The Cost of Closing the Steller Sea Lion Conservation Area

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Overview of Talk

- How we model fisher behavior
- Specifics of SCA closure
- Description of different models
- Welfare estimation
- Predictions
- Related research

The problem: Assessing the impact of an area closure

- Historically a number of areas were open to fishing
- Now an MPA or other closure has shut some of these areas to fishing
- What do fishermen do in response?
- What is the cost of this response?
- Can alternative & less expensive closures achieve the same conservation objectives?

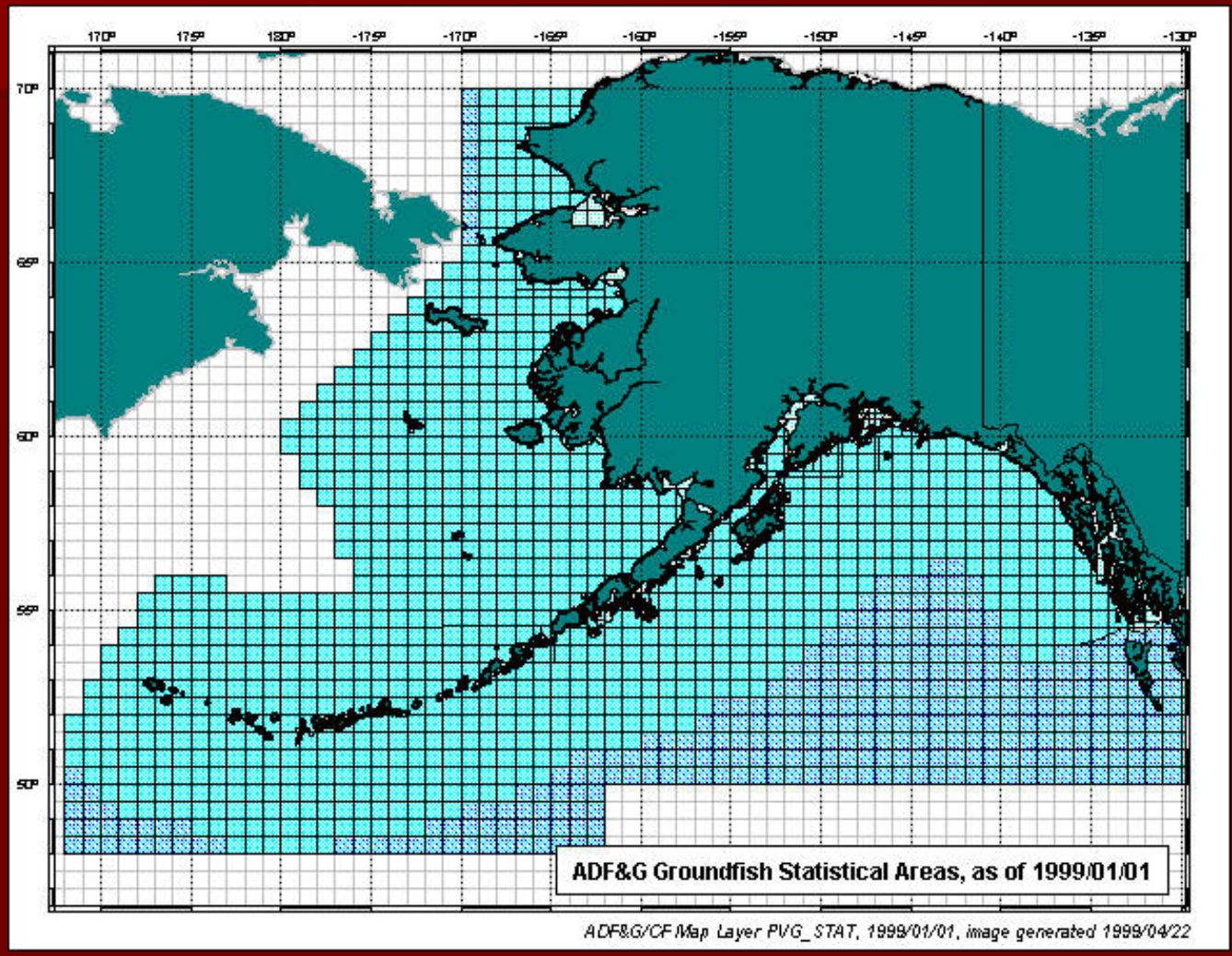
Modeling a fisherman's choice

- A fisherman chooses to fish in a certain location
- Why go fishing?
  - For recreational fishermen, it may be scenic views, the best fishing close to one's favorite bar, etc.
  - For commercial fishermen, it's about fish=$$$

How we model choice

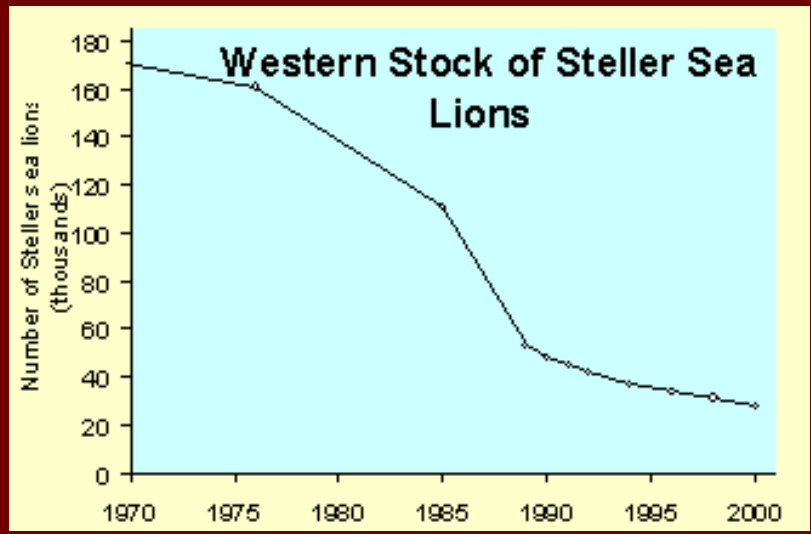
- A fisherman makes a discrete choice of a zone
- The zone is chosen as a function of
  - Expected catch/revenue in the zone
  - Travel costs (fuel, time, wages, the opportunity cost of not using the boat elsewhere)
  - Boat characteristics

