.7	-30.7	-30.4	-30.6
TLP	95.1	90.6	90.6	89.8	90.8
WLP	38.7	39.1	39.1	38.5	39.3
CLP	50.8	51.4	51.2	49.2	51.3
OBS	25.2	23.2	23.2	23.1	23.0
REC	13.6	14.0	13.9	14.5	16.5
TAG	79.2	72.5	72.6	71.3	72.5
SP					14.0
MMB(mil.lb)	4.08	3.94	3.95	3.91	4.00
Legal crab Catchable (mil.lb)	**3.55**	**2.58**	2.60	2.13	2.63
OFL(mil.lb)	**0.75**	**0.57**	0.58	0.51	0.60

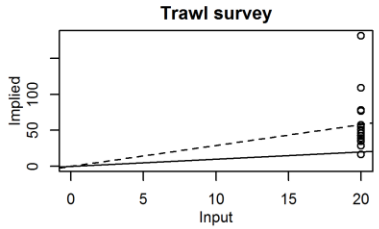
1 parameter vs. 2 parameters fishery selectivity

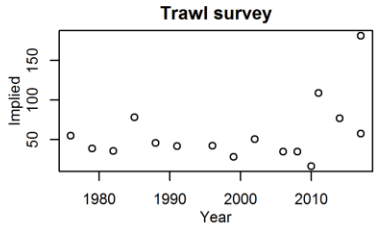
- Model 4 (2 parameters) predicts legal crabs are less catchable than baseline (1 parameter)

