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Spatial and Temporal Analysis of Eastern Bering Sea Echo Integration-trawl Survey and Catch Data of Walleye Pollock, *Theragra chalcogramma,* for 2001 and 2002

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Abstract

The National Marine Fisheries Service (NMFS) is charged with determining whether fisheries for walleye pollock, *Theragra chalcogramma*, affect ecosystem function, specifically, any adverse impacts on endangered species. Although the spatial and temporal scale of fisheries impacts are an important concern, analyzing fisheries interactions at fine spatial scales is hindered by the resolution of available data. Our study had two goals: to analyze echo integration-trawl (EIT) survey data in association with observer catch records to evaluate the intensity of the walleye pollock fisheries, and to define the spatiotemporal resolution reasonable given the dynamic nature of the resource and the limitations of the data. In this analysis we used the concept of Observed Catch to Survey Biomass Ratio (OCSBR) as a tool to measure fishery intensity at local levels. The OCSBR is the ratio of observed catch to EIT survey estimated biomass in a given area for a specified period of time. The OCSBR should not necessarily be considered a proxy for the local exploitation rate. This analysis addresses how varying temporal and spatial resolution changes the OCSBR value. A correlation analysis is used to determine the temporal and spatial scale at which OCSBR is a reasonable measure of fishing intensity.

Contents

Introduction

Walleye pollock, *Theragra chalcogramma* support the largest single species fishery in the North Pacific Ocean. The National Marine Fisheries Service (NMFS) is charged with determining whether fisheries for walleye pollock affect ecosystem function, specifically, any adverse impacts on endangered species (e.g., Steller sea lions). The spatial and temporal scale of fisheries impacts are an important concern of NMFS investigations. However, analyzing fisheries interactions at fine spatial scales is hindered by the resolution of available data. Here we analyze 2001 and 2002 echo integration-trawl (EIT) survey data using contemporaneous observer data to investigate the intensity of the walleye pollock fisheries at local scales. An attempt was made to define an appropriate spatiotemporal scale to address this issue given the dynamic nature of the Bering Sea pollock stock and the limitations of our current data.

In this analysis, the concept of Observed Catch to Survey Biomass Ratio (OCSBR) is introduced as a possible tool to measure fisheries intensity at local scales. The OCSBR is the ratio of observed catch to EIT survey estimated biomass for a given area for a set period of time. The OCSBR should not be considered a proxy for local exploitation ratio; observed catch does not include all catch, and the EIT survey biomass estimates are not a full accounting of local biomass. This analysis addresses how varying temporal and spatial resolution changes the OCSBR value and through correlation analysis, we attempt to determine at what temporal and spatial scale the OCSBR is a reasonable measure of fishing intensity.

Materials and Methods

Data Sources

The study area is located in the section of the designated Steller sea lion critical habitat north of Unalaska and Unimak Islands on the eastern Bering Sea Shelf (Fig. 1). Estimates of walleye pollock biomass were obtained from EIT surveys of the southeastern Bering Sea shelf in winter 2001 and 2002. The surveys were conducted by the Resource Assessment Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center. The EIT surveys provided estimates of walleye pollock biomass from 14 m below the surface to 0.5 m above the bottom with transect spacing of 14.8 km (8 nmi) (Honkalehto et al. 2001, Honkalehto et al. 2002). Biomass estimates were based on mean density along the transect at 0.9 km (0.5 nautical miles (nmi)) and the transect spacing, thus biomass is estimated for 0.9 × 14.8 km (0.5 × 8 nmi) areas (Honkalehto et. al. 2002). The 2001 EIT survey was conducted between 20 February and 3 March. The 2002 EIT survey was conducted between 23 February and 3 March.

Estimates of targeted walleye pollock catch for the 2001 fishing season were obtained from two sources. Estimates of catch for all catcher-processor vessels and observed catcher-only vessels were obtained from the North Pacific Groundfish Observer Program database. In this case, we defined targeted pollock as any pollock caught while the vessel fished using pelagic trawl gear, as targeting of walleye pollock with non-pelagic gear was illegal. In 2001 and 2002, walleye pollock was the only pelagic target in the study area. We did not include bycatch of walleye pollock from other targeted fisheries in our analyses because our study was limited to effects of the directed walleye pollock fishery. In 2001 and 2002, observed pollock bycatch in the study areas for

January through April was 3,935 metric tons (t) and 6,594 t (2.7% and 2.2% of the targeted removals), respectively. Catcher-processor vessels fishing walleye pollock in the Bering Sea are required to carry two observers and observer duties include sampling all hauls for species composition. Catcher-only vessels 125 ft length over all (LOA) and larger are required to carry an observer at all times. Vessels under 125 ft to 60 ft LOA are required to carry observers for 30% of their fishing days. Vessels under 60 ft LOA are not required to carry observers and therefore observer data are not available for these vessels. We calculated observed walleye pollock catch estimates using the weight of pollock from the species composition sample extrapolated up to the official total catch for each observed haul. We assigned the location at which the net was pulled from fishing depth (end latitude and longitude) as the catch location. Catch estimates obtained solely from observed catch information are referred to as observed catch estimates throughout this document.

To account for unobserved catch, we obtained data on total pollock deliveries to shore-based processing plants and floating processors from the Alaska Department of Fish and Game's (ADF&G) landings database. Here we defined targeted walleye pollock as all walleye pollock delivered from vessels reporting the use of pelagic trawl gear. Vessels fishing groundfish in the Bering Sea are required to retain and deliver all walleye pollock caught. Processing plants are required to report landings by ADF&G reporting area (30' latitude $\times$ 60' longitude cells) and by fishing start date and delivery date. We summarized walleye pollock delivery data by the week fishing began and ADF&G reporting area. We also summarized the observed catcher-only vessel data by ADF&G reporting area and the week fishing began. A ratio of landings to observed catch (LOCR) was calculated for each week and ADF&G area (Table 1). We then multiplied the catch weight from each observed catcher-only vessel haul by the appropriate landings to observed catch ratio to obtain a projected overall catch estimate. We used the "raw" observed catch weight in our analysis when we found ADF&G reporting areas and weeks without reported landings. Catch data obtained using this method are referred to as projected catch estimates throughout this document.

The estimates of targeted walleye pollock catch for the 2002 fishing season were obtained exclusively from North Pacific Groundfish Observer Program database. ADF&G landings data for 2002 were not available for this analysis.

Spatial Analysis

We employed ARCGIS software to analyze the EIT survey and targeted walleye pollock catch data. All data points from the two EIT surveys and targeted walleye pollock catch data from 2001 and 2002 were imported into ARCGIS. We created prediction maps from the EIT survey biomass estimates using the kriging tools in ARCGIS. The prediction maps were used as visual aids in identifying pollock concentrations but were not used in the quantitative analysis of the EIT survey biomass data. Specifications of the two ordinary kriged prediction maps can be found in Table 2.

For each EIT survey, we employed the ARCGIS Thiessen function to create two grids with approximately 219 km^2 (8 × 8 nmi), and 1,971 km^2 (24 × 24 nmi) cells. The grid cells in both size resolutions were somewhat irregular due to edge effects and although the actual areas of the cells vary in size, we refer to the grids as 219 km^2 and 1,971 km^2 resolution grids throughout this document. We joined the EIT survey biomass estimates and observed pollock catch data for the time period during the surveys, for the week before the EIT surveys, and the week following the EIT surveys to the grid cells using the "join" feature of ARCGIS. The time period during the survey differed between 2001 and 2002. In 2001 the survey lasted 12 days while in 2002 the survey lasted 9 days. We chose to analyze the time frame during the survey as a unit because the spatial area surveyed was nearly the same between the 2 years. An OCSBR was calculated for each grid cell where fishing was present. The OCSBR is the ratio of observed walleye pollock catch divided by the EIT survey biomass estimate. To aid in the analysis each grid cell was color coded by OCSBR value into one of seven categories; 0 or no fishing (dark green), 0.01 to 0.05 (light green), 0.06 to 0.10 (bright green), 0.11 to 0.20 (yellow-green), 0.21 to 1.00 (yellow), and greater than 1.0 (red). For 2001 the cells were labeled with observed catch in blue, estimated catch (observed catch multiplied by the LOCR) in cyan, and survey estimated biomass in black. For 2002 the cells were labeled with the observed catch in blue and EIT survey estimated biomass in black.

We do not provide OCSBR maps for the periods one week prior to and one week following the EIT surveys at the 219 km^2 resolution. We believe that the high migration rate of pollock at this time of year made OCSBR analysis at the 219 km^2 resolution level inappropriate. This issue is considered in more detail in the Discussion section.

Statistical Analysis

Theoretically, the largest catches would come from areas where the biomass is highest. If fishing is perfectly proportional to the biomass present in an area, local harvest rates would be the same as global harvest rates and no "localized" depletion would be occurring. Of course fishermen do not have perfect knowledge of targeted species location, the survey is not a perfect estimate of the biomass, many high concentrations of pollock are closed to fishing, and significant emigration from the surveyed areas may be occurring. Therefore, we would expect the correlation to be less than 1.0. However, given a small enough temporal resolution and large enough spatial distribution to account for migration and the imperfect knowledge of the fishermen, we would expect a statistically significant positive correlation.

Following the logic above, we may be able to investigate possible signs of "localized" depletion. If there was significant depletion of the biomass due to catch prior to the EIT survey, the correlation of prior catch to biomass would be negative given a small enough temporal resolution and large enough spatial distribution to account for migration and the imperfect knowledge of the fishermen. If catch did not significantly deplete the available biomass then the correlation should be positive. Insignificant findings may indicate either that the catch did not significantly deplete the available biomass or that our analysis resolution is inadequate.

For the weeks prior to, during, and after the EIT surveys the correlation coefficients were calculated using the Spearman rank correlation coefficient:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n^3 - n},$$

where d_i is the difference between ranks of EIT biomass estimates by cell and observed catch estimates and n is the number of cells for which we are calculating r_s (Zar 1999).

For tied ranks, the assigned rank to each of the tied values is the mean of the ranks that would have been assigned to these values had they not been tied. Tied analyses are corrected using:

$$(r_s)_c = \frac{(n^3 - n)/6 - \sum d_i^2 - \sum t_x - \sum t_y}{\sqrt{\left[(n^3 - n)/6 - 2\sum t_x\right]\left[(n^3 - n)/6 - 2\sum t_y\right]}} .$$

Here $\sum t_x = \frac{\sum (t_i^3 - t_i)}{12}$,

where t_i is the number of tied values of EIT survey biomass in a group of ties, and

$$\sum t_y = \frac{\sum (t_i^3 - t_i)}{12},$$

where t_i is the number of tied values of observed catch estimates in a group of ties (Zar 1999).

