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Abundance and spatial distribution of Yellowtail Flounder in Closed Area II South, 2010 vs. 2012, from an image-based survey.

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ABSTRACT

We compare the abundance and spatial distribution of Yellowtail Flounder from two high-resolution, image-based surveys of Closed Area II South from 2010 and 2012. Estimated yellowtail abundance in the survey area was 76% lower 2012 than in 2010 with estimates of 1.36 million and 5.81 million individuals respectively. The spatial distribution of yellowtail also constricted in 2012 compared to 2010. Bottom water temperatures were notably warmer in 2012 than 2010 and the shifts in the spatial distribution correlate well with the shifts in water temperatures. Based on the abundances from the image surveys, we calculate an average efficiency for the NEFSC survey dredge of 0.62 and apply this to the dredge survey data throughout the stock area to get estimates of absolute abundance for the survey time series. The expanded dredge time series abundances are lower than the stock assessment model but the dynamics generally agree for recent years but are lower than the assessment model in the years before 1994.

Introduction

While stock-wide resource surveys with long time series are critical for monitoring the status of stocks, smaller-scale, higher resolution surveys utilizing alternative survey methods can be valuable to validate observed, larger-scale trends and help elucidate factors that influence stock dynamics.

The HabCam2 is a towed underwater imaging vehicle developed by a group of commercial fishermen, independent scientists, and researchers at the Woods Hole Oceanographic Institute (http://HabCam.whoi.edu/HabCam2.html). The vehicle is equipped with a digital still camera synched to four strobes, an altimeter, tilt sensors, and an array of oceanographic instruments. The vehicle is deployed from a commercial fishing vessel on a fiber optic cable and maintained 2-3 meters off the seabed while being towed at 5 knots and capturing overlapping images.

Two intensive HabCam surveys of the southern portion of Closed Area II, on Georges Bank, were conducted in August 2010 and July 2012. The main purpose of these surveys was to estimate sea scallop biomass, but finfish are also observed in the HabCam photos, and the HabCam surveys can be used to estimate abundances of common demersal finfish. Here, we use data from these HabCam surveys to estimate the abundance of yellowtail flounder (*Limanda ferruginea*) and examine the spatial distribution in this region. We compared these estimates to swept area estimates from the NEFSC sea scallop survey in the same area to estimate the gear efficiency of yellowtail in the scallop survey dredge. We used this efficiency to expand the survey dredge catches to actual abundance estimates for the survey time series and compare this to the stock assessment model estimates.

Methods

Complimentary surveys of Closed Area II on Georges Bank were conducted from August 1-4 in 2010 and July 10-12 in 2012 (Fig1). A spatially systematic subset of the collected images were extracted and visually examined and the presence of fishes noted. Images were accepted for data if the quality in all parts of the image was sufficient to clearly discern objects on the benthos. Fishes were considered within the image only if the center of their body was present within the image frame. For 2010, the images were examined by expert members of the HabCam group. For 2012, the images were first examined by students at the School for Marine Science and Technology and fish were placed into general categories. All 2012 images with fishes were then reviewed by biologists at the NEFSC Ecosystems Survey Branch and identified to the lowest possible taxa. For all images, the area captured within the image was calculated based on the vehicle altitude and orientation to the bottom using a calibration algorithm.

For analysis purposes, the study area was cropped to the region within the boundary of the closed area and post-stratified into 10m depth intervals (Fig 2). The <60m depth strata was combined with the 60-70m depth strata because it was small and contained a relatively small number of observations. Within each depth strata, the density of yellowtail flounder were calculated as the total number of observations in the images divided by the sum of the area captured in the images. We then calculated abundance estimates by expanding the densities to the total area of each depth strata. CV's and confidence intervals were calculated by bootstrapping. Two abundance estimates were calculated for 2012. The first estimate is based only on positive identifications of yellowtail flounder. The second estimate includes positively identified yellowtail plus the number of flatfishes that could not be identified to species, pro-rated by the ratio of identified yellowtail flounder to identifiable flatfishes.

We compared the depth distributions by resampling the depth distribution of yellowtail from 2010 and comparing it to the 2012 depth distribution. Aspects of the depth distribution examined include the mean depth, range of depths, minimum depth, and maximum depth.

Because there was a noted shift in the geographic and depth distribution of yellowtail between the two surveys, we explored bottom temperature as a potentially informative environmental parameter. We used the temperature data collected by the CTD on the HabCam vehicle to build interpolated maps of bottom temperature for both years. We then overlayed the temperature fields on the observations of individual yellowtail for both years.