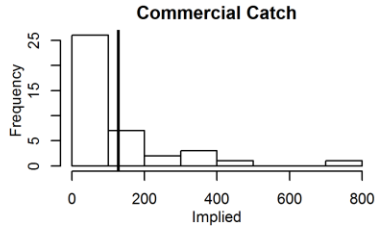


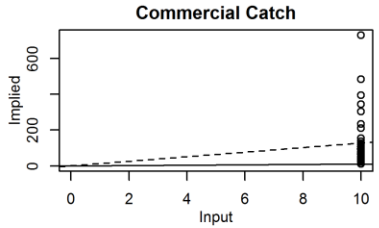
Base model

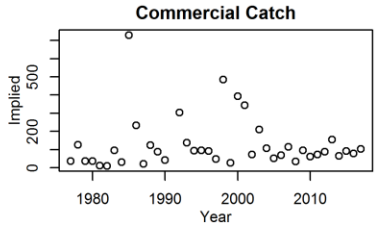

Trawl survey
Frequency
Implied

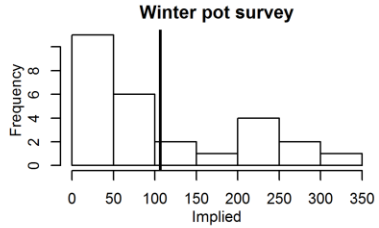

Trawl survey
Implied
Input

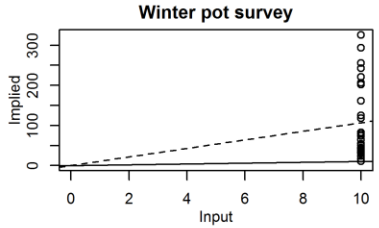

Trawl survey
Implied
Year

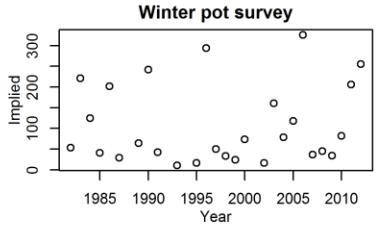

Commercial Catch
Frequency
Implied

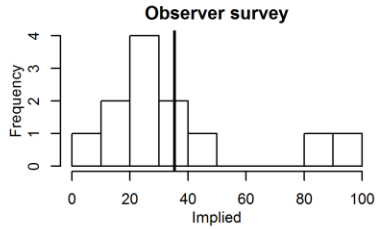

Commercial Catch
Implied
Input

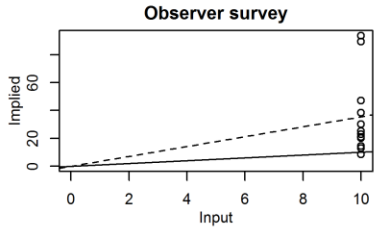

Commercial Catch
Implied
Year

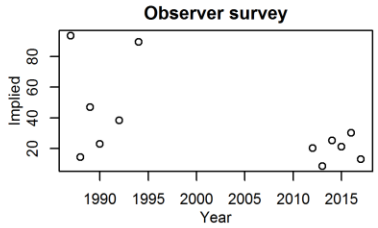

Winter pot survey
Frequency
Implied

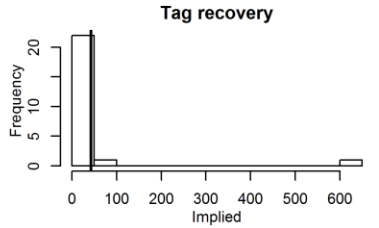

Winter pot survey
Implied
Input

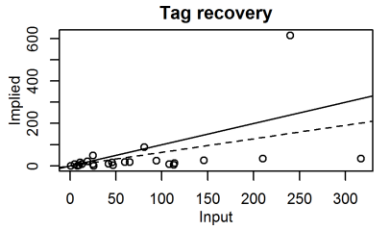

Winter pot survey
Implied
Year


Observer survey
Frequency
Implied

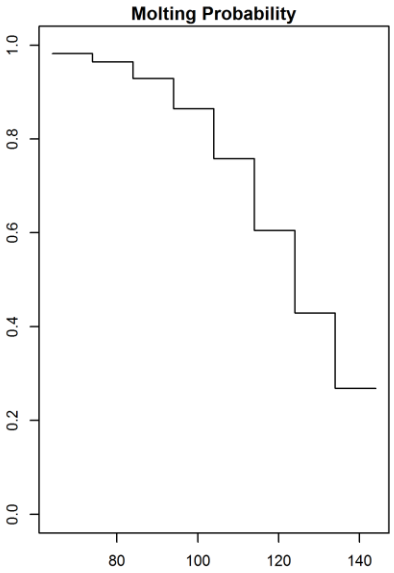