The Spearman rank correlation coefficients were calculated for all the cells in the study area, all the cells fished, and then for all the cells fished with a sizable catch (greater than 250 t for the 219 km^2 cells, and greater than 1,000 t for the 1,971 km^2 cells). This resulted in 18 separate analyses.

The Spearman rank correlation coefficients were tested against critical values for the Spearman rank coefficient ($\alpha = 0.05$) (Zar 1999).

For each test with n greater than 10, the Fisher *z*-transformation was used to further provide a two-tailed *P*-value. The formula for the Fisher *z*- transformation was

$$Z = \frac{0.5 \ln \frac{(1 + r_s)}{(1 - r_s)}}{\sqrt{\frac{1.060}{n - 3}}} .$$

The two-tailed *P*-values were calculated to 3 significant digits using

$$P = 1 - \sqrt{1 - e^{-c^2}} ,$$

where $c = 0.806Z(1 - 0.018Z)$ (Zar 1999).

Results

Visual inspection of the 2001 and 2002 EIT survey results and kriged prediction maps reveal a patchy distribution of walleye pollock with inter-annually consistent concentrations of biomass in the east surrounding Amak Island and following the 200 m isobath near the western edge of the study area (Figs. 2 and 3). Both surveys revealed higher concentrations of walleye pollock in the eastern half of the study area. In 2001 the pollock biomass estimated to be within pollock fishing exclusion zones (20 nmi pollock trawl and 10 nmi trawl exclusion zones) in the study area (Fig. 1) was 321,355 t or 38% of the EIT survey estimated biomass for the study area. In 2002 the pollock biomass estimated to be within pollock fishing exclusion zones (the Bering Sea pollock restriction area and 10 nmi trawl exclusion zones) in the study area (Fig.1) was 393,200 t or 29% of the EIT survey estimated biomass for the study area. Analysis of the concentration of pollock biomass and catch by 219 km^2 cells revealed that although walleye pollock biomass was relatively less concentrated in 2001 than in 2002, the proportion of catch in 2001 was concentrated in relatively fewer cells (Fig. 4).

2001

In 2001 the EIT survey biomass estimate for the study area was 852,254 t for 44,600 km^2 (19.1 t/km^2). Targeted pollock catch in the study area prior to the survey (20 January - 19 February) is estimated to be 93,608 t observed. Applying the landings to observed catch ratios results in an estimate of 124,170 t of pollock catch prior to the 2001 survey. During and after the EIT survey an additional 52,078 t observed (63,569 t projected) were removed in the Pollock A-season and following the Community Development Quota (CDQ) fishery through 28 April 2001 (Table 3).

The correlation analysis for 2001 resulted in only three statistically significant findings at $\alpha = 0.05$. The 1,971 km^2 and 219 km^2 grids during the survey and the 219 km^2 grid for the week prior to the survey resulted in significant positive correlations at the analysis level of all cells in the study area (ALL) (Table 4). There were no other statistically significant correlations, positive or negative, for any other time period, grid resolution, or analysis level.

The OCSBR analysis of the 2001 observed catch and EIT survey data were limited to the week prior to the survey, 12 days during the survey, and the week after the survey (Fig. 5). During the 12 days of the survey (20 February - 3 March) a total of 18,249 t observed of walleye pollock were removed from the study area. During the survey at the 1,971 km^2 resolution, 17 of 32 cells were fished. Two of the cells had an OCSBR greater than 0.20, three cells had OCSBR values of between 0.05 and 0.10, and the majority of cells (n=12) had OCSBR values of less than 0.05 (Table 6 and Fig. 7). During the survey at the 219 km^2 grid resolution, 49 of 215 cells were fished. There were 3 cells with OCSBR values greater than 1.00, 7 cells had OCSBR values between 0.20

and 1.00, 16 cells with OCSBR values between 0.05 and 0.15, and 23 cells had OCSBR values of less than 0.05 (Fig. 9).

In 2001 there were 11,138 t observed of walleye pollock removed from the study area the week prior to the beginning of the EIT survey (13 February - 19 February). At the 1,971 km^2 resolution, 13 of 32 cells were fished. One cell had an OCSBR greater than 0.20, 2 cells had OCSBR values between 0.05 and 0.15, and the majority of the fished cells (n=10) had OCSBR values of less than 0.05 (Fig. 11).

There were 6,970 t observed of walleye pollock removed from the study area the week following the end of the EIT survey (4 March - 10 March). At the 1,971 km^2 resolution, 10 of 32 cells were fished. There were no cells with OCSBR values greater than 0.15, two cells with OCSBR values between 0.05 and 0.15, and eight cells with OCSBR values of less than 0.05 (Fig. 13).

2002

In 2002 the EIT survey biomass estimate for the study area was 1,354,659 t for 41,610 km^2 (32.6 t/km^2). Targeted pollock catch in the study area prior to the survey (20 January - 22 February) is estimated to be 197,203 t observed. During and after the EIT survey an additional 99,360 t observed were removed in the Pollock A-season and following CDQ fishery through 28 April 2001 (Table 3).

The correlation analysis for 2002 resulted in eight statistically significant findings at $\alpha = 0.05$. At the analysis level of all cells in the study area, all of the correlation coefficients for both grid resolutions for before, during, and after resulted in significantly positive correlations. In addition, for the 1,971 km^2 grid resolution during the survey both the fished cells and cells with greater than 1,000 t of observed catch analysis resolutions resulted in significant positive correlations. The other 10 time periods, grid resolution, and analysis level combinations were not found to have statistically significant correlations (Table 5).

The OCSBR analysis of the 2002 observed catch and EIT survey data were limited to the week prior to the survey, 9 days during the survey, and the week after the survey (Fig. 6). During the 9 days of the survey (23 February - 3 March) a total of 67,391 t observed of walleye pollock were removed from the study area. During the survey at the 1,971 km^2 resolution, 21 of 38 cells were fished. There were 2 cells with OCSBR values greater than 1.00, 2 cells with OCSBR values between 0.20 and 1.00 , 10 cells with OCSBR values of between 0.05 and 0.20, and 7 cells with OCSBR values of less than 0.05 (Table 7 and Fig. 8). During the survey at the 219 km^2 grid resolution 70 of 205 cells were fished. There were 7 cells with OCSBR values greater than 1.00, 22 cells with OCSBR values between 0.20 and 1.00, 20 cells with OCSBR values between 0.05 and 0.15, and 21 cells with OCSBR values of less than 0.05 (Fig. 10).

In 2002 there were 37,206 t observed of walleye pollock removed from the study area the week prior to the beginning of the EIT survey (16 February - 22 February). At the 1,971 km^2 resolution there were 17 of 38 cells were fished. Two cells had OCSBR values greater than 1.00, two cells had OCSBR values greater than 0.20, 1 cell had an OCSBR between 0.05 and 0.10, and the majority of the fished cells (n=12) had OCSBR values of less than 0.05 (Fig. 12).

There were 17,524 t observed of walleye pollock removed from the study area the week following the end of the EIT survey (4 March - 10 March). At the 1,971 km^2

resolution, there were 12 of 38 cells fished. There were no cells with an OCSBR value greater than 1.00, one cell with an OCSBR between 0.20 and 1.00, three cells with OCSBR values between 0.05 and 0.15, and eight cells with OCSBR values of less than 0.05 (Fig. 14).

Discussion

Analyzing fisheries interactions at fine-scale resolutions is hindered by the temporal and spatial resolution of available data. The EIT survey estimates of biomass are at a relatively fine spatial resolution (0.9 × 14.8 km) but are limited in that they only provide a snapshot of the stock's distribution. For pelagic stocks such as walleye pollock, concentrations identified at small spatiotemporal resolutions will not be representative for an entire season and due to migration may not be representative at smaller time scales. Radchenko and Sobolevskiy (1993) report that walleye pollock aggregations in areas of the western Bering Sea may cover 15 to 17.6 km (8.1 to 9.5 nmi) per day while feeding and 27.8 km (15 nmi) per day while returning to spawning sites. Assuming similar rates of travel in the Eastern Bering Sea, the EIT survey biomass estimates for a 0.9 × 14.8 km resolution could be inaccurate in less than a day for a given sampling location.

In addition, the EIT surveys do not include fish located below 0.5 m from the bottom and 14 m from the surface and therefore is a minimum estimate of true biomass. Surveying along transects yields an inexact estimate of true biomass. For these reasons our OCSBR should be considered an index of fishing intensity and should not be interpreted as an actual measure of the local exploitation rate.

Determining the spatial resolution of the observed catch data is hampered by long towing periods and the lack of information concerning the trawl path between starting and ending positions. Observers do not provide estimates of catch as it enters the net nor do they provide minute-by-minute position reports as a vessel fishes. An arbitrary choice must be made assigning the catch to either the start position or end position. In the Eastern Bering Sea walleye pollock fishery tow lengths often exceed 20 km. Thus, if data are assigned to either starting or ending positions the spatial analysis of catch data versus biomass estimates at a smaller resolution than 20 km may provide erroneously high OCSBR values.

Correlation Analysis

The correlation between catch and survey biomass was higher in 2002 than in 2001. This finding may be explained in part by the differences in distribution and concentration of walleye pollock between the 2 years. In 2001 the EIT survey estimated that there were 503,400 fewer tons of walleye pollock in the study area than in 2002 and that the fish were less concentrated. The lower correlation between catch and biomass in 2001 may be explained by the fishermen being unable to routinely locate concentrations of fish due to the wider dispersion of pollock in 2001 and thus may have chosen to fish on lower concentrations of pollock.

For 2001 and 2002 we found positive correlations between the EIT survey biomass estimates and observed catch during the survey for both the 219 km^2 and 1,971 km^2 grid resolutions at the analysis level of all cells in the study area. Based on this result we may conclude that fishermen caught walleye pollock in cells where the EIT survey indicated there were higher concentrations of walleye pollock. Although this conclusion would seem to be intuitive, the catch and biomass estimates could have been greatly disparate given a possible pollock migration speed of up to 27.8 km per day (Radchenko and Sobolevskiy, 1993) and the patchy concentrations of pollock observed in the EIT survey.

