ESTIMATING THE ECONOMIC IMPACT OF THE STELLER SEA LION CONSERVATION AREA: DEVELOPING AND APPLYING NEW METHODS FOR EVALUATING SPATIALLY COMPLEX AREA CLOSURES

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ABSTRACT

Economists and biologists have recognized that spatial and temporal area-closures may provide an effective means of managing the impact that fisheries have on one another and upon threatened species. To date, however, little work has been done to estimate the economic impact of protected areas on commercial fishing. One significant protected area in the Bering Sea is the Steller sea lion Conservation Area (SCA). The benefits of the SCA consist of improvements to Steller sea lion populations as excluding commercial fishing leaves more prey for sea lions. The primary cost of the SCA is the potential reduction in profits that occurs as boats incur additional costs as they travel to more distant locations and/or experience lower levels of catch in alternative fishing areas. Estimating the economic impacts of the SCA thus requires explicit modeling of fishing location choice as location choice is the aspect of behavior that is directly affected. A substantial literature has developed over recent decades which explores the factors that influence location choice. This literature has utilized discrete choice econometric models to estimate the probability that fishers choose to fish within a specific area or zone. New protected areas will generally not conform to existing statistical areas, making analysis of the economic impacts of an area closure difficult. With our development of an improved discrete choice model, specifically designed to model fishing location choice, we are able to develop ex-ante and ex-post estimates of the economic impacts of the SCA upon the Bering Sea Pollock fishery. Here we do not present welfare estimates, but present estimation results and discuss future research.

Keywords: Fishery; Marine Protected Areas; Area-closures; Marine mammals; Econometrics

INTRODUCTION

Marine Protected Areas (MPAs) have become an important instrument for marine preservation. MPAs have different purposes: many are created to encourage economic spillovers to neighboring fisheries, while others, including the Steller Sea Lion Conservation Area (SCA) in the Bering Sea, have been created to provide additional prey for endangered or threatened species. How do fishermen respond to closures and what are the welfare implications? This paper uses conventional and new methods to assess the impact of the closures.

From 1999-2002, Bering Sea pollock (*Theragra chalcogramma*) accounted for 73 percent of the groundfish caught off of Alaska. The fishery is broken up into 3 primary sectors: catcher boats that deliver fish to an inshore processing sector (50 percent of total catch), catcher processors (40 percent) and motherships (10 percent).

For more than three decades, the population of the Western stock of Steller sea lions has declined substantially, and was declared endangered in 1990. Most of the area that makes up the SCA was designated as Steller sea lion critical habitat in the early 1990's, but the SCA as we define it came to exist and to restrict fishing effort in 1999. Figure 1 illustrates the boundaries of the SCA, inside of which the primary fishing grounds of the inshore pollock fishery reside. Biologists and economists have debated the degree to which reserves create sources for fish (see for example Sanchirico and Wilen 1999), but the SCA is not designed to increase catch, but to ensure that the pollock are locally abundant seasonally for Steller sea lions.

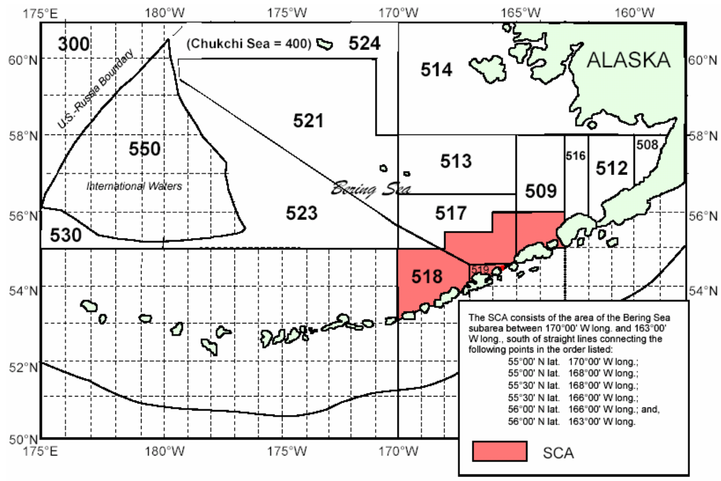

Figure 1: Steller Sea Lion Conservation Area (SCA) and the Bering Sea (Source: NOAA)

This paper focuses upon the impact that closures and area-specific catch limitations of the SCA have had upon the pollock catcher boat fleet. We focus here on this sector because it allows us to model the fisher location decision as a function of the miles from port to a fishing site, which is less of a constraint for the offshore sectors of the fishery (catcher processors and motherships).