Yellowtail are commonly captured as bycatch in the annual NEFSC dredge survey of the US sea scallop resource. Dredge surveys of the two primary strata in Closed Area II were conducted from June 14 – 16 in 2010 and from July 2-3 in 2012, completing 32 and 19 dredge tows, respectively. To compare the two survey gear types, we cropped the HabCam survey data to the geographic extent of the dredge strata. The mean dredge catch of yellowtail was then converted to a mean catch per unit area swept and compared to the observed HabCam densities to obtain estimates and confidence intervals for dredge efficiency for yellowtail. Using these efficiencies, we expanded the scallop survey to the entire stock area for each year to give an estimated abundance for the entire time series and compared this to the stock assessment model estimates.

Results

A total of 158,983 images were examined for yellowtail in 2010, 273 of which contained a yellowtail (Fig 2). Estimated total abundance for the study area was 5.81 million individuals (95% CI = 5.21 to 6.44 million, Table 1). For 2012, we sampled 83,760 images in which a total of 240 flatfishes were observed. Of these fishes, 19 were positively identified as yellowtail and 44 were not identifiable to species (Fig 2). Estimated total abundance for the study area was 1.36 million (95% CI= 0.87 to 1.89 million). Mean total abundance including the pro-rated unidentified flatfishes was 1.73 million.

The depth distribution of yellowtail was also different between the 2010 and 2012 surveys (Fig 3 & 4). In 2010, the majority of the population was in the <70m depth strata and yellowtail were present in all depth strata. In 2012, the majority of the population was in the 70-80m depth strata and yellowtail were lacking from the deepest strata. The depth range was narrower in 2012 than in 2010 (range of 66.0-82.2m vs. 59.2-92.8m respectively, p=0.04) and the shallow extent was deeper in 2012 than in 2010 (p=0.02). There was also a weak tendency for the mean depth to be deeper in 2012 vs 2010 (73.0m vs 71.5m respectively, p=0.15) and the deep extent to be shallower (p=0.14) in 2012.

Qualitatively, bottom temperatures are markedly different between 2010 and 2012 (Fig 5). In 2010, most of the study area is below 9.5^{o}C with large areas <8.5^{o}C and temperatures >10^{o}C present only along the eastern margin and to the far south of the study area. In 2012, temperatures less than 9.5^{o}C are virtually absent from the study area with significant portions of both east and west margins exceeding 10.5^{o}C.

Based on the HabCam total abundance estimates, the estimated dredge efficiencies for yellowtail were 0.43 (SE=0.07) and 0.82 (SE=0.27) for 2010 and 2012 respectively giving a mean efficiency across surveys of 0.62 (SE=0.20). Based on this efficiency, we estimated absolute abundances of yellowtail for the dredge time series since 1982 and compared it to the model estimates from the 2012 assessment (Fig 6, Table 3). The dredge survey, with an applied efficiency of 0.62, gives lower abundance estimates than the stock assessment model (terminal year abundances of 6.6 million and 17.8 million respectively). However, the dynamics of the two time series generally agree for recent years but diverge for years prior to 1994.

Discussion

Interpreting the differences observed in the 2010 and 2012 surveys is complex. A working paper submitted to 2013 TRAC documented a marked increase in yellowtail densities in the same study area between June and August in 2012 (Barkley et al 2013). If this movement is part of an annual migration, then the timing of surveys in different years may be critical for interpreting interannual variations in yellowtail abundances and some portion of the observed differences between 2010 and 2012 may be attributable to these movements. However, the expanded dredge survey recorded a stock-wide decline of 57% between 2010 and 2012 so movements within the stock alone would not account for the differences observed within the dredge survey. Additionally, tagging studies have demonstrated that yellowtail on Georges Bank generally do not move outside of the stock area (Cadrin 2010) so interannual differences are probably not due to fish moving outside of the region surveyed by the dredge survey.