For 2001, we found positive correlations between the EIT survey biomass and observed catch at the 219 km^2 grid resolution at the analysis level of all cells in the study area for the week prior to the survey. For 2002, we found positive correlations between the EIT survey biomass and observed catch at both the 219 km^2 and 1,971 km^2 grid resolutions at the analysis level of all cells in the study area for the week prior to the survey. There were no statistically significant correlations, positive or negative, prior to or after the survey at the analysis level of fished cells in the study area at the 1,971 km^2 or the 219 km^2 grid resolutions. No firm conclusions can be drawn from these findings. Although there is no strong indication that catch measurably depleted pollock biomass in the study area the week prior to the EIT survey, the lack of significance for many of the correlations may suggest that our grid resolutions are too fine for analyzing data greater than one week duration from the beginning or end of the survey.

In both 2001 and 2002 the correlation coefficients were higher at the 1,971 km^2 resolution than at the 219 km^2 resolution and the pre- and post-survey correlation coefficients were lower than the correlations coefficients during the EIT survey. At larger grid resolutions and less duration between survey estimates and catch estimates, we obtained higher correlation coefficients; at smaller grid resolutions and longer duration between catch and survey estimates, we obtained lower correlation coefficients.

These results support the conclusion that the quality of our analysis is affected by grid and temporal resolution. We equate this to mean there is less uncertainty in our estimates of OCSBR at higher spatial scales and shorter durations between catch and survey biomass estimates.

OCSBR Analysis

The OCSBR analysis revealed that in 2001 and 2002, fishing was not evenly distributed throughout the study area and that fishing pressure may differ considerably from one location to the next. As one would expect, the spatial distribution of fishing catch tended to follow the spatial distribution of estimated biomass. In 2001 and 2002, we found patchy biomass distributions and patchy catch distributions in the study area.

The 2002 data show a higher biomass and also a much more intense pollock fishery in the study area. In 2002, fishermen harvested 67,400 t observed of walleye pollock from the study area during the 9 days of the EIT survey, compared to 18,400 t observed during the 13 days of the 2001 EIT survey. The increase in the volume of pollock harvested in 2002 was reflected in an overall increase in the OCSBR values even though the fishery was less concentrated (Fig. 4). The overall OCSBR value for the study area during the 2001 survey was 0.022 and during the 2002 survey was 0.050. The median OCSBR value in 2001 during the survey period was 0.012 at the 1,971 km^2 resolution and 0.059 at the 219 km^2 resolution, while during the 2002 survey period the median values were 0.077 and 0.122, respectively (Fig. 5 and Fig. 6).

In both 2001 and 2002, high OCSBR values (greater than 0.20) tended to be associated with cells with low biomass estimates, adjacent to cells with high biomass estimates. In 2002 at the 1,971 km^2 resolution every cell with an OCSBR value greater than 0.20 were cells having below the mean estimated biomass (35,600 t) and were directly adjacent to cells having 2 to 5 times the mean estimated survey biomass (Fig. 8). This is also true for 2001 except for one cell located in the western portion of the study area (Fig. 7). These findings suggest that emigration from the high to low biomass cells may have skewed our OCSBR values, that using the ending position for observed catch may have overestimated OCSBR values for these cells, or that our spatial resolution even at 1,971 km^2 is too fine for the available data.

Conclusion

This analysis was undertaken in an attempt to better define what analysis resolution was reasonable given the dynamic nature of the walleye pollock distribution and the limitations of our current data. We found that smaller spatial scale analyses (i.e., smaller than 1,971 km^2) of EIT survey data and Observer data were too fine for our current data set and that even at the larger spatial scales, analyses should be restricted to very near the time the EIT survey data were collected. Our analysis does not help define what scale, temporal or spatial, is important to Steller sea lions (*Eumetopias jubatus*). At the finest spatial and temporal resolutions, that of the tracks of the trawl nets the exploitation rate of walleye pollock approaches 100% (minus possible escapement), while at the other end of the scale, the entire range of walleye pollock, the exploitation rate approaches the annual harvest rate of eastern Bering Sea walleye pollock. Defining what spatial and temporal scale is important to walleye pollock stocks, to dependent species such as Steller sea lions, and to the Bering Sea ecosystem as a whole is a difficult, but necessary step to fulfill NMFS' stewardship responsibilities.

Citations

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Table 1. Landings to Observed Catch Ratios (LOCR). Light shaded cells indicate more observed catch than reported landings. Dark shaded cells indicate observed catch, but no landings data (NL).

ADF&G Area	Start Week							
	2/03/01	2/10/01	2/17/01	2/24/01	3/03/01	3/10/01	3/17/01	3/24/01
635530		0.8713		0.2921	4.2972	6.8946		
645434	1.0471		1.0560	0.1404			0.8570	
645501	2.0032	2.2414	2.7479	2.4607	7.5073	16.6095	1.9529	1.1916
645530	2.2357	1.3674	3.9986	12.5248	2.8353	4.0801	1.0630	
655430	1.5317	1.9981	1.9654				3.4900	
655500	1.3334	1.5003	3.0589	27.3701				
655530	1.0421			4.5478	NL			
665401						1.2881	0.9437	2.2366
665430								NL
665530		0.2350						
665630						1.2017		
675430						82.6681		
685500								1.8875
685530							NL	NL

Table 2. Ordinary kriging specifications for Echo Integration-trawl (EIT) survey data.

			2001	2002
Selected Method:			Ordinary Kriging	Ordinary Kriging
Output:			Prediction Map	Prediction Map
Number of Datasets Currently in Use:			1	1
Number of Points:			2838	3676
Semivariogram/Covariance Model:			3e8*Spherical(300000)+ 1000000*Nugget	3e8*Spherical(400000) +1000000*Nugget
Error Modeling:	Microstructure:		1000000 (100%)	1000000 (100%)
	Measurement Error:		0 (0%)	0 (0%)
Searching Neighborhood:	Neighbors to Include:		10 or at least 1 for each angular sector	10 or at least 1 for each angular sector
	Searching Ellipse:	Angle:	0	0
		Major Semiaxis:	300000	400000
		Minor Semiaxis:	300000	400000
		Angular Sectors:	4	4

Table 3. Echo Integration-trawl (EIT) survey biomass estimates and catch estimates for the study area.

	2001		2002	
EIT Survey Dates	20 Feb. – 3 Mar.		23 Feb. – 3 Mar.	
EIT Survey Biomass (t)	851,254		1,354,659	
EIT Survey Area (km^2)	44,600		41,610	
	Observed	W/ LOCR	Observed	W/ LOCR
Pre-Survey Removals (t)	93,608	124,170	197,203	NA
During and Post-Survey Removals (t)	52,078	63,569	99,360	NA
Overall CSBR	0.1542	0.1925	0.1911	NA

Table 4. Spearman rank correlation coefficient analysis (Zar 1999) conducted for 2001. Shaded rows indicate r_s values significant to 0.05. All biomass estimates came from the 2001 EIT Survey 20 Feb. - 3 Mar. Resolution ALL means all cells in the study area, Fished means all cells where fishing was present in the study area, and >1,000 and >250 means cells where greater than 1,000 or greater than 250 t of pollock were caught.

2001	Resolution		r_s	n	$r_{0.05(2),n}$	*P*
1 Week Before	1,971 km^2	ALL	0.202	32	0.350	0.285
(13 Feb. – 19 Feb.)		Fished	-0.030	14	0.538	0.922
		>1,000	0.600	4	1.000	-
	219 km^2	ALL	0.173	215	0.138	0.014
		Fished	0.215	38	0.321	0.209
		> 250	-0.156	16	0.503	0.574
During	1,971 km^2	ALL	0.403	32	0.350	0.026
(20 Feb. – 3 Mar.)		Fished	0.120	17	0.485	0.660
		>1,000	0.543	6	0.886	-
	219 km^2	ALL	0.226	215	0.138	0.001
		Fished	0.180	49	0.282	0.230
		> 250	-0.056	17	0.485	0.835
1 Week After	1,971 km^2	ALL	0.242	32	0.350	0.197
(4 Mar. – 10 Mar.)		Fished	0.182	11	0.618	0.612
		>1,000	NA	-	-	-
	219 km^2	ALL	0.082	215	0.138	0.243
		Fished	0.103	28	0.375	0.613
		>250	-0.217	12	0.587	0.511

Table 5. Spearman rank correlation coefficient analysis (Zar 1999) conducted for 2002. Shaded rows indicate r_s values significant to 0.05. All biomass estimates came from the 2002 EIT Survey 23 Feb. - 3 Mar.. Resolution ALL means all cells in the study area, Fished means all cells where fishing was present in the study area, and >1,000 and >250 means all cells where greater than 1,000 or greater than 250 t of pollock were caught.

2002	Resolution		r_s	n	$r_{0.05(2),n}$	*P*
1 Week Before	1,971 km^2	ALL	0.333	38	0.321	0.047
(16 Feb. – 22 Feb.)		Fished	0.314	17	0.485	0.239
		>1,000	0.214	8	0.783	-
	219 km^2	ALL	0.346	205	0.138	0.000
		Fished	0.003	50	0.279	0.983
		> 250	-0.246	32	0.350	0.168
During	1,971 km^2	ALL	0.563	38	0.321	0.000
(23 Feb. – 3 Mar.)		Fished	0.679	21	0.435	0.001
		>1,000	0.832	12	0.587	0.000
	219 km^2	ALL	0.507	205	0.138	0.000
		Fished	0.114	70	0.235	0.363
		> 250	0.132	55	0.266	0.354
1 Week After	1,971 km^2	ALL	0.519	38	0.321	0.001
(4 Mar. – 10 Mar.)		Fished	-0.119	12	0.587	0.723
		>1,000	NA	-	-	-
	219 km^2	ALL	0.322	205	0.138	0.000
		Fished	0.315	31	0.356	0.094
		> 250	0.429	21	0.435	0.059

Table 6. Observed catch to survey biomass ratio (OCSBR) analysis conducted for 2001 with number of cells.

2001	Resolution	Total Cells	Cells Fished	OCSBR					
				>1.00	0.20-1.00	0.15-0.20	0.10-0.15	0.05-0.10	0.01-0.05
1 Week Before	1,971 km^2	32	13	0	1	0	1	1	10
Catch (11,138 t)	219 km^2	215	38	1	7	2	3	9	16
During	1,971 km^2	32	17	0	2	0	2	1	12
Catch (18,429 t)	219 km^2	215	49	3	7	0	7	9	23
1 Week After	1,971 km^2	32	10	0	0	0	1	1	8
Catch (6,970 t)	219 km^2	215	27	1	5	1	6	5	9

Table 7. Observed catch to survey biomass ratio (OCSBR) analysis conducted for 2002 with number of cells.