In the following section of this paper, we discuss the primary approaches that have been taken to model fisher location choice, and then set up our approach this problem. We then present a description of our data and preliminary results. Finally, we offer conclusions and a discussion of future research. Many caveats are offered throughout the paper about the preliminary nature of this work, and in the concluding section we offer a discussion of how we will address many of these issues.

MODELING FISHER LOCATION CHOICE

Our approach to this problem builds upon the literature which assesses how fishermen make site location choices. The literature in this area is quite substantial, and is typically traced to the work of Bockstael and Opaluch (1982) and Eales and Wilen (1986). Bockstael and Opaluch (1982) employ a discrete choice model to assess the factors that cause fishers to switch fisheries. Eales and Wilen (1986) introduce the idea of using a two-stage model where in the first stage the expected catch of an area is estimated using the average catch from that area in previous periods, and in the second stage, location choice is modeled as a function of expected catch in each area. This literature has used variations of logit models (conditional logit, nested logit, etc.) to model how fishers make location choices. The more recent work in this literature has included much more complex covariates (e.g. Dupont 1993; Holland and Sutinen, 1999, 2000; Campbell and Hand, 1999; Curtis and Hicks, 2000; Smith 2000, 2001). Numerous interesting issues have been addressed in this literature, including the effort by Curtis and Hicks to place a value on the closure of a large area of the Pacific Ocean for turtle protection.

What is the right type of model to measure the economic impact of MPA's such as the SCA? The problem lies within a continuum of models from extremely simple but not fully utilizing the information available to models that more efficiently use information but at the cost of increasing complexity of estimation. In future work we will address the range of these models in greater detail, but here we consider three models that capture important aspects of the problem: 1) a zonal conditional logit, 2) a 2-stage average catch model ("Y-Average"), and 3) the Expected Profit Model, our new model which jointly estimates catch and choice parameters.

The zonal logit is simple but in some sense elegant in regards to evaluating area closures. The zonal logit and the Y-average model are both conditional logit models where the fisher chooses a location to maximize utility where utility is a function of fisher and area characteristics, subject to random error:

$$U_{ij} = \beta x_{ij} + \varepsilon_{ij} \tag{1}$$

$$P(j = k) = \frac{\exp \beta' x_{ik}}{\sum_{j=1}^{J} \exp \beta' x_{ij}} \tag{2}$$

The area chosen (k) comes from a discrete number of available zones (j=1…J). For the zonal logit that we examine here, we estimate zone-specific constants (α_j) (with an appropriate normalization) and a parameter on the miles required to travel to the chosen zone (β_{miles}). While this is a quite very basic model, it provides a simple means to turn zones "on" and "off" with area closures.

The Y-average model is also a conditional logit, but we replace the zone-specific constants with a parameter on average catch for the zone, which we calculate prior to estimating the choice model. Variations on this model are the standard model for this type of analysis, though it is often employed in a nested logit and with finer temporal resolution (not just the seasonal average, but the daily or monthly average, for example). The most common model in the literature is a nested logit which most commonly involves a first stage decision of what fishery to fish in, followed by a second stage of where to fish.[i]

The Expected Profit Model (EPM) is a joint discrete-continuous model. In the EPM, we simultaneously estimate the expected catch (or revenue) for each zone, and a logit choice model. This work builds upon several earlier discrete-continuous models (e.g. Duncan 1980 and Hanemann 1984) as well as the recent work of Morey and Waldeman (1998, 2000).[ii] In unpublished Monte Carlo simulations, this model has outperformed the other models included here.

Our initial assumption is that fishers choose zones to maximize expected variable profits from the trip, where variable profits are defined as revenues minus travel costs .[iii] A fisher's expected profits are formulated as follows (with Y representing catch and C costs):

$$E(\pi_{ij}) = E(P\,Y_{ij} - C_{ij}) = E(P\,Y_{ij}) - E(C_{ij}) \tag{3}$$

$E(Y_{ij}) = E(Y_j) = \alpha_j$.