Observer survey
Implied
Input

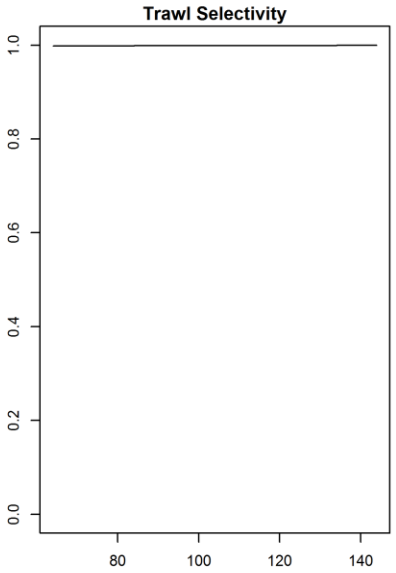

Observer survey
Implied
Year

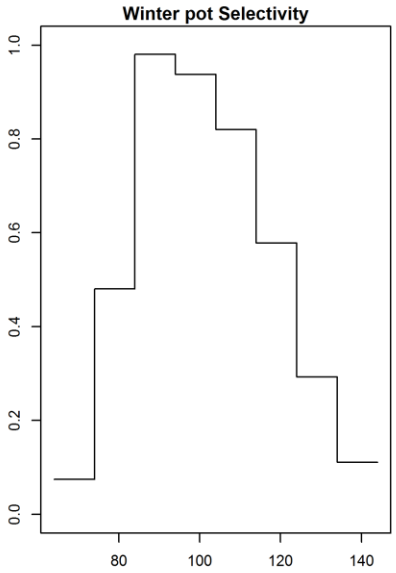

Tag recovery
Frequency
Implied

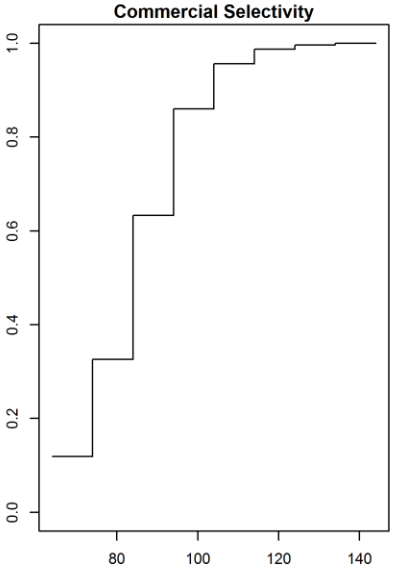

Tag recovery
Implied
Input

Base Model

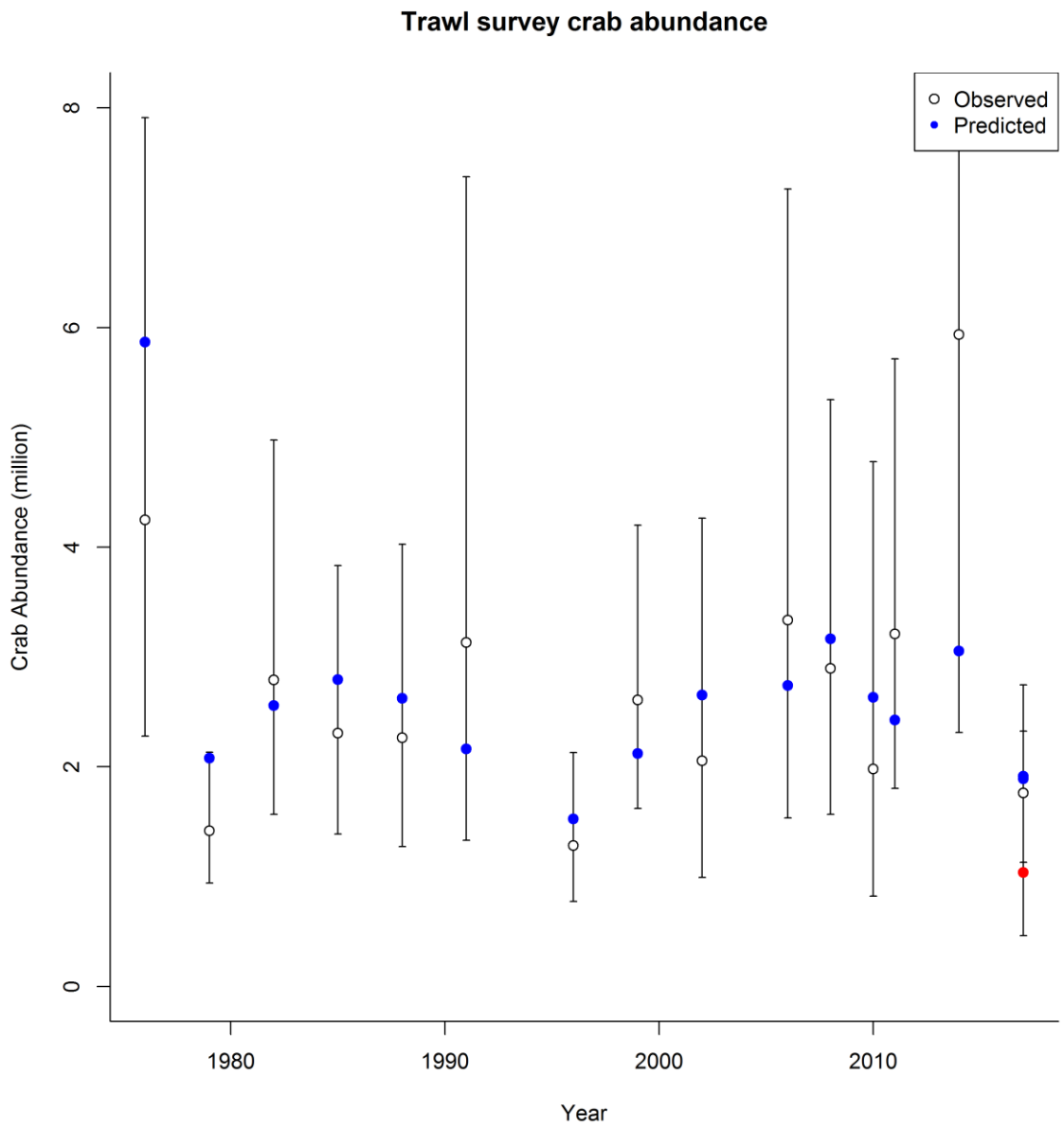

Molting Probability
0.0
0.2
0.4
0.6
0.8
1.0
80
100
120
140


Trawl Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
80
100
120
140

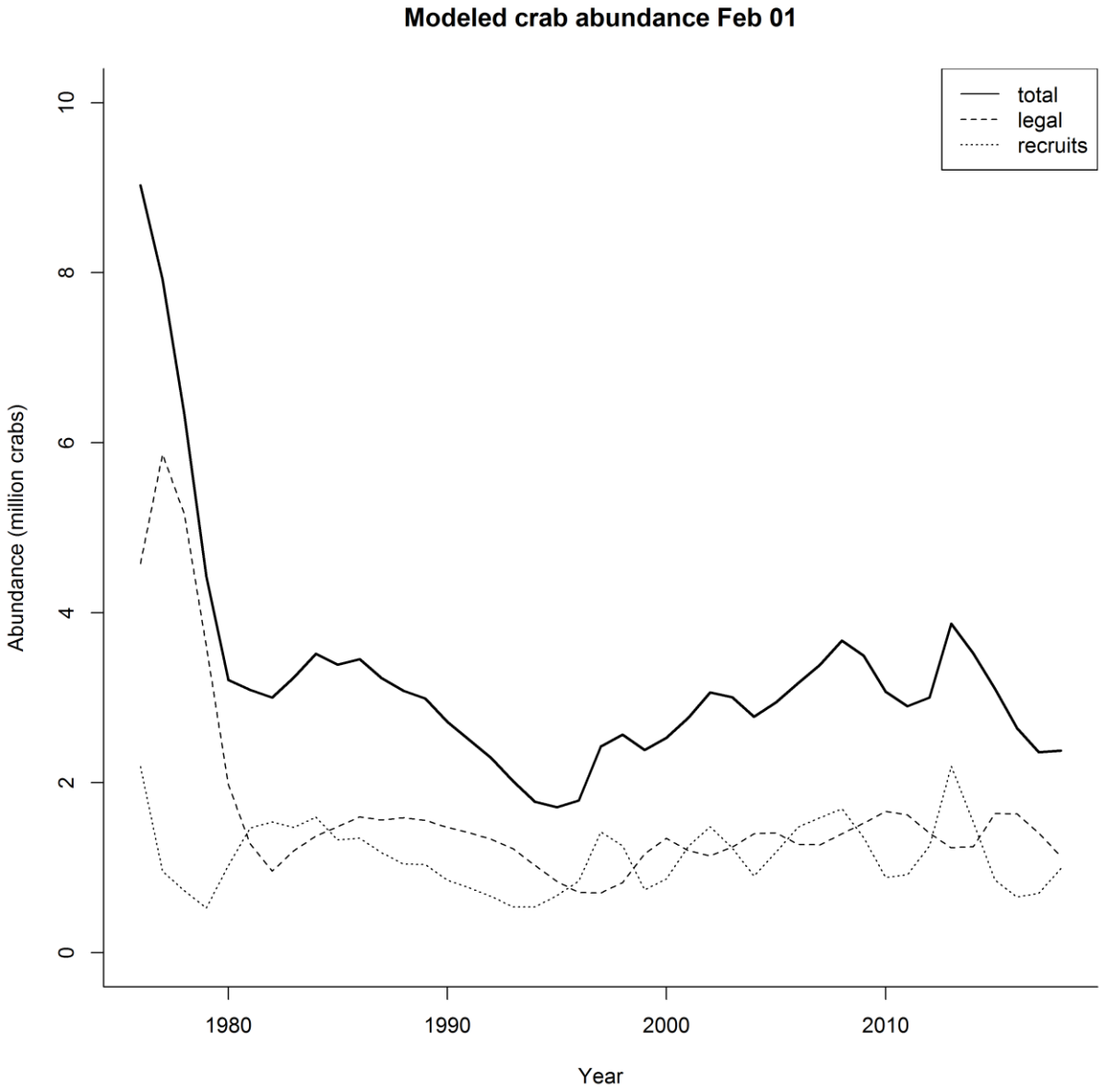

Winter pot Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
80
100
120
140


Commercial Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
80
100
120
140

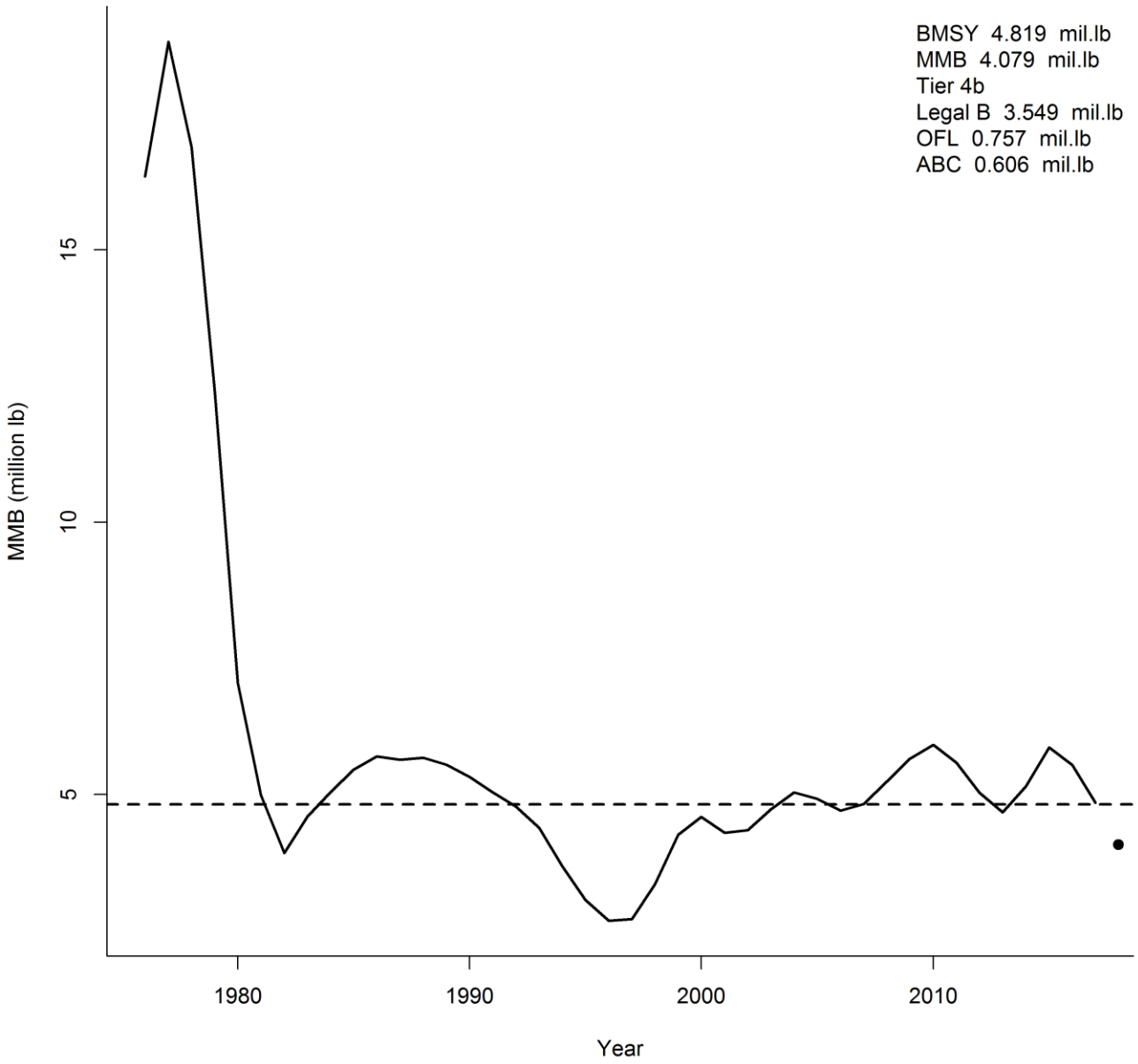
Base Model


Trawl survey crab abundance
Observed
Predicted
Crab Abundance (million)
0
2
4
6
8
1980
1990
2000
2010
Year