2002	Resolution	Total Cells	Cells Fished	OCSBR					
				>1.00	0.20-1.00	0.15-0.20	0.10-0.15	0.05-0.10	0.01-0.05
1 Week Before	1,971 km^2	38	17	2	2	0	0	1	12
Catch (37,206 t)	219 km^2	205	50	7	9	3	1	11	19
During	1,971 km^2	38	21	2	2	1	2	7	7
Catch (67,391 t)	219 km^2	205	70	7	22	5	5	10	21
1 Week After	1,971 km^2	38	12	0	1	0	1	2	8
Catch (17,524 t)	219 km^2	205	31	2	4	3	2	5	15

Figure 1. 2001 and 2002 study areas on the eastern Bering Sea shelf.

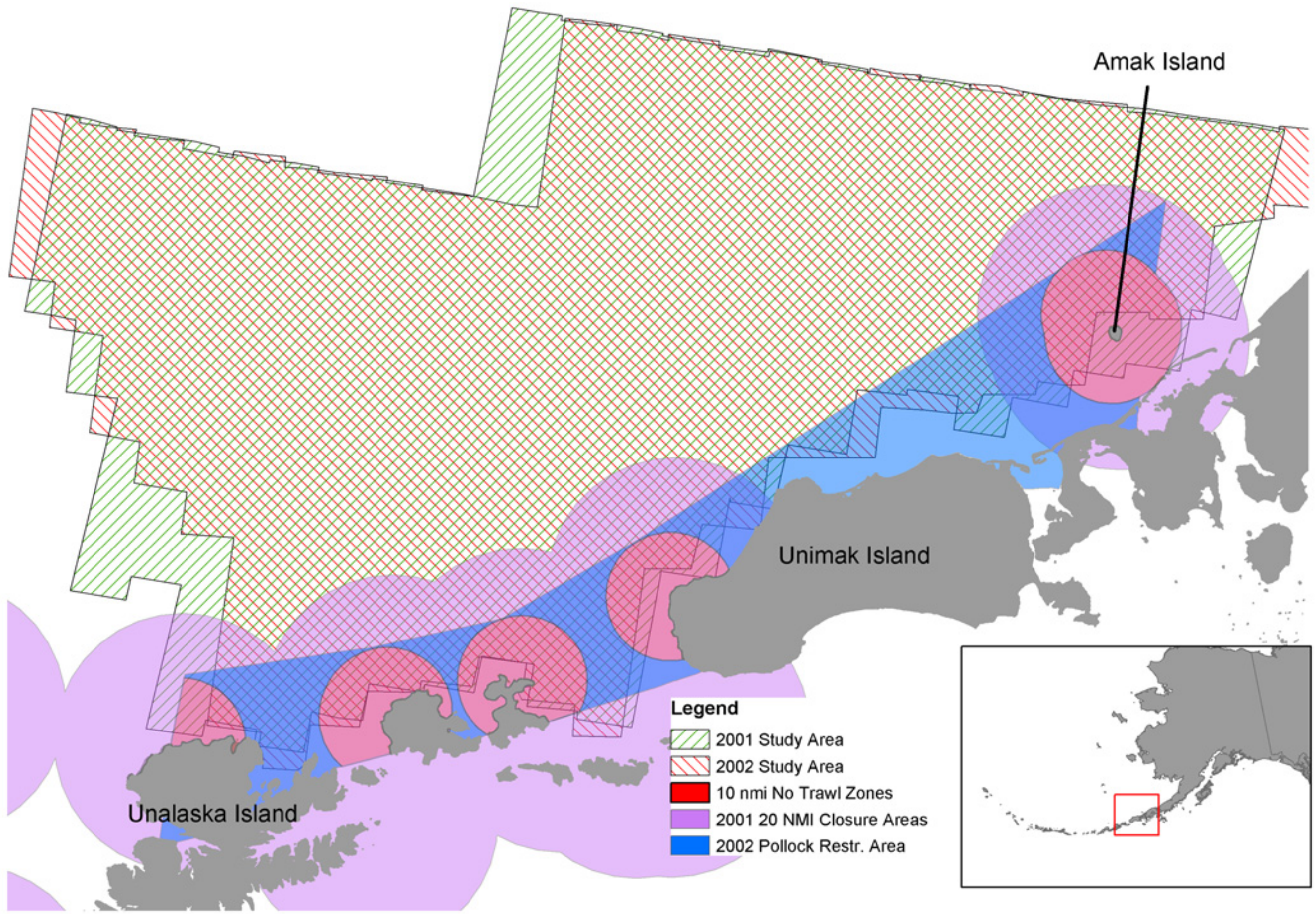


Figure 2. 2001 echo integration-trawl (EIT) survey biomass ordinary kriged prediction map with overlay bubbles of relative biomass. Green areas are relatively low estimates of biomass, and orange areas are areas of relatively high estimates of biomass. The solid blue line is the 200 m isobath.

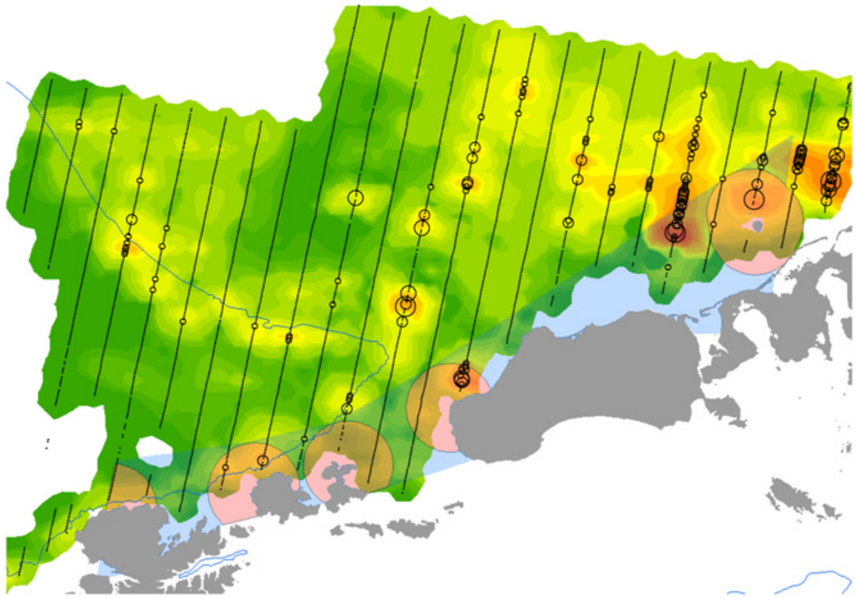


Figure 3. 2002 echo integration-trawl (EIT) survey biomass ordinary kriged prediction map with overlay bubbles of relative biomass. Green areas are relatively low estimates of biomass, and orange areas are areas of relatively high estimates of biomass. The solid blue line is the 200 m isobath.

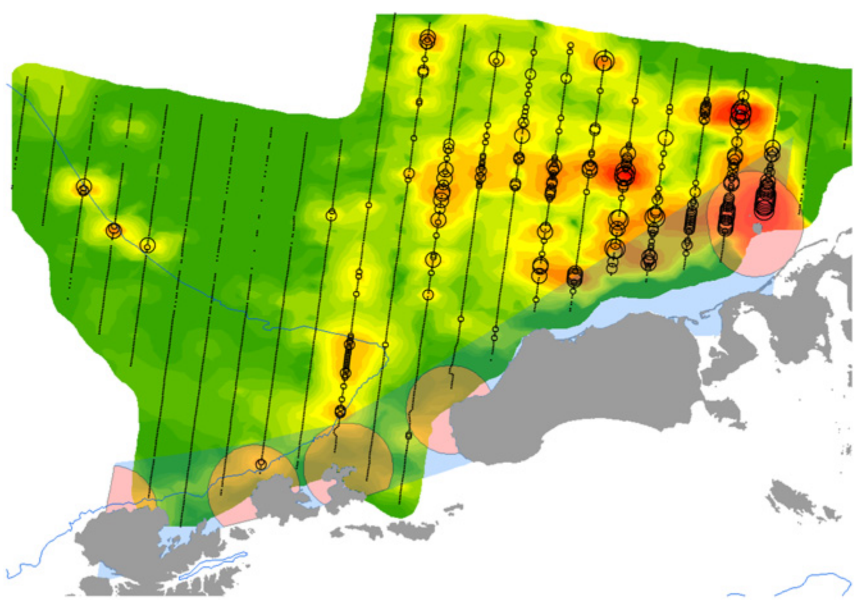


Figure 4. Fish biomass concentrations from observed catch during the survey periods and echo integration-trawl (EIT) surveys and for 2001 and 2002 by 219 km^2 cells.