We model the fisher's expected profit as function of expected catch, cost coefficients to be estimated, and an additive error (similar in spirit to work by Chicchetti and Dubin 1994 in another context):

$$E(\pi_{ij}) = P\alpha_j - X_{ij}\beta + \varepsilon_{ij} \tag{4}$$

$$\varepsilon_{ij} \sim TYPE\ I\ EV\left(0, \sigma_{\varepsilon}\right)$$

$$Y_{ij} = \alpha_j + \eta_{ij}$$

$$\eta_{ij} \sim Normal\left(0, \sigma_j\right)$$

Thus the model has two error terms and two types of variances that can be estimated. Because of the nature of the joint estimation and the fact that we observe the catch from a trip as well as the choice of a zone, we are able to identify the scale parameters, which we describe as sigmacatch (σ_j) and sigmachoice (σ_ε). Sigmacatch can be restricted so that it is equal for all zones, but here we estimate a separate sigmacatch for each zone.

As in a standard Random Utility Model, we assume that for individual *i* and zone *j*:

$$E\left(\pi_{ij}\right) > E\left(\pi_{ik}\right) \ \forall \ k \neq j \Rightarrow$$

$$P\alpha_j - X\beta_{ij} + \varepsilon_{ij} > P\alpha_k - X\beta_{ik} + \varepsilon_{ik} \ \forall \ k \neq j$$

The model is estimated using full-information maximum likelihood (FIML). For example, for a trip to zone 1, we maximize the logarithm of the following expression:

$$\ell_1 = \underbrace{\frac{1}{\sigma_1\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{Y_{i1} - \alpha_1}{\sigma_1}\right)^2\right]}_{continuous} \times \underbrace{\frac{e^{\left(\frac{P\,\alpha_1 - X_{i1}\,\beta}{\sigma_\varepsilon}\right)}}{\sum_{j=1}^{J} e^{\left(\frac{P\,\alpha_j - X_{ij}\,\beta}{\sigma_\varepsilon}\right)}}}_{discrete} \qquad \textbf{(5)}$$

Here Y is the actual catch and X is the miles from the centroid of the chosen and alternative areas to the landing port of the trips. In the results presented here, P is the yearly average annual ex-vessel pollock price.

Because all of the parameters are identified, including scale, we are able to actually calculate the welfare impact of closing a zone. What we calculate might be called ‘variable profits’ or ‘net revenues,’ in that it ignores fixed costs and calculates the expected difference in revenues and travel costs for each zone.

DESCRIPTION OF DATA

The data used in this analysis are from fish ticket data reported by fishers and NOAA observer data that comes from the NOAA observer program. All of these data are protected by confidentiality agreements so no data are presented which reveal trade secrets or any information about particular vessels or processors.

The data that we utilize here have the following characteristics:

- Summer trips only
- Catcher boat trips only
- Catch quantity and location data are based upon observer data from 1995-2002
- Fish ticket data are used to determine when trips start and begin
- Price data are taken from the NMFS Economic SAFE documents.

Data are recorded by the NOAA Observer Program in three different scales/resolutions: NMFS area, ADF&G 'STAT6' statistical areas, and the latitude and longitude where a haul starts and ends. The vast majority of trips take place just a few of the NMFS areas, so we have used the STAT6 areas, which have a finer resolution than the NMFS area, as the discrete choice used in this model. This scale allows us to distinguish meaningfully among choice opportunities and to continue to use the discrete choice framework.

For each trip, the centroid of each haul is calculated. Using ArcGIS, the STAT6 area of the centroid is determined. The one-way distance from the landing port to the centroid of the STAT6 area is then used as the distance of the trip. For 1995-1998, there were a total of 2268 trips to 29 zones. We only included those zones that had more than 5 trips to them for these years, which resulted in a model with 18 zones and 2247 trips (the deleted 11 zones collectively accounted for less than 1% of all trips). In future work, we will re-insert these additional zones. Table 1 illustrates how during the restriction/closure periods in 1999 and 2000, a number of trips were taken outside of the 18 zones included in the model. We recognize the omissions of the extra zones for 2000 may be significant, and we will reinclude those zones in future work.