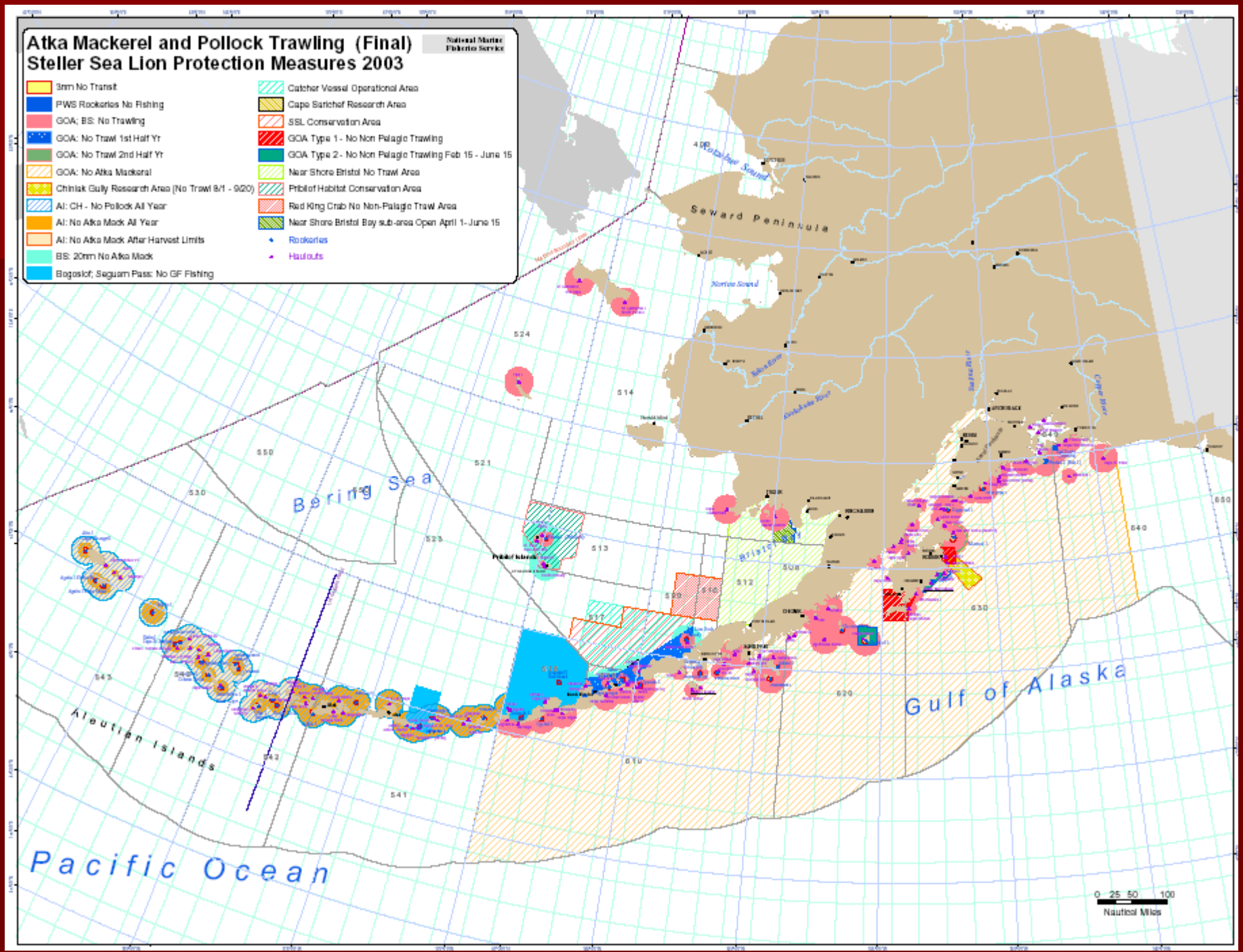
STAT6 Areas in the Bering Sea



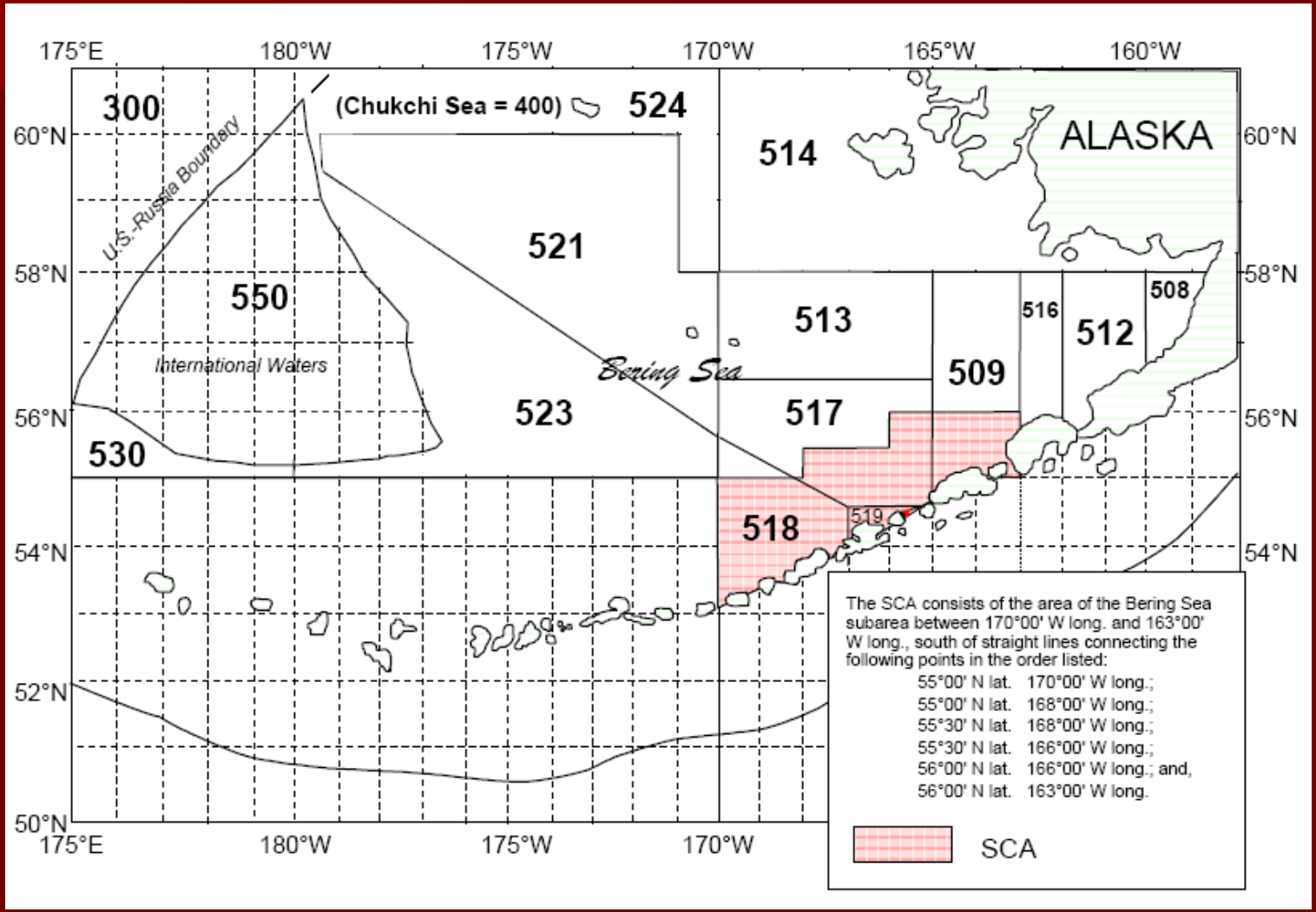
Steller Sea Lion protective measures

- Stellers declared endangered in 1990
- Rookeries and haulouts protected beginning in early 1990s
- Critical Habitat (later becomes the SCA) designated in 1998
- Seasonal limitations of TAC in the SCA imposed in 1999
- Emergency closure late summer 2000




Atka Mackerel and Pollock Trawling (Final)
Steller Sea Lion Protection Measures 2003
National Marine Fisheries Service
3nm No Transit
PWS Rookeries No Fishing
GOA; BS: No Trawling
GOA: No Trawl 1st Half Yr
GOA: No Trawl 2nd Half Yr
GOA: No Atka Mackerel
Chiniak Gully Research Area (No Trawl 8/1 - 9/20)
AI: CH - No Pollock All Year
AI: No Atka Mack All Year
AI: No Atka Mack After Harvest Limits
BS: 20nm No Atka Mack
Bogoslof; Seguam Pass: No GF Fishing
Catcher Vessel Operational Area
Cape Sarichef Research Area
SSL Conservation Area
GOA Type 1 - No Non Pelagic Trawling
GOA Type 2 - No Non Pelagic Trawling Feb 15 - June 15
Near Shore Bristol No Trawl Area
Pribilof Habitat Conservation Area
Red King Crab No Non-Pelagic Trawl Area
Near Shore Bristol Bay sub-area Open April 1- June 15
Rookeries
Haulouts
Bering Sea
Aleutian Islands
Pacific Ocean
Gulf of Alaska
Seward Peninsula
Norton Sound
Bristol Bay
0 25 50 100
Nautical Miles

Steller Sea Lion Conservation Area (SCA)