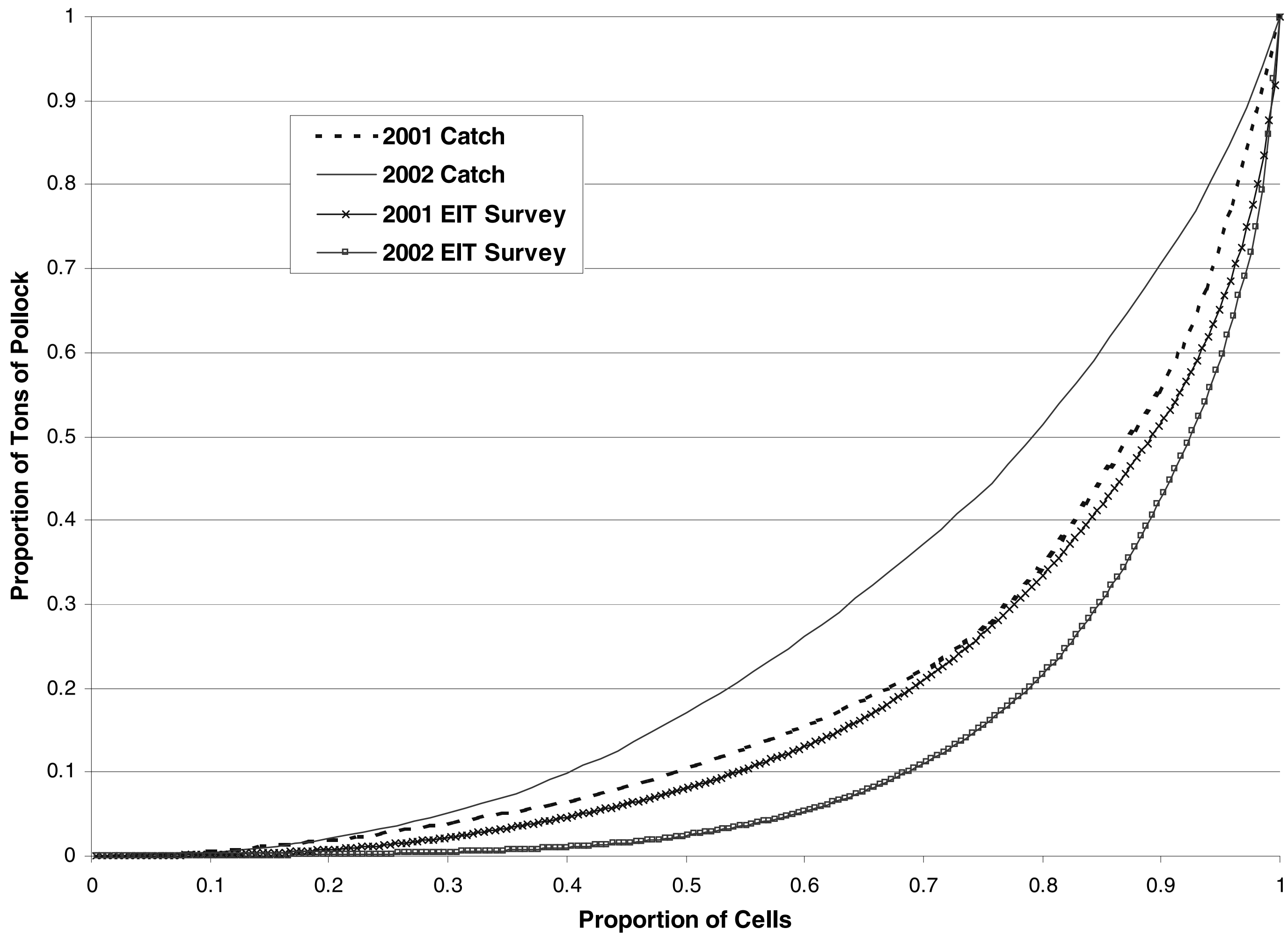


Figure 5. 2001 distribution of observed catch to survey biomass ratios (OCSBR) with medians plotted. Please note that the OCSBR axis is on a logarithmic scale.

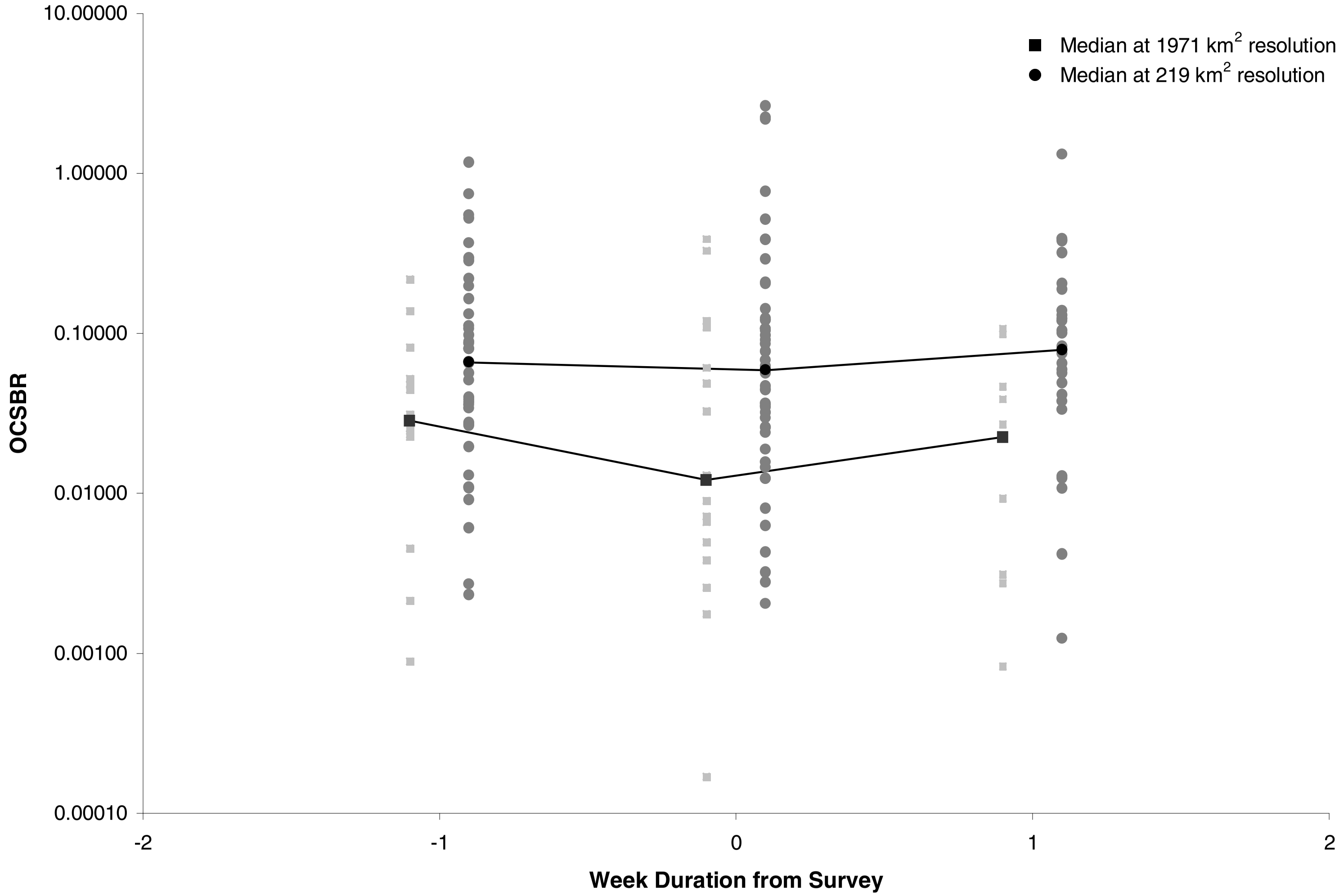


Figure 6. 2002 distribution of observed catch to survey biomass ratios (OCSBR) with medians plotted. Please note that the OCSBR axis is on a logarithmic scale.

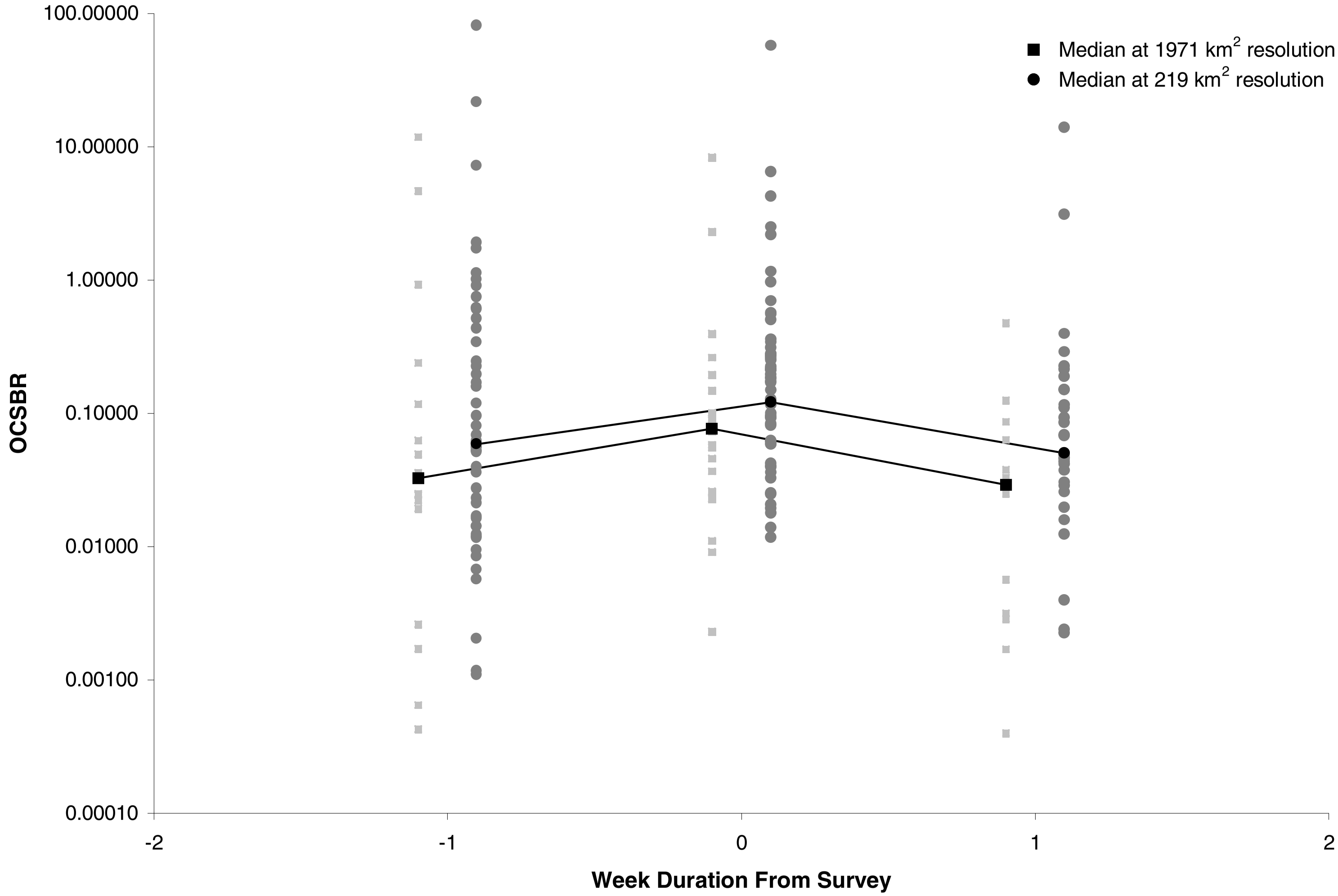


Figure 7. 2001 observed catch to survey biomass ratios (OCSBR) for 1,971 km^2 cells for observed catch and echo integration-trawl (EIT) survey estimates from 20 February to 3 March.