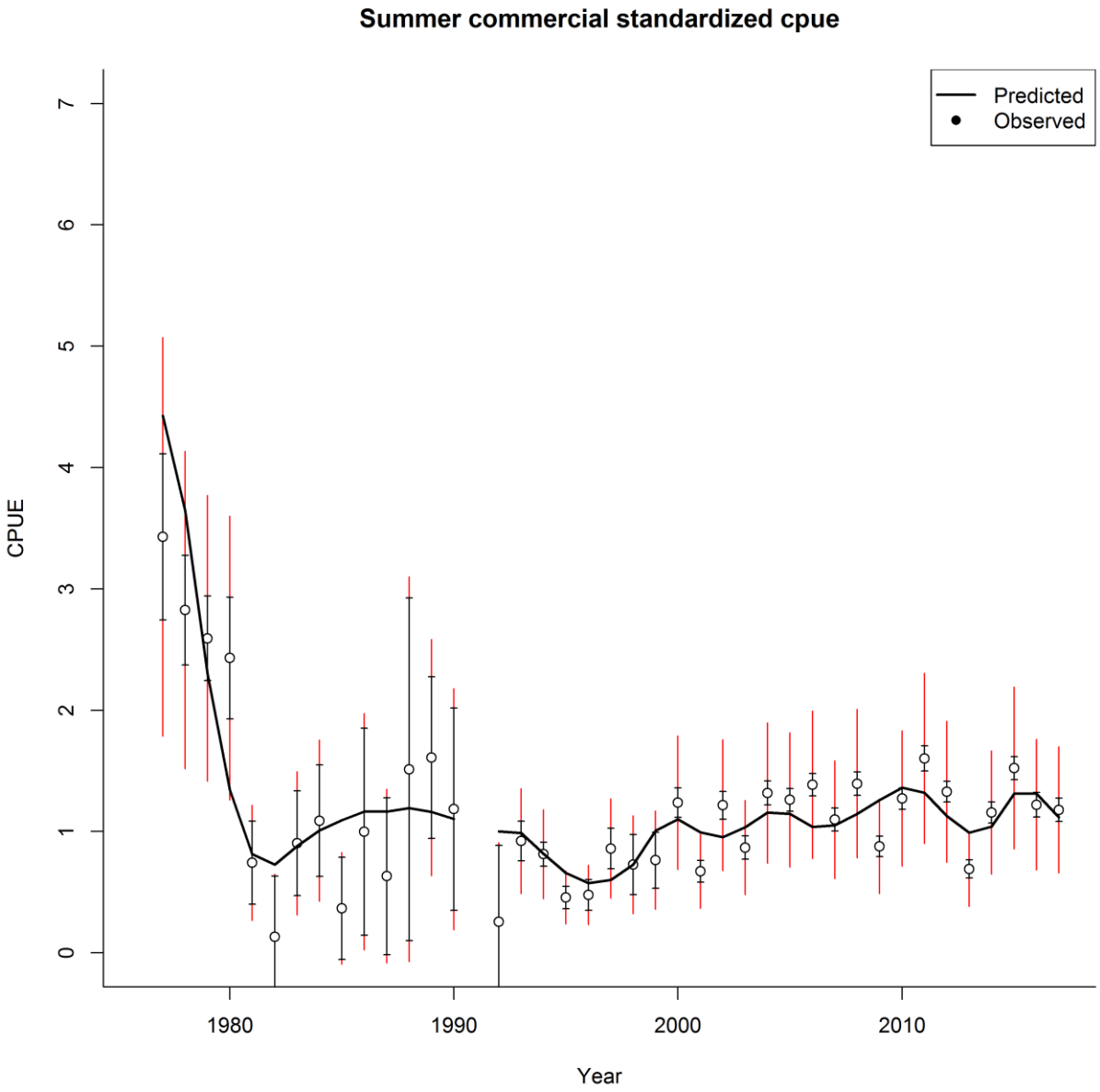
Base Model


Modeled crab abundance Feb 01
total
legal
recruits
Abundance (million crabs)
0
2
4
6
8
10
1980
1990
2000
2010
Year

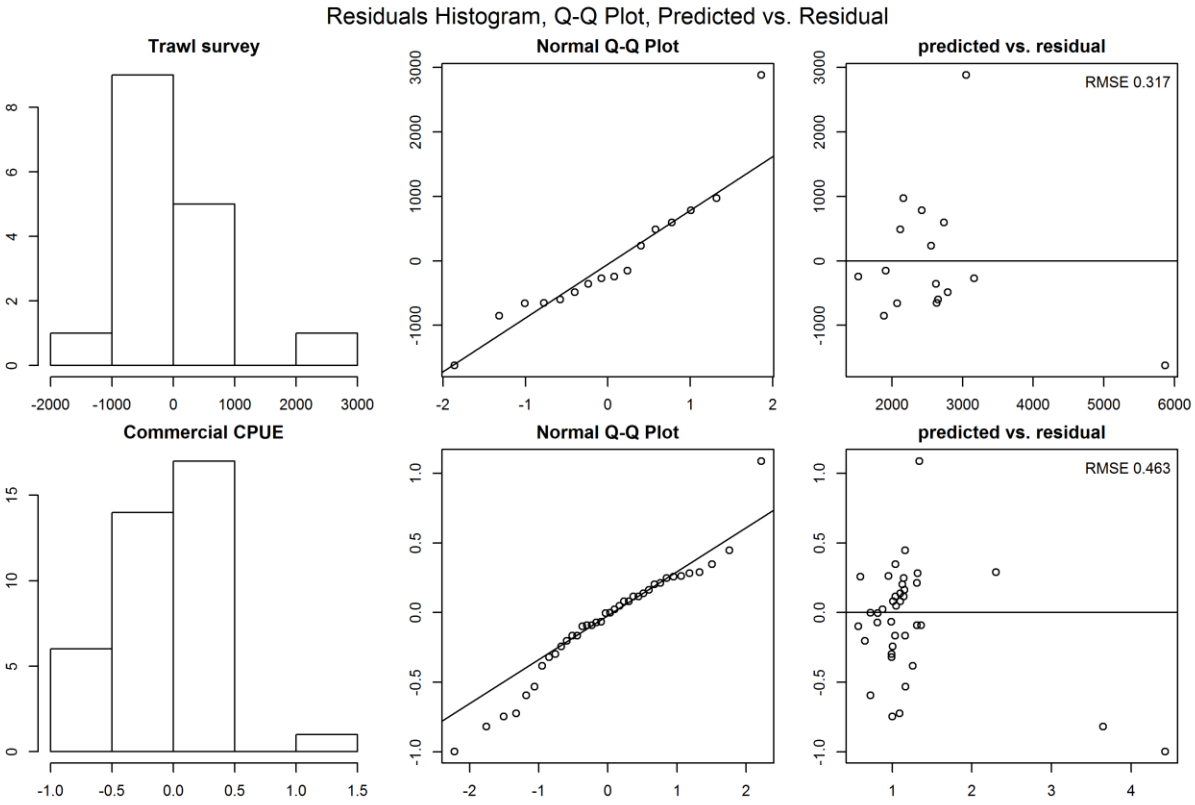
Base Model


MMB Feb 01
BMSY 4.819 mil.lb
MMB 4.079 mil.lb
Tier 4b
Legal B 3.549 mil.lb
OFL 0.757 mil.lb
ABC 0.606 mil.lb
MMB (million lb)
5
10
15
1980
1990
2000
2010
Year