Table 1: Number of trips in and out of the model's estimation areas

	95-98	1999	2000c	2000d	2001-02
trips in included zones	2247	538	133	413	1617
total trips	2268	577	182	558	1638
% of trips included	99%	93%	73%	74%	99%

During 1999 and 2000, NOAA Fisheries established spatially explicit TACs for the SCA. In 1999, the summer catch was split equally between the "C" and "D" seasons. In the C and D season, the average SCA TAC was 56% of the total TAC. In 2000, the C Season SCA TAC was 13.5% of the total TAC, and the D season TAC was set at 22.5% of the seasonal TAC. On August 9, 2000, prior to the end of the C season, however, the SCA was closed by judicial mandate to all trawling. Thus the 2000 D Season there was no fishing inside the SCA.

Table 2 illustrates how SCA restrictions impacted the fishery (in terms of trips, not catch). 1999 and 2000 are the years in which the SCA was partially or totally closed.

Table 2: Catcher boat trips in and out of the SCA, by year

SCA	1995	1996	1997	1998	1999	2000	2001	2002
Outside	1	3	0	60	253	654	30	0
Inside	583	543	539	539	324	86	761	847
% Inside	99.8	99.5	100.0	90.0	56.2	11.6	96.2	100.0

RESULTS

Computation of the EPM is difficultly without careful scaling. Here the model is run with catch in 1000's of tons, miles in 100's of miles and prices per ton divided 100. Thus "variable profits" are being measured in$100,000 units.

In Table 3, we present results here for three models: zonal logit, Y-AVG model, and the EPM. For the EPM, an alpha and sigmacatch parameter are estimated for each of the 18 zones for a total of 38 parameters, while for the zonal logit, no scale parameter can be estimated, and results are presented relative to the base zone, which is arbitrarily chosen here as zone 1(for a total of 18 parameters).

Table 3: Estimation Results for 3 Models

MODEL 1: EPM					*MODEL 2: Zonal Conditional Logit*			
	Estimate	SE	Est./SE			Estimate	SE	Est./SE
alpha1	0.188	0.013	14.26		Zone 1	**0**		
alpha2	0.211	0.004	54.70		zone 2	3.08	0.290	10.61
alpha3	0.194	0.011	18.14		zone 3	0.94	0.382	2.45
alpha4	0.195	0.011	17.11		zone 4	1.33	0.387	3.44
alpha5	0.214	0.003	61.92		zone 5	3.19	0.290	10.99
alpha6	0.180	0.017	10.49		zone 6	-1.15	0.482	-2.38
alpha7	0.220	0.005	46.58		zone 7	4.20	0.279	15.07
alpha8	0.210	0.004	51.30		zone 8	2.89	0.286	10.11
alpha9	0.200	0.008	25.65		zone 9	1.67	0.338	4.94
alpha10	0.191	0.013	15.18		zone 10	0.77	0.456	1.69
alpha11	0.198	0.008	25.05		zone 11	1.07	0.312	3.42
alpha12	0.186	0.014	13.21		zone 12	-0.50	0.373	-1.35
alpha13	0.199	0.008	25.44		zone 13	1.17	0.309	3.80
alpha14	0.189	0.013	14.80		zone 14	0.19	0.383	0.49
alpha15	0.188	0.014	13.37		zone 15	0.30	0.427	0.71
alpha16	0.193	0.011	17.72		zone 16	1.08	0.415	2.59
alpha17	0.192	0.012	16.49		zone 17	0.44	0.378	1.17
alpha18	0.188	0.013	14.08		zone 18	0.33	0.443	0.76
miles	-0.016	0.007	-2.12		miles	-1.48	0.186	-7.99
sigmachoice	0.014	0.007	2.05					
sigma1	0.142	0.034	4.24		initial LL	-6494.7		
sigma2	0.118	0.006	20.34		LL	-3753.3		
sigma3	0.129	0.024	5.30		pseudo R	0.422		
sigma4	0.158	0.039	4.04					
sigma5	0.209	0.007	29.66		*MODEL 3: Exogenous Average Catch*			
sigma6	0.127	0.045	2.81			Estimate	SE	Est./SE
sigma7	0.146	0.003	42.08		miles	-2.61	0.08	-34.85
sigma8	0.105	0.004	24.84		YAVG	-7.59	0.34	-22.29
sigma9	0.136	0.017	8.03					
sigma10	0.124	0.030	4.18					
sigma11	0.331	0.029	11.25		initial LL	-6494.7		
sigma12	0.385	0.092	4.16		LL	-5720.3		
sigma13	0.152	0.027	5.68		pseudo R	0.119		
sigma14	0.201	0.037	5.42					
sigma15	0.087	0.019	4.70		*NOTES:*			
sigma16	0.078	0.022	3.51		Data: 1995-1998 summer season			
sigma17	0.164	0.047	3.49		>5 trips per zone			
sigma18	0.061	0.016	3.82					