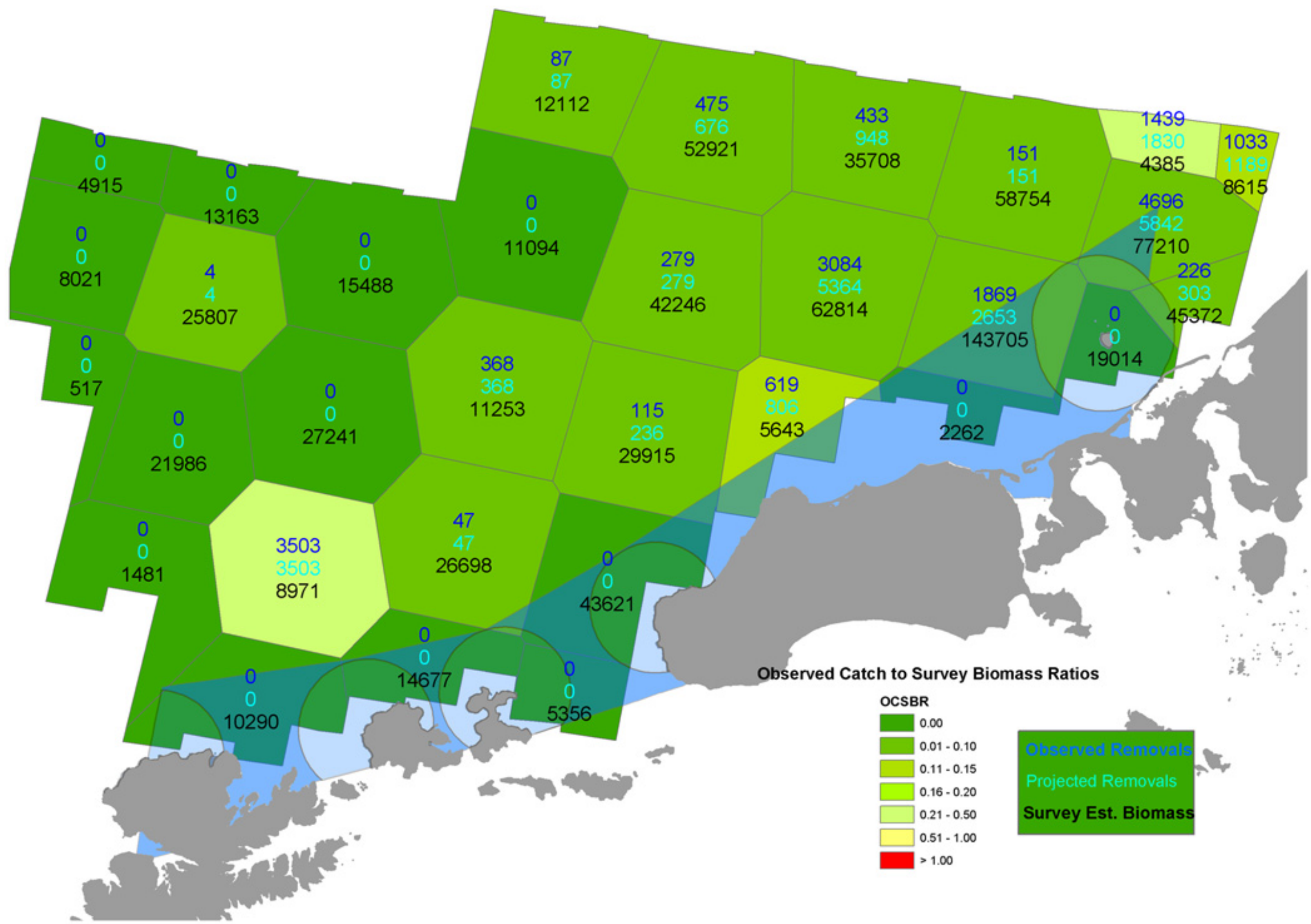


Figure 8. 2002 observed catch to survey biomass ratios (OCSBR) for 1,971 km^2 cells for observed catch and echo integration-trawl (EIT) survey estimates from 23 February to 3 March.

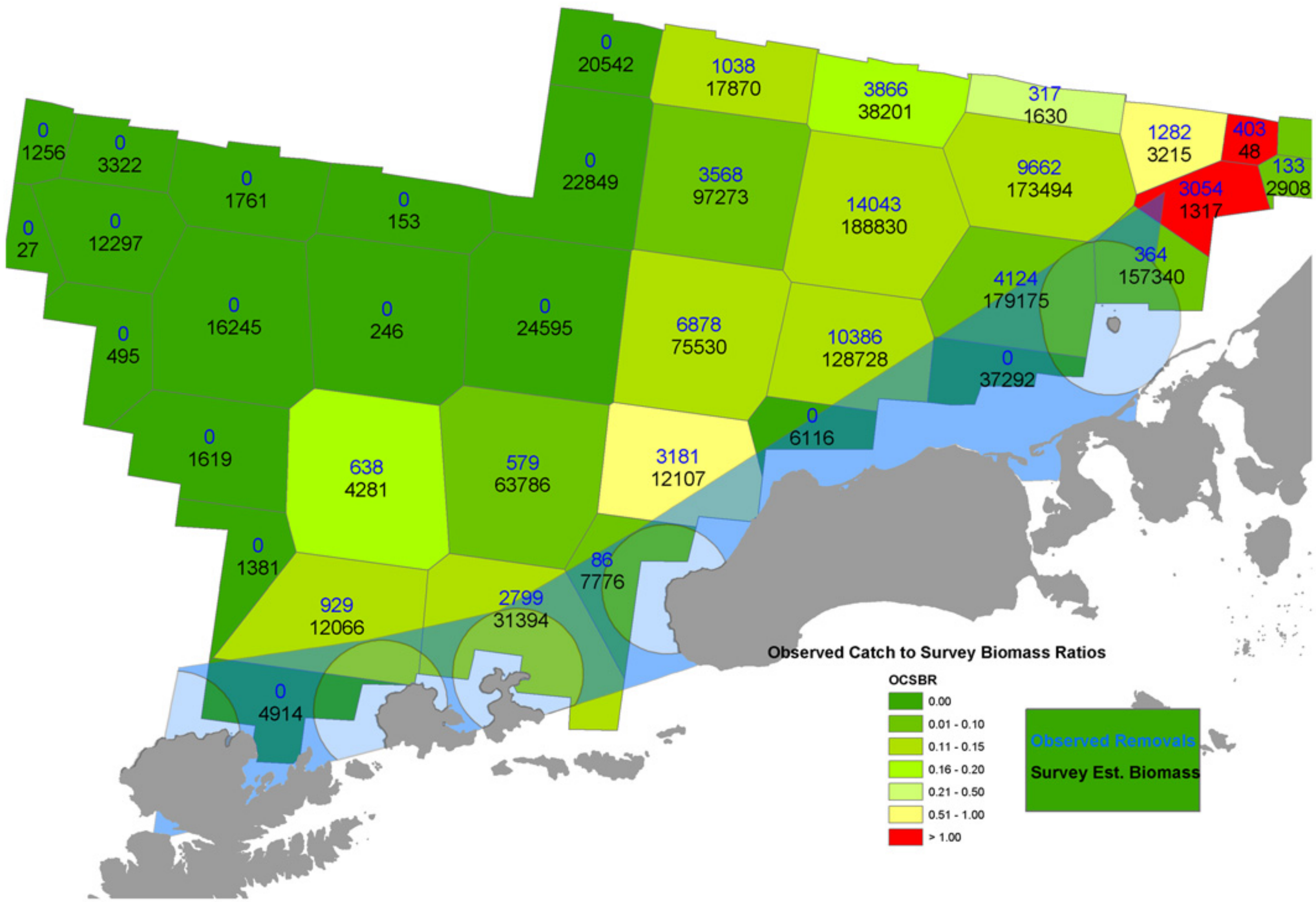


Figure 9. 2001 observed catch to survey biomass ratios (OCSBR) for 219 km^2 cells for observed catch and echo integration-trawl (EIT) survey estimates from 20 February to 3 March.

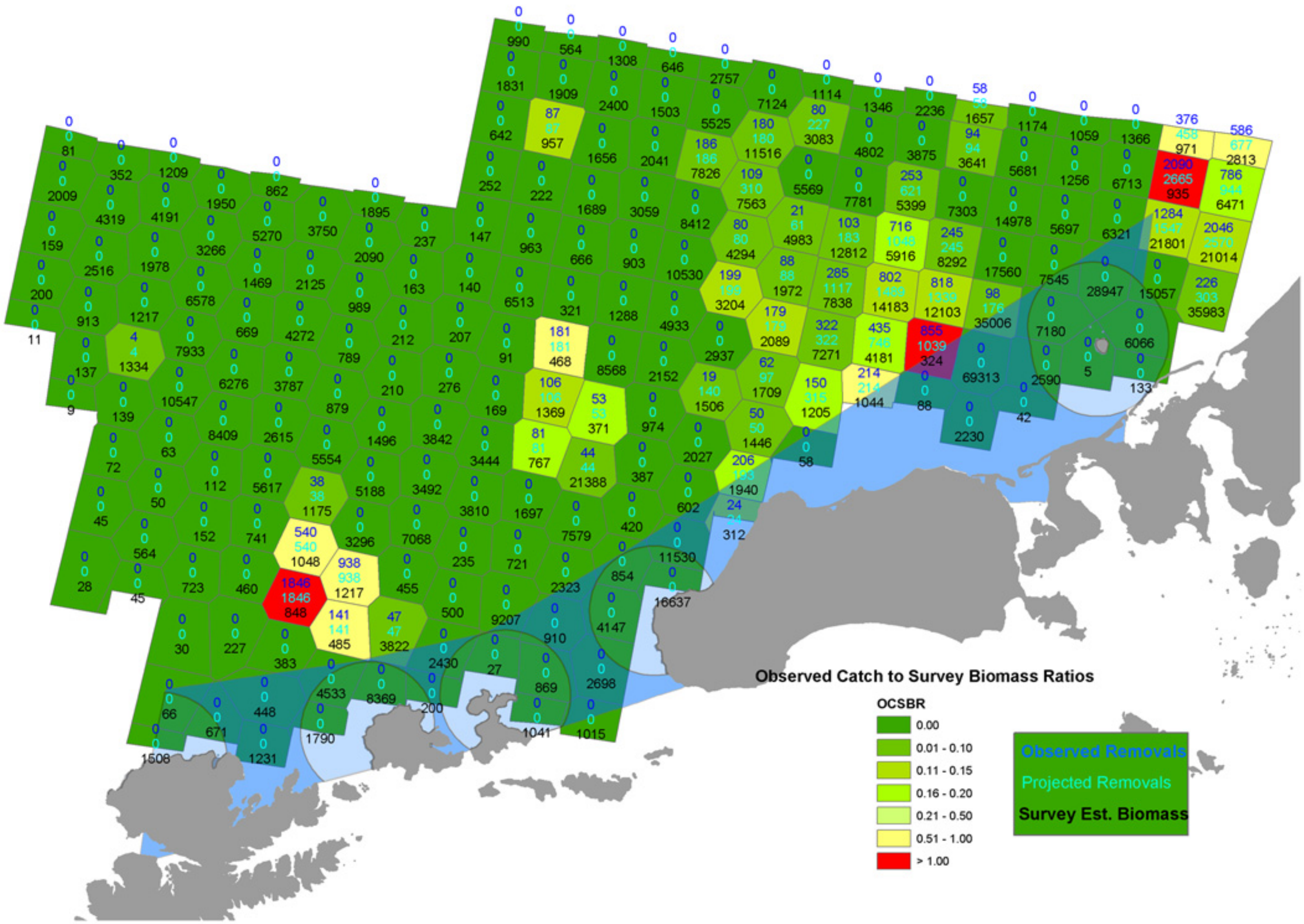


Figure 10. 2002 observed catch to survey biomass ratios (OCSBR) for 219 km^2 cells for observed catch and echo integration-trawl (EIT) survey estimates from 23 February to 3 March.