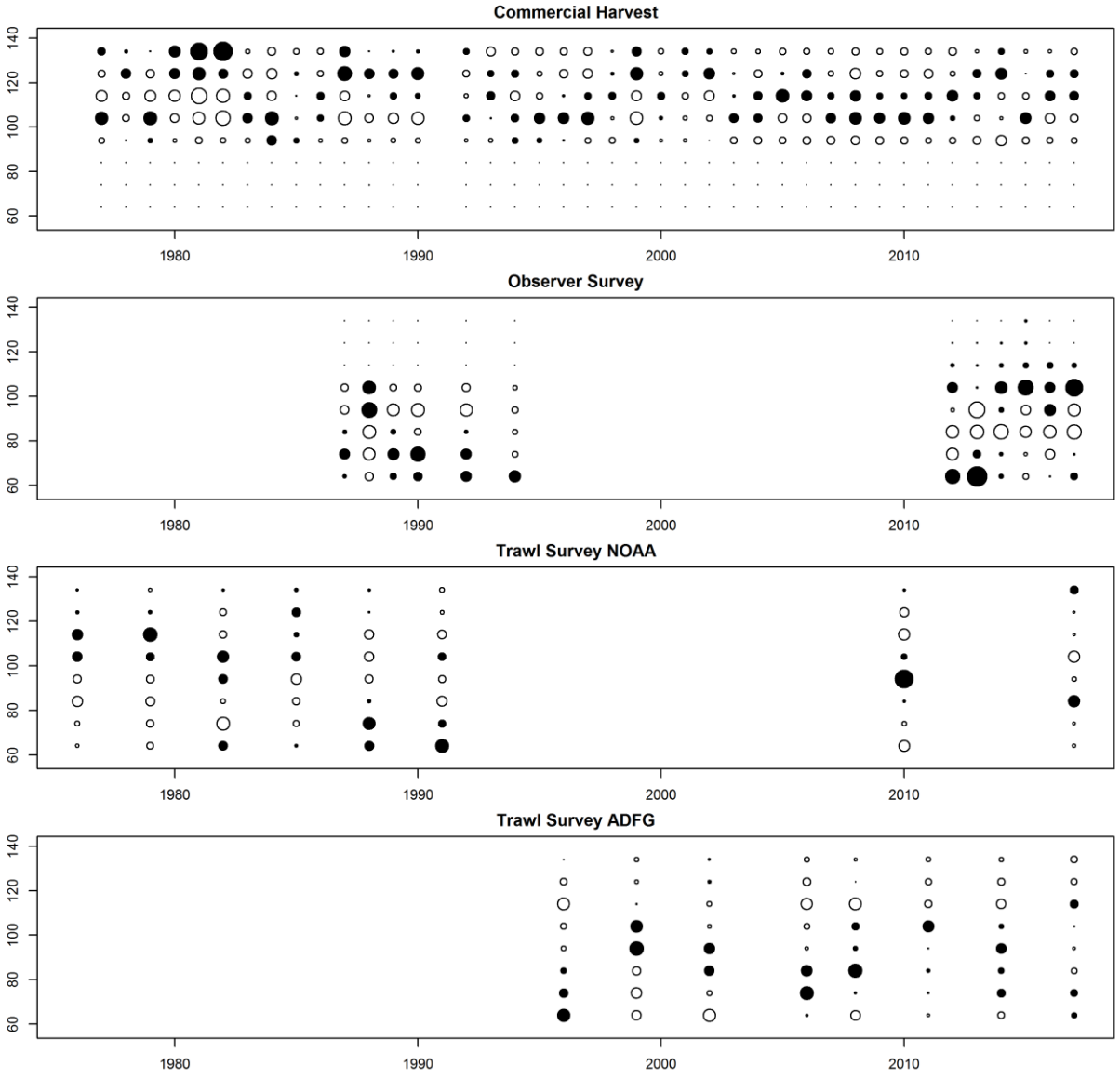
Base Model


Summer commercial standardized cpue
Predicted
Observed
CPUE
0
1
2
3
4
5
6
7
1980
1990
2000
2010
Year

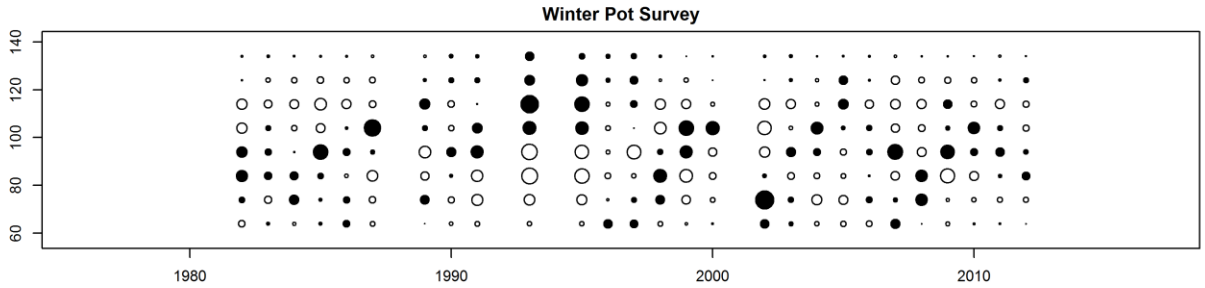
Base Model


Residuals Histogram, Q-Q Plot, Predicted vs. Residual
Trawl survey
Normal Q-Q Plot
predicted vs. residual
RMSE 0.317
Commercial CPUE
Normal Q-Q Plot
predicted vs. residual
RMSE 0.463

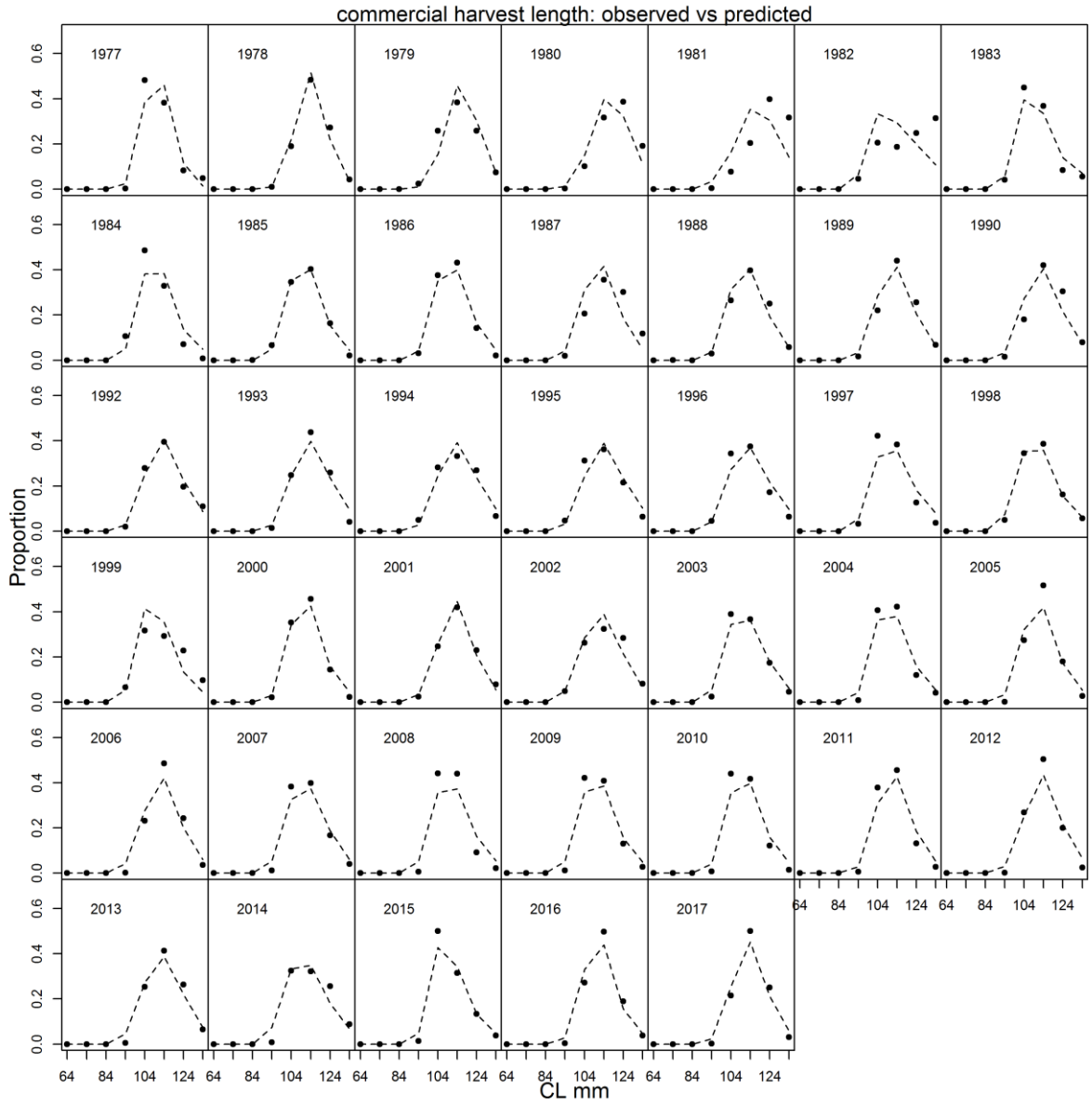
Base Model


Commercial Harvest
Observer Survey
Trawl Survey NOAA
Trawl Survey ADFG
60
80
100
120
140
1980
1990
2000
2010