Comparison of Model predictions

In Table 3 we display the pseudo-R^2 for the zonal logit and Y-average models. The zonal logit does much better (0.422) by this comparison. For the EPM, because of the nature of its joint estimation, a pseudo-R^2 cannot be calculated for the complete likelihood. For the choice portion of the EPM likelihood, the pseudo-R^2 is slightly better than the zonal logit (0.423). In Table 4, we show a comparison of the predictive abilities of the three models for the different periods of study. Here is a brief description of the characteristics of the different time periods:

- **1995-98** – during this period, there were no substantial SCA closures. The model is estimated with pooled data from these years (summer season only), then predictions are made for the other years.
- **1999** – during the summer season only 56 percent of the TAC could be taken from the SCA
- **2000C** – during all but the last 10 days of this period, the SCA TAC was 13.5%; during the last 10 days, the SCA was closed.
- **2000D** – the SCA was closed to pollock trawling.
- **2001-2002** – the SCA is open during the summer season.

Predictions are made here for 1999, 2000C, and 2000D by making the SCA TAC binding and reallocating probabilities accordingly. For the complete closure in the 2000D season, all of the trips were attributed to the non-SCA zones that made up a small number of the trips in the 1995-98 period. Through another Steller sea lion protective measure, virtually all of zone 5 is closed in 1999 and 2000, and no trips were taken to this zone. We closed the area for this analysis.

In Table 4 we present the estimated percentage of trips to each zone and the mean-squared-errors (MSE) for each time period and each model. The MSE is the sum of the squared difference of the predicted and actual number of trips for each zone.

The next step that we will pursue with these results is to calculate the welfare impacts of the area closures from the SCA. Using the α's estimated for the EPM in Table 3, we can calculate the expected variable profit using Equation 4. By using prices for the time-period when the closure is in effect and the miles per trip from each homeport to centroid, we can calculate the variable profits for each zone. With this information, we can then calculate the welfare implications of closing the SCA.

Table 4: Comparison of model predictions

	1995-1998							1999						
Zone	% of Actual Trips	Logit estimate % trips	EPM estimate % trips	Y-AVG estimate % trips	Logit 9598 MSE	EPM 9598 MSE	YAVG 9598 MSE	% of Actual Trips	Logit estimate % trips	EPM estimate % trips	YAVG estimate % trips	Logit 1999 MSE	EPM 1999 MSE	YAVG 1999 MSE
1	0.53	0.52	0.15	7.96	0.000	0.2	55	0.0	0.4	0.3	5.5	0.16	0.08	30.45
2	8.19	7.56	6.72	4.95	0.394	2.2	10	3.3	5.8	6.0	3.4	6.21	6.90	0.01
3	0.67	0.60	0.26	3.26	0.005	0.2	7	1.1	0.5	0.4	2.3	0.43	0.51	1.30
4	0.67	0.60	0.22	0.83	0.005	0.2	0	0.9	12.4	12.9	4.7	130.8	143.2	14.52
5	24.17	25.34	23.69	11.49	1.379	0.2	161		0.0	0.0	0.0			
6	0.27	0.27	0.05	17.13	0.000	0.0	284	0.2	0.2	0.1	11.9	0.00	0.00	136.57
7	46.19	46.32	58.09	8.52	0.016	141.4	1419	26.2	35.8	37.6	5.9	91.3	129.9	412.30
8	8.32	7.77	6.24	6.66	0.302	4.3	3	17.5	6.0	5.8	4.6	131.6	136.4	165.27
9	1.56	1.44	0.78	1.97	0.014	0.6	0	7.6	1.1	1.0	1.4	42.4	43.8	39.15
10	0.40	0.36	0.11	0.64	0.001	0.1	0	7.2	7.5	7.4	3.7	0.06	0.02	12.95
11	3.29	3.51	1.56	7.31	0.046	3.0	16	0.0	2.7	2.1	5.1	7.33	4.51	25.66
12	0.85	0.92	0.18	7.55	0.006	0.4	45	0.0	0.7	0.4	5.2	0.51	0.14	27.35
13	2.40	2.45	1.27	8.74	0.002	1.3	40	0.2	1.9	1.7	6.1	2.92	2.27	34.47
14	0.58	0.56	0.15	4.39	0.000	0.2	14	2.4	0.4	0.3	3.0	3.94	4.59	0.39
15	0.40	0.35	0.09	3.80	0.003	0.1	12	15.2	7.2	7.0	21.8	64.5	68.4	42.58
16	0.53	0.49	0.17	0.75	0.002	0.1	0	6.9	10.1	10.5	4.3	10.2	12.8	6.56
17	0.62	0.60	0.21	2.38	0.000	0.2	3	1.7	0.5	0.4	1.6	1.46	1.71	0.00
18	0.36	0.33	0.08	1.67	0.001	0.1	2	9.5	6.9	6.3	9.5	6.85	10.20	0.00
Total	100	100	100	100	2.2	154.8	2072	100	100	100	100	501	565	950