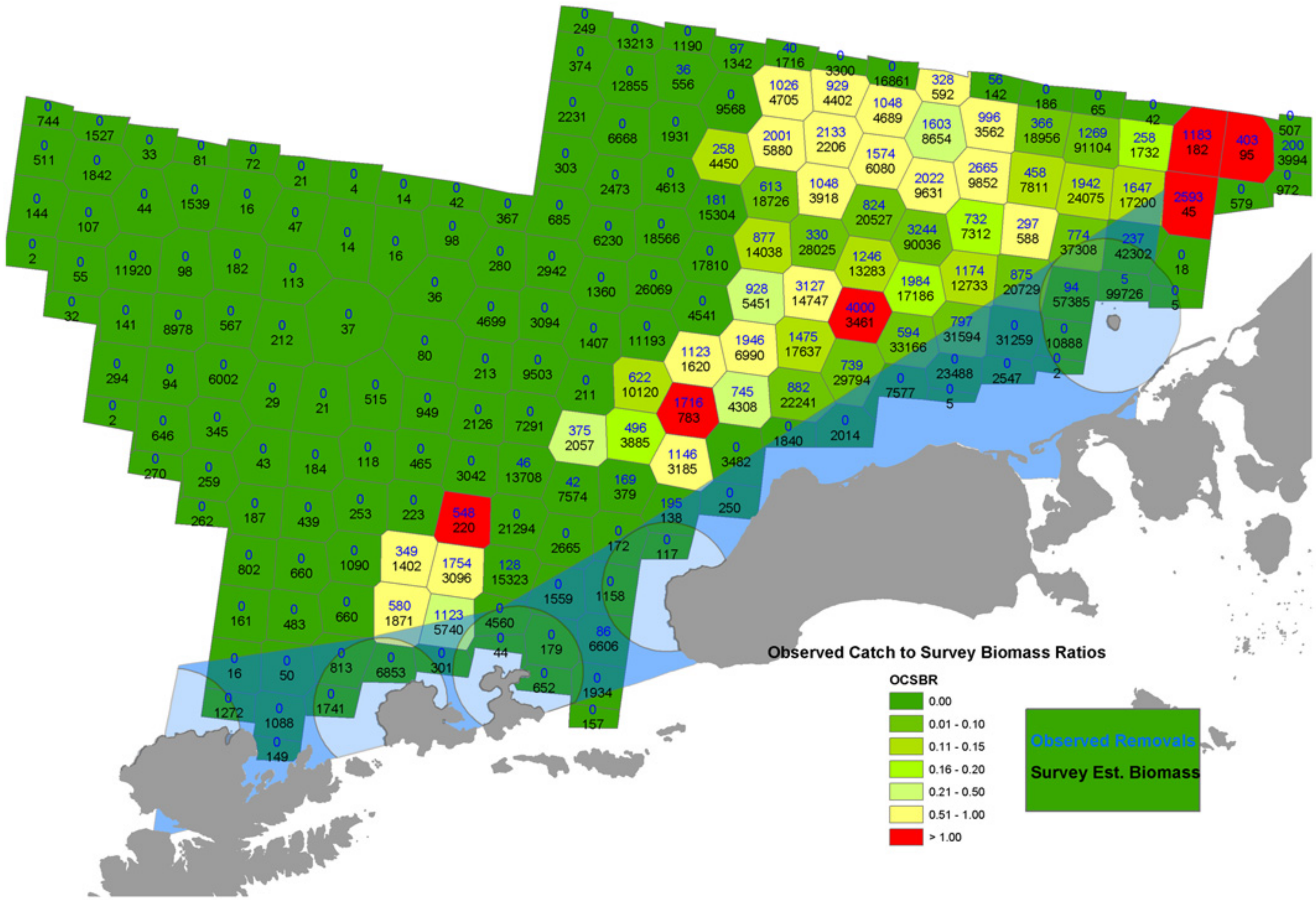


Figure 11. 2001 observed catch to survey biomass ratios (OCSBR) for 1,971 km^2 cells for observed catch from 13 February to 19 February and echo integration-trawl (EIT) survey estimates from 20 February to 3 March.

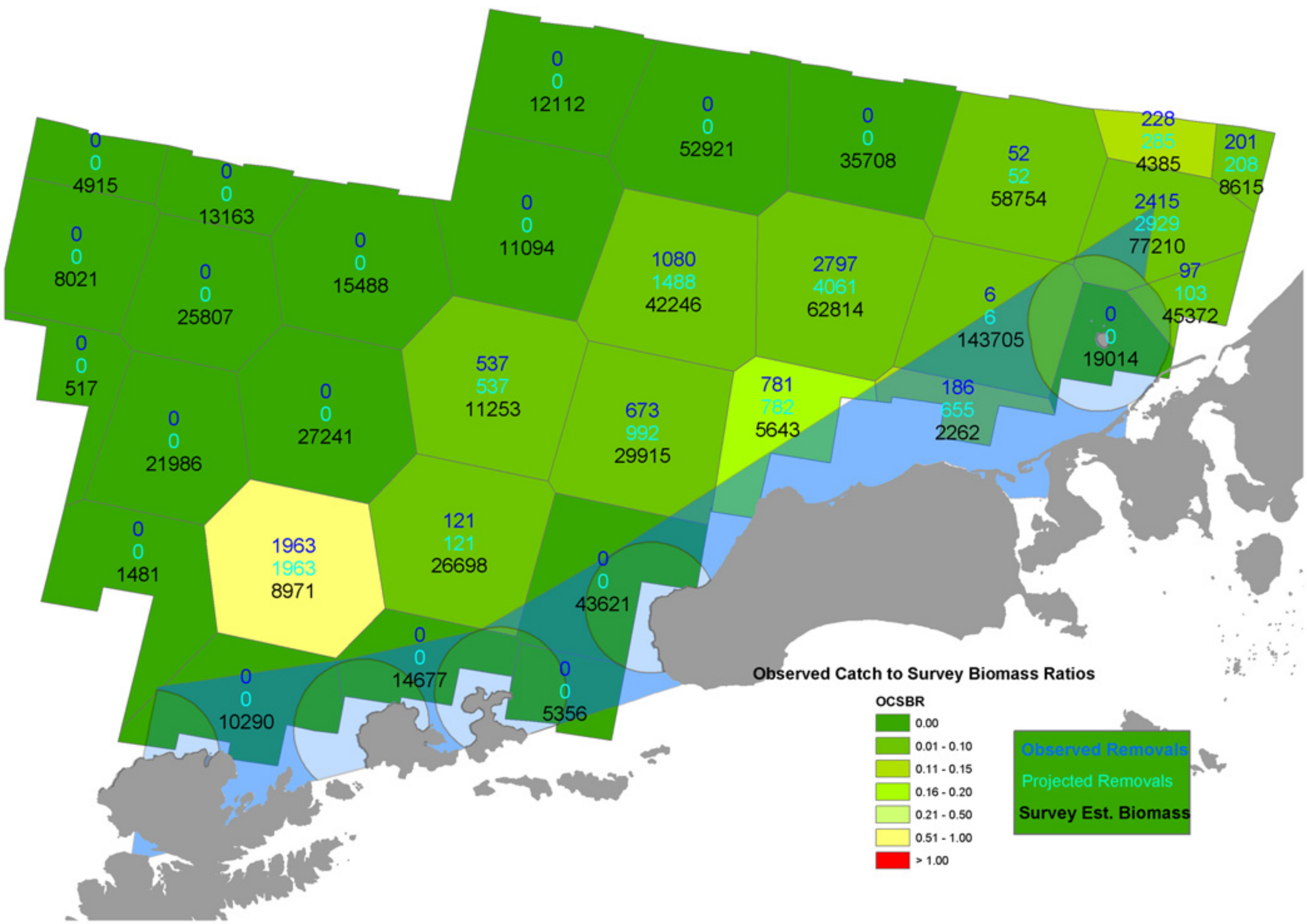


Figure 12. 2002 observed catch to survey biomass ratios (OCSBR) for 1,971 km^2 cells for observed catch from 16 February to 22 February and echo integration-trawl (EIT) survey estimates from 23 February to 3 March.