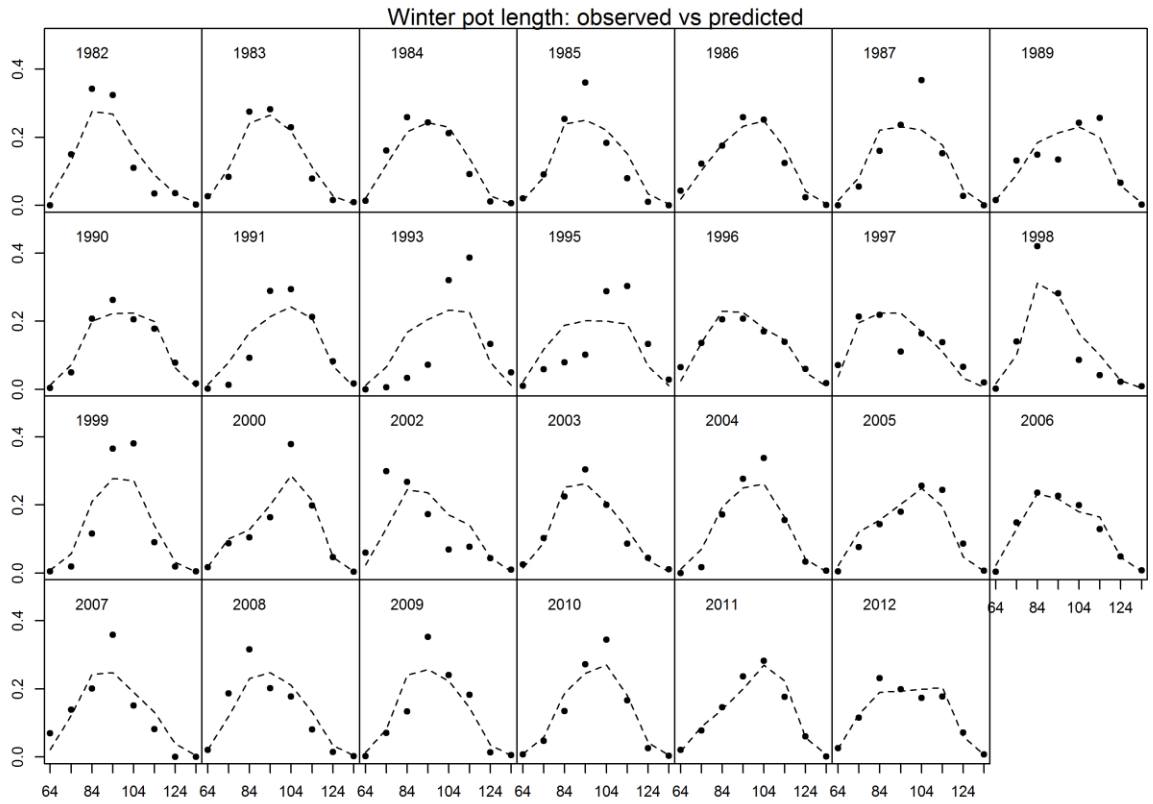
Base Model



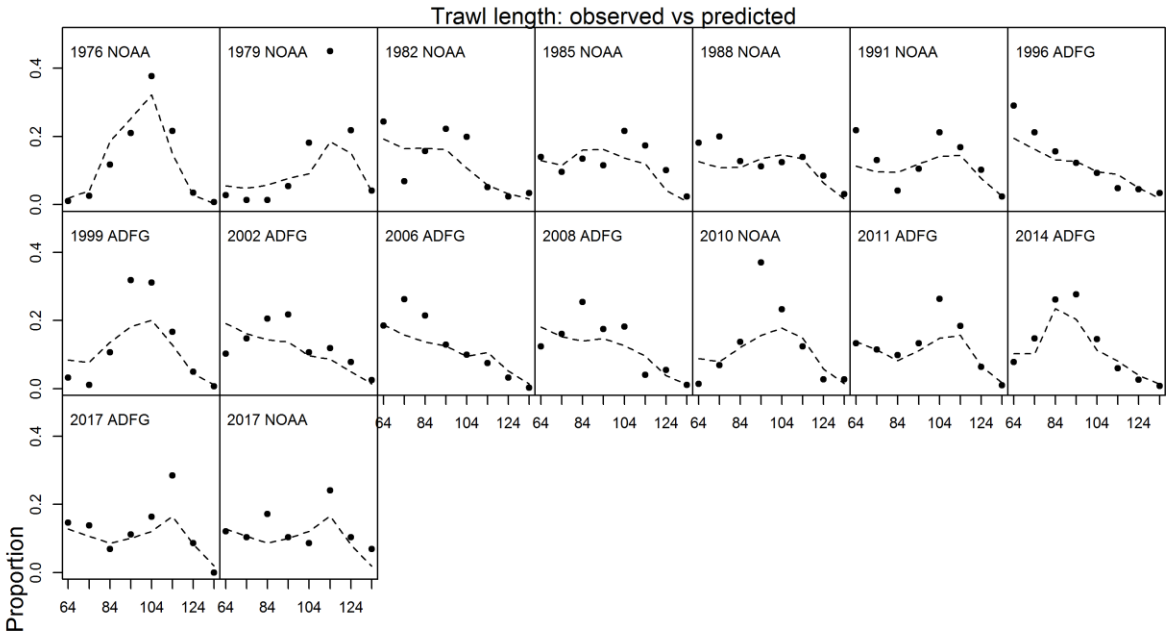
Base Model

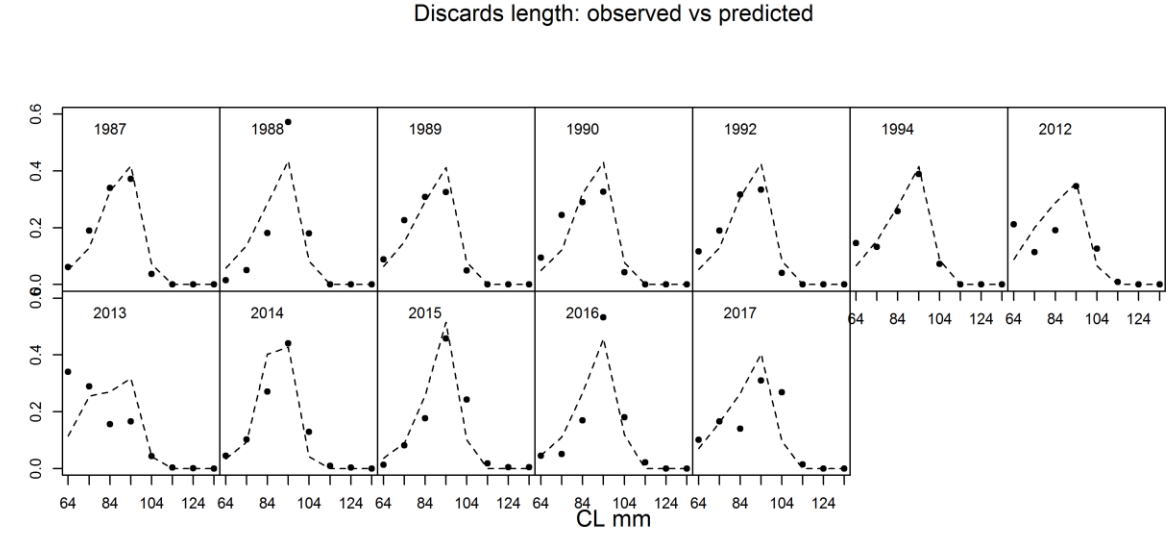

commercial harvest length: observed vs predicted
Proportion
CL mm
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