Zone	2000c (pre-closure)						
	% of Actual Trips	Logit estimate % trips	EPM estimate % trips	Y-AVG estimate % trips	Logit 2000c MSE	EPM 2000c MSE	YAVG 2000c MSE
1		0.10	0.03	1.33	0.01	0.00	1.77
2	19.5	1.41	1.20	0.83	329	337	350.51
3	3.0	0.11	0.05	0.54	8.39	8.77	6.07
4	14.3	24.31	28.17	9.32	101	193	24.67
5		0.00	0.00	0.00	0.00	0.00	0.00
6		0.05	0.01	2.86	0.00	0.00	8.19
7	12.0	8.62	10.37	1.42	11.6	2.8	112.51
8	13.5	1.45	1.11	1.11	146	154	154.28
9	2.3	0.27	0.14	0.33	3.95	4.48	3.71
10	10.5	14.74	13.98	7.18	18	12	11.22
11		0.65	0.28	1.22	0.43	0.08	1.49
12		0.17	0.03	1.26	0.03	0.00	1.59
13		0.46	0.23	1.46	0.21	0.05	2.13
14		0.10	0.03	0.73	0.01	0.00	0.54
15	5.3	14.17	12.02	42.79	79	46	1408
16	18.8	19.79	21.48	8.48	0.99	7.20	106.35
17		0.11	0.04	0.40	0.01	0.00	0.16
18	0.8	13.49	10.85	18.73	162	102	323.14
Total					860.7	866.6	2516.7

Zone	2000d (post-closure)						
	% of Actual Trips	Logit estimate % trips	EPM estimate % trips	Y-AVG estimate % trips	Logit 2000d MSE	EPM 2000d MSE	YAVG 2000d MSE
1		0	0	0			
2		0	0	0			
3		0	0	0			
4	23.5	28.11	32.6	10.8	21	82	163
5		0	0	0			
6		0	0	0			
7		0	0	0			
8		0	0	0			
9		0	0	0			
10	51.0	17.04	16.2	8.3	1152	1212	1822
11		0	0	0			
12		0	0	0			
13		0	0	0			
14		0	0	0			
15	0.5	16.39	13.9	49.5	253	180	2399
16	19.9	22.88	24.8	9.8	9	25	
17		0.0	0	0			
18	5.1	15.59	12.5	21.7	109	55	272
Total	100	100	100	100	1544	1553	4656

Zone	2001-2002						
	% of Actual Trips	Logit estimate % trips	EPM estimate % trips	Y-AVG estimate % trips	Logit 0102 MSE	EPM 0102 MSE	Y-AVG 0102 MSE
1		0.52	0.15	7.96	0.27	0	55
2	3.59	7.56	6.72	4.95	15.80	9.82	7
3	0.37	0.60	0.26	3.26	0.05	0.01	7
4		0.60	0.22	0.83	0.36	0.05	0
5	29.81	25.34	23.69	11.49	19.97	37.49	192
6	0.56	0.27	0.05	17.13	0.08	0.26	284
7	47.99	46.32	58.09	8.52	2.79	102.0	1429
8	5.50	7.77	6.24	6.66	5.15	0.54	1
9	0.19	1.44	0.78	1.97	1.57	0.35	0
10	0.31	0.36	0.11	0.64	0.00	0.04	0
11	1.18	3.51	1.56	7.31	5.44	0.15	14
12	0.25	0.92	0.18	7.55	0.46	0.00	44
13	5.81	2.45	1.27	8.74	11.29	20.65	40
14	1.42	0.56	0.15	4.39	0.74	1.63	15
15	0.06	0.35	0.09	3.80	0.08	0.00	12
16	0.80	0.49	0.17	0.75	0.10	0.41	0
17	2.16	0.60	0.21	2.38	2.44	3.81	3
18		0.33	0.08	1.67	0.11	0.01	2
Total	100	100	100	100	67	177	2105