Standard Discrete Choice Formulation

- Fishers (i = 1…n) choose the zone (j = 1…n) with the highest utility

$$U_{ij} = X_{ij}\beta + \nu_{ij}$$

- Two-stage expected catch (or revenue) is typically employed

- Usually a conditional or nested logit is employed. For example, for a binomial conditional logit model:

$$\Pr(Y=1) = \frac{e^{\left(\frac{X_{i1}\ \beta}{\sigma_\varepsilon}\right)}}{e^{\left(\frac{X_{i1}\ \beta}{\sigma_\varepsilon}\right)} + e^{\left(\frac{X_{i2}\ \beta}{\sigma_\varepsilon}\right)}}$$

Select Literature in Commercial Fishing Location Choice

- Bockstael and Opaluch (1983)
- Eales and Wilen (1986)
- Campbell and Hand (1999)
- Holland and Sutinen (1999, 2000)
- Curtis and Hicks (2000)
- Mistiaen and Strand (2000)
- Smith (2000, 2001)

Expected Profit Model (EPM)

- Based on joint work with David Layton at UW
- Main idea: jointly endogenously estimate expected catch/profit
- Because of the fact that we actually observe prices and because of the separability of the discrete portion of likelihood, all parameters are potentially identifiable.
- The EPM lets us directly estimate how fishermen trade off expected revenues with travel costs

Model Basics

- Actual catch deviates from expected catch by a normal error

$$Y_{ij} = \alpha_j + \eta_{ij} \qquad \eta_{ij} \sim Normal\left(0, \sigma_j\right)$$

- Expected profits are a function of expected revenues, estimated costs, and random error

$$E\left(\pi_{ij}\right) = P\alpha_j - X_{ij}\beta + \varepsilon_{ij} \qquad \varepsilon_{ij} \sim TYPE\ I\ EV\left(0, \sigma_\varepsilon\right)$$

EPM –
joint catch/choice equation estimated with MLE

$$\ell_j = \underbrace{\frac{1}{\sigma_{v_j}\sqrt{2\pi}}\exp\left[-\frac{1}{2}\left(\frac{Y_{ij} - \alpha_j}{\sigma_{v_j}}\right)^2\right]}_{c} \underbrace{\frac{e^{\left(\frac{P_j\alpha_j - X_j\beta}{\sigma_\varepsilon}\right)}}{\sum_k e^{\left(\frac{P_{ik}\alpha_k - X_{ik}\beta}{\sigma_\varepsilon}\right)}}}_{d}$$

- σ_{vj}= zone specific variance in catch
- Y_{ij}= actual catch
- Alphas = endogenously estimated average catch
- X's = miles and boat characteristics
- σ_ε = scale factor on the logit

Summary of Data

- Data for years 1995-2002 (summer season)
  - 1995-1998 data(2265 trips) used to predict impact for 1999-2000 closures
- Observer data on catch and location for all hauls in the Bering Sea (haul observations are used to find the centroid of hauls on a trip)
- Hauls are grouped into discrete half-degree zones (STAT6 areas)
- Miles from port to catch sites
- Prices

Frequentist Model Averaging

- This method based on Buckland et al (*Biometrics* 1997)
- More recent exploration by Hjort and Claeskens (2003) in *JASA*
- Frequentist analog to Bayesian model averaging
- Don't know true model– why choose only one?

Oh so many models

Model		(all non-miles terms are interacted with miles)					boat characteristics are nomalized to 1 for each BC				
1	miles										
2	miles	miles^2									
3	miles	tons	HP	length	age						
4	miles	miles^2	tons	tons^2	HP	HP^2	age	age^2	length	len^2	
5	miles	tons	HP	age	length	tons*HP	tons*len	tons*age	HP*len	HP*age	len*age
a	EPM										
b	EPM random paramenters										
c	Zonal logit										
d	zona logit RP										