Base Model

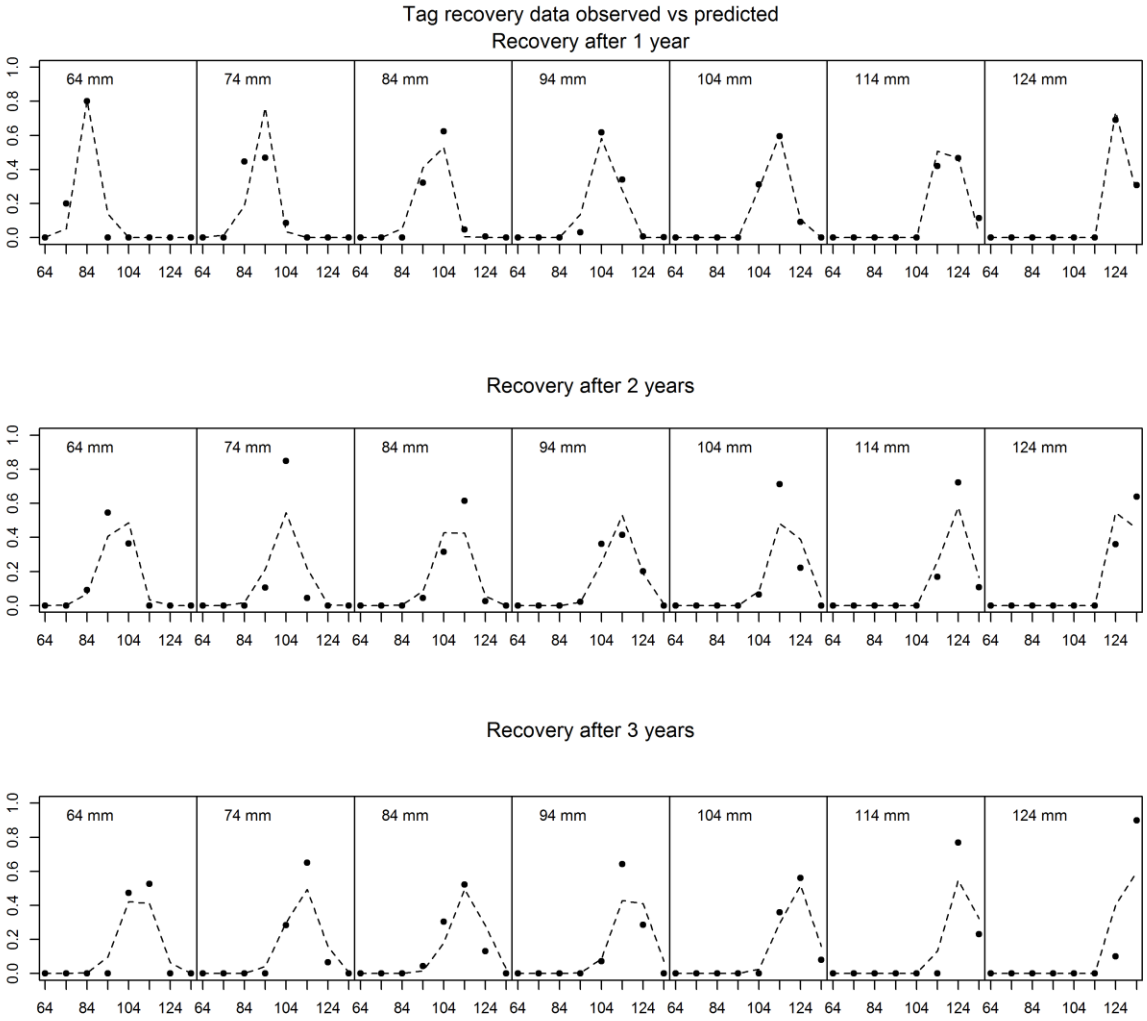

Winter pot length: observed vs predicted
1982
1983
1984
1985
1986
1987
1989
1990
1991
1993
1995
1996
1997
1998
1999
2000
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
0.0
0.2
0.4
64
84
104
124