DISCUSSION AND DIRECTIONS FOR FUTURE RESEARCH

Key findings from this work include:

- The zonal logit and EPM provide similar levels of prediction, though the zonal logit provides at least a slightly lower MSE for most of the periods estimated.
- The average catch (Y-Average) model does much worse than the other two models for all time periods. We are investigating the nature of the negative coefficient on the Y-average term. This may be due to model misspecification, or it may represent something more fundamental.
- Predictions are best when we are looking at well-fished zones. The models do the worst when trying to predict what happens when the SCA is completely closed. In particular, the models completely miss the mark on zone 15 in the 2000D season, when the areas representing over 97 percent of previous catch were closed.
- The zonal model gives a relatively good fit, despite the absence of a large number of variables that we would expect affect location choice.
- The EPM allows us to directly calculate the welfare losses of closures. The zonal logit will allow us to evaluate the relative costs of closing different areas.

The results included here are preliminary, but lay the groundwork for a new method that will allow us to explicitly calculate the welfare implications of area closures such as the SCA. There are a number of caveats that should be added to this work.

- The impact of bycatch closures is not included here. Certain zones were voluntarily avoided by fishers during different years due to bycatch "hotspots" that could close down the fishery. We are cataloging and including all of these closures.
- After 1999 (for catcher boats), the American Fisheries Act (AFA) has gone into affect, which ended the race for fish in this fishery. This may affect location choice for 2000-2002, and is not accounted for here. Note that because of this, our models are estimated using the data from 1995-1998 only.
- We have attempted to include boat characteristics in the model, but this has not increased the performance of the model.
- Although we include in the model the 18 zones that make up 99.8 percent of the trips from 1995-98, the 11 omitted zones are the location for more than 25 percent of the trips in 2000. We will include these deleted zones in future work.
- We focus here upon the summer season, largely because the winter season is the roe season, and we do not observe the quantity of roe caught per trip (we observe the quantity of pollock, but not the quantity or value of the roe in the pollock). Whereas in the summer there is not a difference in price between areas, in the winter some area provide roe for which fishers receive roe bonuses that we do not observer. We are attempting to create a function of expected roe content, which will potentially address this issue. Another approach might be to model roe content as an additional latent variable which would result in the discrete choice component having a mixed-logit like structure. Seasonal TAC limitations in the winter continue and have a large impact on all three sectors of the fishery.
- For simple seasonal closures our model has good predictive performance. Modeling intra-season closures is far more challenging.
- In examining the results above, we can see the difficulty of assessing how trips are redistributed to infrequently visited zones. In the '2000D' period in Table 4, after the SCA zones are closed, we are predicting from a very small number of trips made to the non-SCA zones how trips will be distributed. There are a number of different ways to address this issue. We have worked extensively to develop a functional model of the EPM, in which alpha is estimated as a function of latitude and longitude. This would allow us to predict what would happen with any closure, but to date we have not been able to establish a strong functional relationship in this fishery. This may be due to the omission of other closures from the model, or other environmental variables that could also be included in such a functional model.

This preliminary work shows the potential for the EPM and a zonal logit to provide meaningful information about area closures. We are currently attempting to resolve the challenges outlined above and will address these issues as we finalize this work.

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ENDNOTES

[i] Because of the AFA, we are taking the decision to fish for pollock in the Bering Sea as given. We recognize with the presence of sideboards for other species there are a small percentage of trips that are not for pollock, but for the time-being we are assuming that these are not significant.

[ii] A more thorough description of this model is available in the proceedings of the Agricultural Economics meetings in Montreal in 2003 (Layton, Haynie, Huppert 2003).

[iii] It may be the case that they have other objectives in the short term (e.g. catch maximization to establish catch history or information for future trips), so this assumption will be loosened and tested in future work.