	EPM	EPM RP	Z logit	Z logit RP			
no tons	e	f	g	h			
3	miles	HP	length	age			
4	miles	HP	HP^2	age	age^2	length	len^2
5	miles	HP	age	length	HP*age	HP*len	len*age
no HP	i	j	k	l			
3	miles	HP	length	age			
4	miles	HP	HP^2	age	age^2	length	len^2
5	miles	HP	age	length	HP*age	HP*len	len*age
no age	m	n	o	p			
3	miles	HP	length	age			
4	miles	HP	HP^2	age	age^2	length	len^2
5	miles	HP	age	length	HP*age	HP*len	len*age
no len	q	r	s	t			
3	miles	HP	length	age			
4	miles	HP	HP^2	age	age^2	length	len^2
5	miles	HP	age	length	HP*age	HP*len	len*age

Frequentist Model Averaging Procedure

- Step 1: Choose Model Selection Criteria with which to weight models (the smaller the number, the better)

$$AIC = -2\ell + 2p$$

$$AICc = AIC + \frac{2p(p+1)}{n-p-1}$$

$$BIC = -2\ell + p\ln(n)$$

- Where l = likelihood, p=# of parameters, n=number of observations

Frequentist Model Averaging Procedure

- Step 2: Weight different models

$$w_m = \frac{\exp\left(\frac{-crit_m}{2}\right)}{\sum_{i=1}^{M} \exp\left(\frac{-crit_i}{2}\right)}$$

- Step 3: Calculate welfare weights based upon weights calculated in step 2

$$EW_{Mavg} = \sum_{1}^{M} w_i \, EW_i$$

Model Comparison

							Frequentist weights		
Models		LL	Parameters	AIC	AICc	BIC	AIC w	AICc w	BIC w
5a	EPM	-2766.8	56	5645.6	5648.5	5966.2	0.290	0.270	0.0000126
5b	EPM RP	-2765.9	57	5645.8	5648.8	5972.1	0.265	0.235	0.0000007
5e	**no tons, non-RP**	**-2771.1**	**52**	**5646.1**	**5648.6**	**5943.9**	**0.2236**	**0.2546**	**0.9142**
5f	**no ton, RP**	**-2770.1**	**53**	**5646.3**	**5648.9**	**5949.7**	**0.2085**	**0.2261**	**0.0487**
5i	no HP, non-RP	-2787.8	52	5679.6	5682.1	5977.3	0.00000001	0.00000001	0.00000005
5j	no HP, RP	-2786.2	53	5678.4	5681.0	5981.8	0.00000002	0.00000002	0.00000001
5q	**no len, non-RP**	**-2774.3**	**52**	**5652.6**	**5655.1**	**5950.3**	**0.0088**	**0.0101**	**0.0362**
5r	no len, RP	-2774.1	53	5654.2	5656.8	5957.6	0.0040	0.0043	0.0009

Three models contribute almost all of the weight to the model average if we utilize the BIC criterion.

Welfare Estimation

The welfare loss can be computed as the amount of money that must be given (or taken away) to equate profits before and after the policy change. This is found by the relation:

$$E\left(MAX\left(U_{ij}, j=1:m1\right)\right) = E\left(Max\left(U_{ij}, j=1:M\right)\right)$$

Welfare Estimation (2)

- In the EPM, we can find the welfare loss directly. The expected value of the maximum can be shown to be:

$$E\left(Max\left(U_{ij}, j=1:M\right)\right)=\sigma_{\varepsilon}\ln\left(\sum_{j=1}^{j=M}\exp^{V_{ij}/\sigma_{\varepsilon}}\right)-\sigma_{\varepsilon}\times 0.57721$$

- We can directly calculate the welfare loss:

$$E\left(MAX\left(U_{ij}, j=1:m1\right)\right)-E\left(Max\left(U_{ij}, j=1:M\right)\right)=W$$

How much does the SCA cost?

Models		0.025	0.05	median	0.95	0.975
1a	EPM	-9491	-8933	-5512	-2121	-1631
1b	EPM RP	-10035	-9589	-7187	-5000	-4541
2a	EPM	-12797	-12009	-8167	-4308	-3664
3a	EPM	-7623	-6973	-3983	-1206	-698
3b	EPM RP	-12465	-9968	-4249	-1425	-649
4a	EPM	-6935	-6881	-6154	-5496	-5409
4b	EPM RP	-8356	-7791	-5660	-4144	-3885
5a	EPM	-5706	-5618	-4817	-4361	-4282
5b	EPM RP	-9688	-9256	-7311	-6186	-6036
5e	no tons, non-RP	-5624	-5547	**-4746**	-4360	-4257
5f	no ton, RP	-28501	-23602	**-8066**	-6329	-6308
5q	no len, non-RP	-5439	-5379	**-4656**	-4328	-4227

Results corrected for 30% coverage boats. The 4% of trips and 1% of the Catch reported by 0% coverage boats are not included.