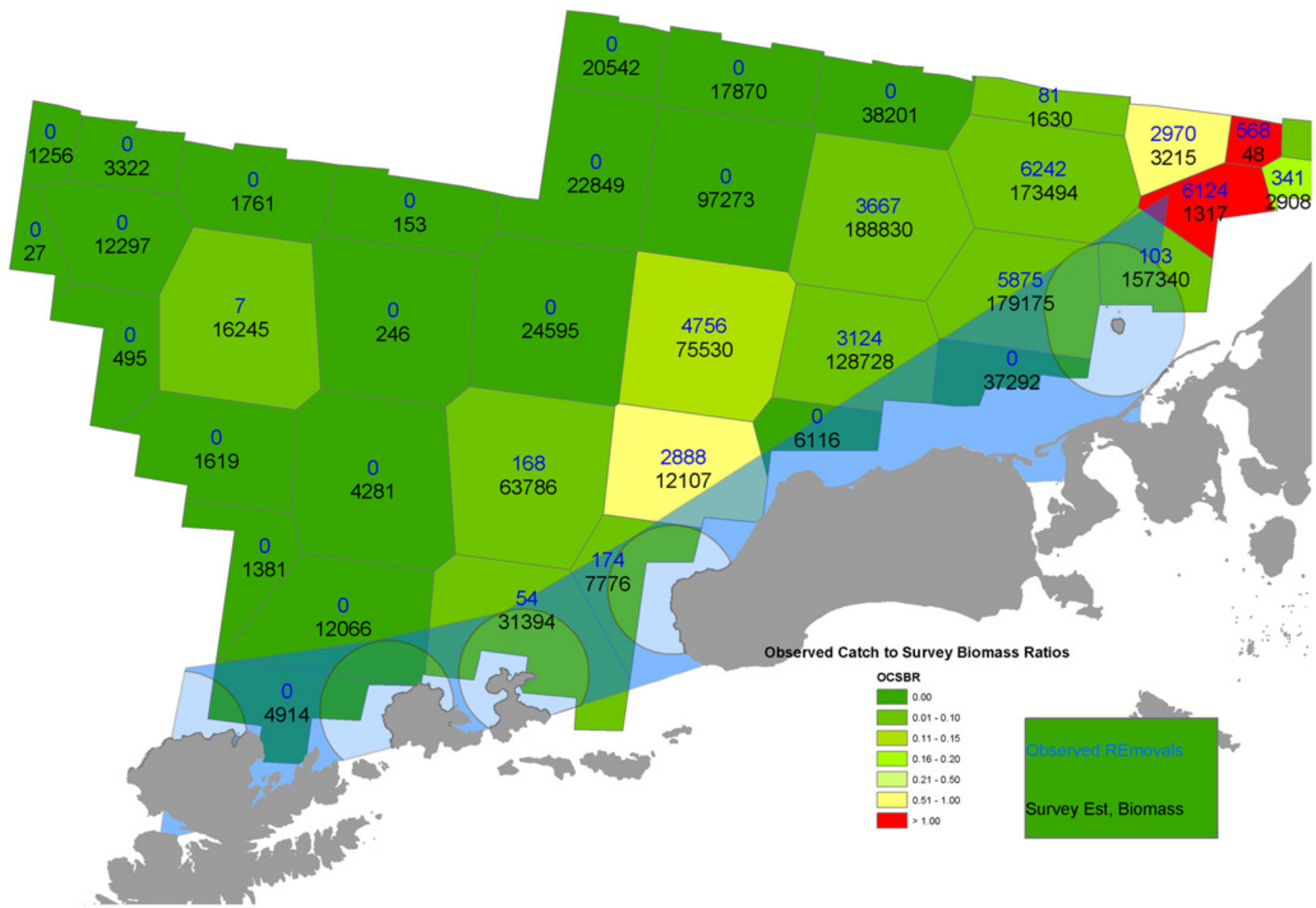


Figure 13. 2001 observed catch to survey biomass ratios (OCSBR) for 1,971 km^2 cells for observed catch from 4 March to 10 March and echo integration-trawl (EIT)survey estimates from 20 February to 3 March.

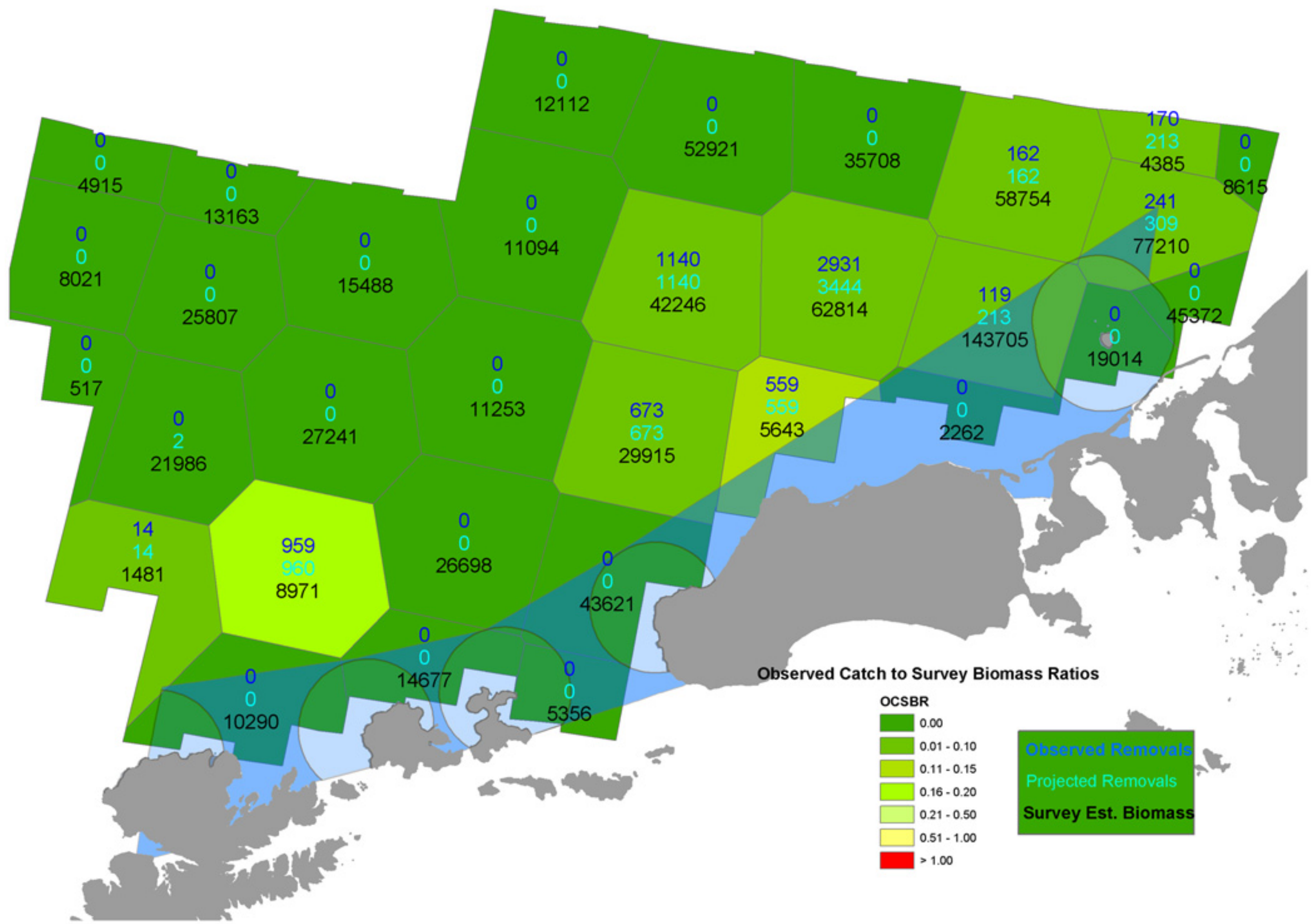
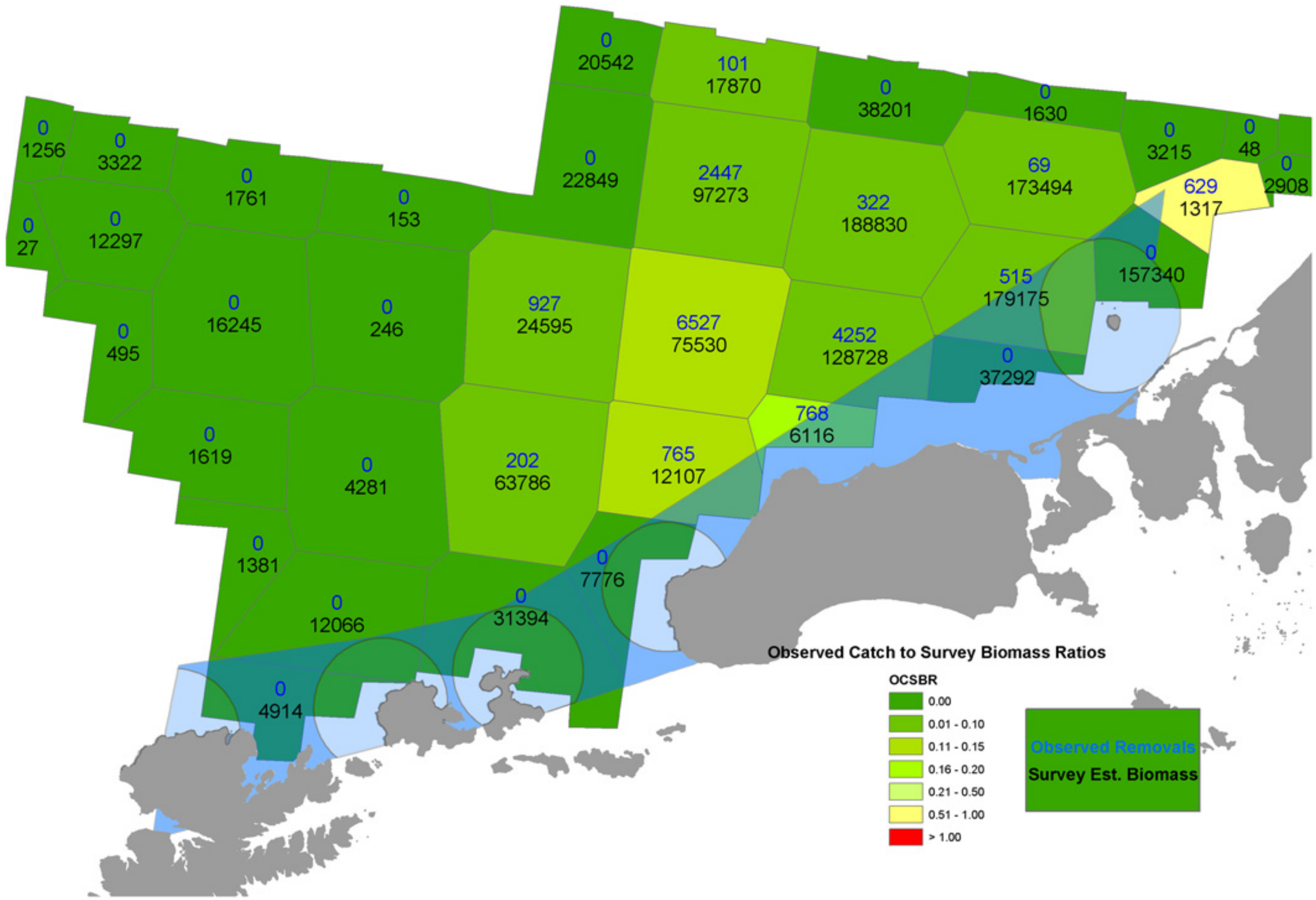


Figure 14. 2002 observed catch to survey biomass ratios (OCSBR) for 1,971 km^2 cells for observed catch from 4 March to 10 March and echo integration-trawl (EIT) survey estimates from 20 February to 3 March.



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