Base Model

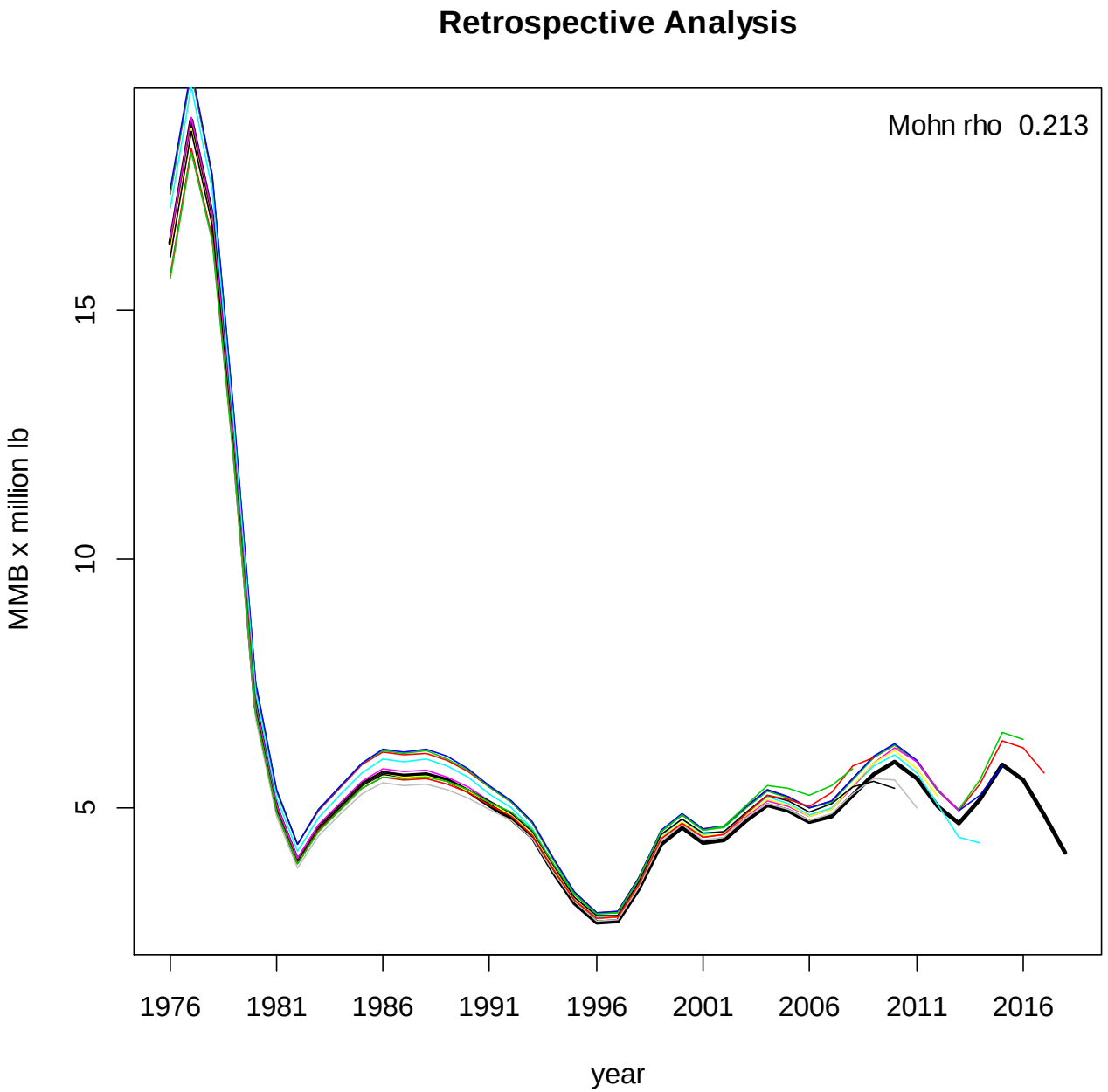

Trawl length: observed vs predicted
1976 NOAA
1979 NOAA
1982 NOAA
1985 NOAA
1988 NOAA
1991 NOAA
1996 ADFG
1999 ADFG
2002 ADFG
2006 ADFG
2008 ADFG
2010 NOAA
2011 ADFG
2014 ADFG
2017 ADFG
2017 NOAA
Proportion
0.0
0.2
0.4
64
84
104
124


Discards length: observed vs predicted
1987
1988
1989
1990
1992
1994
2012
2013
2014
2015
2016
2017
0.0
0.2
0.4
0.6
64
84
104
124
CL mm

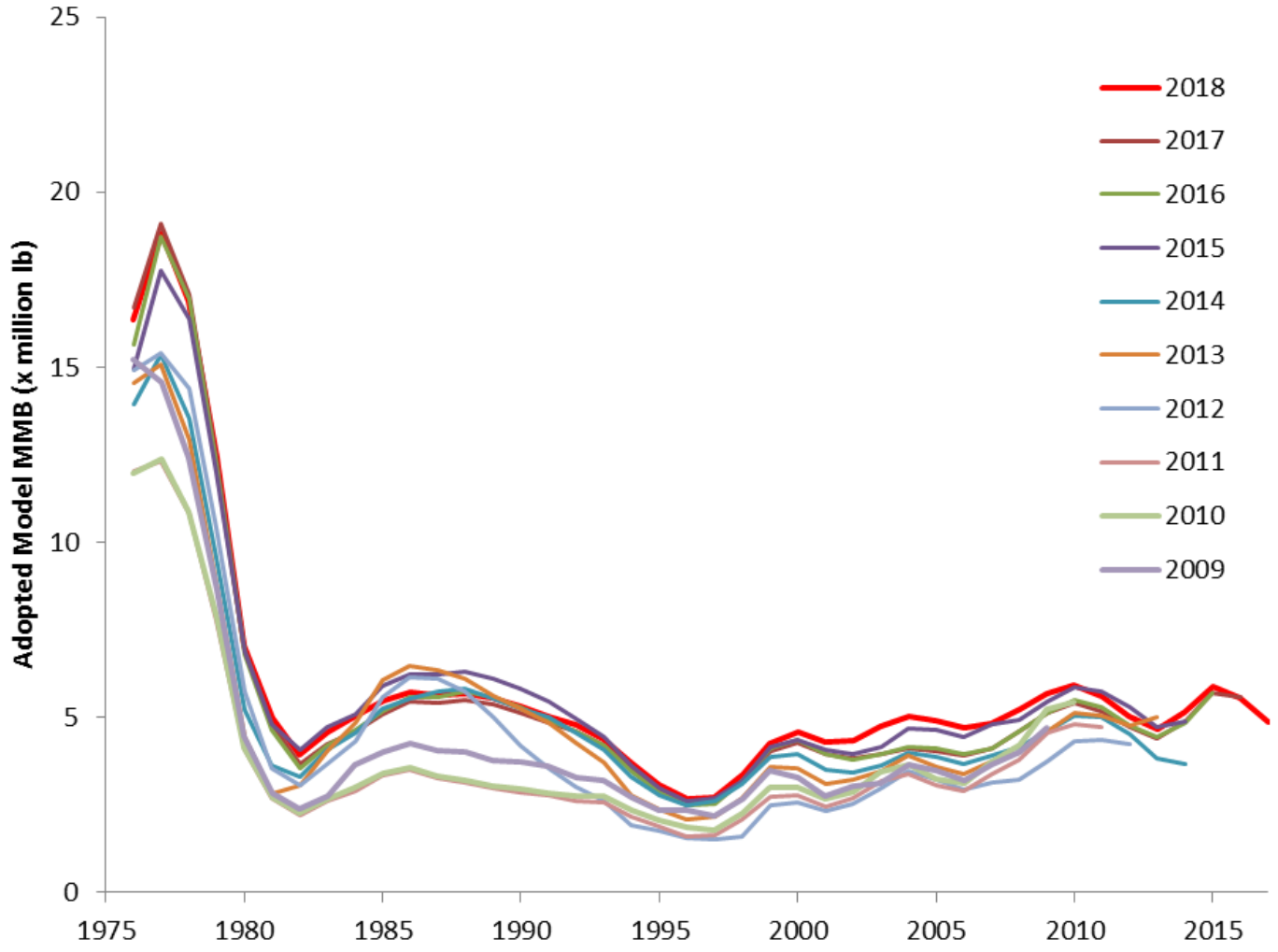
Base Model


Tag recovery data observed vs predicted
Recovery after 1 year
64 mm
74 mm
84 mm
94 mm
104 mm
114 mm
124 mm
0.0 0.2 0.4 0.6 0.8 1.0
64 84 104 124
Recovery after 2 years
Recovery after 3 years

Base Model


Retrospective Analysis
Mohn rho 0.213
MMB x million lb
5
10
15
1976
1981
1986
1991
1996
2001
2006
2011
2016
year

Putting all together



OFL & ABC

- $B_{MSY\ Proxy}$
  - Average MMB from 1980-2018 = 4.82 million lb
- MMB
  - MMB (2018) = 4.08 million lb

- MMB < $B_{MSY\ Proxy}$: Tier 4b

$$F_{OFL,l} = \gamma M_l (B / B_{MSY\,prox} - \alpha) / (1 - \alpha)$$

M_l = 0.18 (CL:63-123mm), 0.58 (CL: ≥124mm)

γ = 1, α = 0.1

$$OFL_r = \sum_l \left[Legal\_B_{w,l} \left(1 - e^{-(F_{OF,l} + 0.42M_l)} - (1 - e^{-0.42M_l}) \left(\frac{1 - p \cdot (1 - e^{-(F_{OFL,l} + 0.42M_l)})}{1 - p \cdot (1 - e^{-0.42M_l})} \right) \right) \right]$$

OFL & ABC

- $B_{MSY\ Proxy}$
  - Average MMB from 1980-2018 = 4.47 million lb
- MMB
  - MMB (2017) = 3.94 million lb

- MMB < $B_{MSY\ Proxy}$: Tier 4b

- Legal Male Biomass (Feb 01, 2019) : 3.55 million lb
- OFL_r = 0.76 million lb = 0.32 kMT

ABC = 0.8*OFL_r = 0.61 million lb = 0.27 kMT