How much does the SCA cost?

- There were 4014 catcher boat trips during the closure period in 2000 when the SCA was totally closed

Criteria	Welfare loss (per trip)	Total Loss (millions)
AIC	-6,119	-24.6
AICc	-6,096	-24.5
BIC	-4,900	-19.7

How much does the SCA cost?

Expected profit or net revenue	**$/Trip**
Before SCA closure	56,164
With SCA closure	51,264
Net loss from closure	4,900
Percentage loss per trip	8.7%

Comments on Predictions

- Zonal logit does very well with predictions (comparable to, and usually slightly better than the EPM)
- Models work very well to predict what will happen in well-fished areas. Predicting what will happen in rarely-visited areas is much more difficult

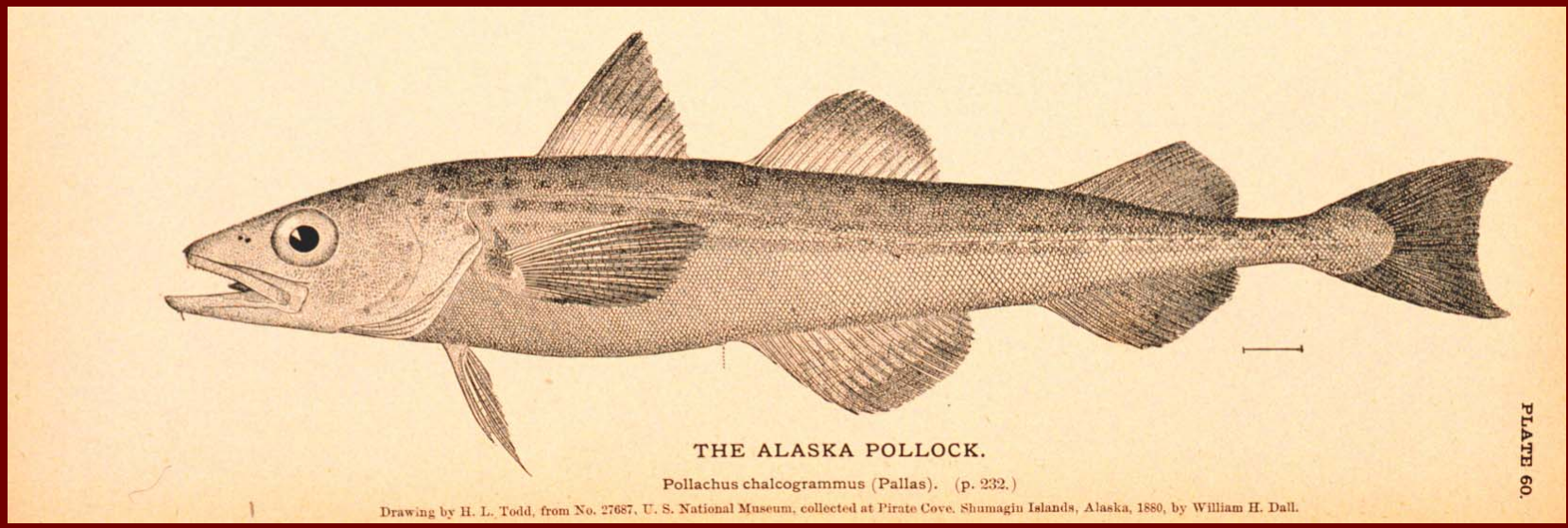
Predictions from EPM

	1995-1998			1999			2000c (pre-closure)			2000d (post-closure)			2001-2002		
STAT22 Zone	% of Actual Trips	EPM estimate % trips	EPM 9598 MSE	% of Actual Trips	EPM estimate % trips	EPM 1999 MSE	% of Actual Trips	EPM estimate % trips	EPM 2000a MSE	% of Actual Trips	EPM estimate % trips	EPM 2000b MSE	% of Actual Trips	EPM estimate % trips	EPM 0102 MSE
1	0.53	0.55	0.00	0.0	0.3	0.1		0.03	0.0		0			0.55	0
2	8.12	8.03	0.01	3.3	6.0	7.2	18.8	1.23	310.2		0		3.6	8.03	19.88
3	0.66	0.69	0.00	1.1	0.4	0.5	2.9	0.05	8.1	0.4	0	0	0.4	0.69	0.10
4	0.66	0.55	0.01	0.9	11.1	103.9	13.8	24.74	120.4	21.6	28.6	49		0.55	0.31
5	0.18	0.16	0.00	0.2	2.7	6.3	0.7	4.52	14.4	5.4	5.2	0		0.16	0.02
6	23.97	24.64	0.44	0.0	0.0	0.0		0.00	0.0		0		29.6	24.64	25.06
7	0.26	0.29	0.00	0.2	0.1	0.0		0.01	0.0		0		0.6	0.29	0.07
8	45.83	45.25	0.33	26.1	37.5	130.4	11.6	10.34	1.6		0		47.7	45.25	6.12
9	8.26	7.93	0.11	17.4	5.8	133.4	13.0	1.13	141.9		0		5.5	7.93	6.04
10	1.55	1.57	0.00	7.6	1.0	43.2	2.2	0.14	4.1	0.7	0.0	0	0.2	1.57	1.93
11	0.40	0.34	0.00	7.2	6.4	0.7	10.1	12.29	4.6	46.7	14.2	1058	0.3	0.34	0.00
12	0.18	0.17	0.00	0.0	0.0	0.0		0.00	0.0		0		0.5	0.17	0.10
13	3.27	3.49	0.05	0.0	2.1	4.2		0.26	0.1		0		1.2	3.49	5.39
14	0.84	0.80	0.00	0.0	0.3	0.1		0.03	0.0		0		0.2	0.80	0.31
15	2.38	2.74	0.12	0.2	1.7	2.2		0.22	0.0		0.0	0	5.8	2.74	9.28
16	0.57	0.54	0.00	2.4	0.3	4.5		0.03	0.0		0.0	0	1.4	0.54	0.76
17	0.40	0.36	0.00	15.2	6.2	80.4	5.1	11.12	36.6	0.4	12.9	154	0.1	0.36	0.09
18	0.53	0.46	0.00	6.8	8.9	4.2	18.1	18.48	0.1	18.2	21.4	10	0.8	0.46	0.11
19	0.22	0.19	0.00	0.4	3.4	9.0	2.9	5.86	8.8	1.8	6.8	25		0.19	0.04
20	0.22	0.27	0.00	0.0	0.1	0.0		0.01	0.0		0.0	0	0.1	0.27	0.04
21	0.62	0.67	0.00	1.7	0.4	1.7		0.04	0.0		0.0	0	2.2	0.67	2.19
22	0.35	0.31	0.00	9.4	5.4	16.4	0.7	9.49	76.7	4.7	11.0	39		0.31	0.10
Total	100	100	**1.10**	100	100	**549**	100	100	**727.7**	100	100	**1336**	100	100	**78**

Other research questions

- How do closures effect different sized vessels?
- How has location choice behavior changed post-AFA
- Winter season model
  - How do fishermen trade off roe for other catch
  - What's the impact of percentage restrictions
- Other closures in other fisheries

The End



THE ALASKA POLLOCK.

Pollachus chalcogrammus (Pallas). (p. 232.)

Drawing by H. L. Todd, from No. 27687, U. S. National Museum, collected at Pirate Cove, Shumagin Islands, Alaska, 1880, by William H. Dall.

PLATE 60.