The difference in bottom temperatures is striking between the two surveys. It would appear, based on shifts in depth distributions between the surveys, that yellowtail may be responding to spatially-shifting thermal habitat. We have not found detailed information on optimal temperatures or the thermal tolerance of adult yellowtail flounder. S. Cadrin suggested that yellowtail may become thermally stressed above 10^{o}C (pers.comm.). However, the NMFS flatfish survey in August 2013 commonly found yellowtail above 14^{o}C (Martin and Legault 2013) and yellowtail may be found in waters as warm as 18^{o}C in Southern New England (L. Alade, pers.comm). Thus, while bottom temperatures in 2012 may not have been highly stressful, they may have been sub-optimal and flounder may have been moving to seek out more optimal habitat. It is worth noting that the 2012 survey was conducted in the middle of July, weeks before water temperatures in this region typically reach their annual maximum. Thus, it would be useful to better understand the thermal tolerance of yellowtail and reconstruct the temperature time series for this region to determine if this is a possible factor contributing to population decline.

In 2012, the dredge and HabCam surveys occurred only a week apart. However, the surveys were nearly two months apart in 2010. The calculated dredge efficiency was higher in 2012 than in 2010, which would agree with a seasonal migration hypothesis. If so, then the dredge efficiency for 2012 is more accurate and the dredge efficiency could be increased accordingly.

Finally, the calculated dredge efficiency assumes that the HabCam efficiency is 100% a common assumption when calibrating mobile survey gear to visual survey data (Krieger and Sigler 1996, Somerton et al. 1999). However, environmental and biological factors may cause efficiency to deviate from 1 (Adams et al. 1995, Trenkel et al. 2004). Examination of the HabCam images with yellowtail in them revealed that fish are either partially buried in the sediment or actively fleeing the vehicle a portion of the images (Shank and Duquette 2014). Thus, some partially buried fish may have been missed due to observer error and fleeing fish may have moved off the imaging track. Either effect would decrease the HabCam efficiency below 1, in turn lowering the dredge efficiency and raising the expanded dredge estimates.

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Table 1. Yellowtail abundance estimates for the HabCam survey area.

	2010	2012
Total abundance	5,952,289	1,361,136
Lower 95% CI	5,216,661	872,484
Upper 95% CI	6,444,026	1,894,908
CV	0.062	0.142
Abundance by Depth Strata		
60-70m	3,020,526	488,002
70-80m	2,315,416	756,534
80-90m	501,920	116,600
90-100m	114,427	0

Table 2. Calculated HabCam and Dredge swept area abundances and calculated dredge efficiency.

2010	Date	Mean	SE	CV	95% CI
Habcam	8/1-8/4	6,928,866	443,447	0.06	
Dredge	6/14 – 6/16	2,962,205	477,734	0.16	
Implied Efficiency		0.428	0.074	0.17	0.286 - 0.575
2012					
Habcam	7/10-7/12	1,572,217	361,610	0.23	
Dredge	7/2-7/3	1,286,564	296,158	0.23	
Implied Efficiency		0.818	0.266	0.33	0.087-0.999
Mean Efficiency		0.623	0.20	0.31	0.338-0.867

Table 3. Comparison of Yellowtail Abundance Estimates from the Stock Assessment Model and the NEFSC Dredge Survey with different estimated gear efficiencies.

Year	VPA Estimate	Dredge Swept Area Abundance	Dredge abundance estimate @ q=0.62	Lower 95%; q=0.87	Upper 95% CI; q=0.34
1973	110.4	NA	NA	NA	NA
1974	111.2	NA	NA	NA	NA
1975	131.9	NA	NA	NA	NA
1976	93.2	NA	NA	NA	NA
1977	57.3	NA	NA	NA	NA
1978	81.0	NA	NA	NA	NA
1979	73.3	NA	NA	NA	NA
1980	68.6	NA	NA	NA	NA
1981	104.7	NA	NA	NA	NA
1982	96.7	7.1	11.3	20.9	8.1
1983	56.6	6.8	10.9	20.0	7.8
1984	31.4	3.4	5.5	10.2	4.0
1985	29.6	3.6	5.8	10.7	4.2
1986	25.7	1.5	2.3	4.3	1.7
1987	22.7	1.7	2.7	5.0	2.0
1988	34.4	1.2	1.9	3.6	1.4
1989	32.3	NA	NA	NA	NA
1990	34.0	2.7	4.3	7.9	3.1
1991	41.0	10.1	16.3	30.0	11.7
1992	45.9	2.5	4.0	7.3	2.8
1993	36.5	8.4	13.5	24.8	9.7
1994	31.7	11.9	19.1	35.2	13.8
1995	28.6	11.2	18.0	33.2	13.0
1996	34.3	11.8	19.0	35.0	13.7
1997	44.3	17.4	27.9	51.3	20.1
1998	53.5	23.2	37.2	68.5	26.8
1999	60.0	NA	NA	NA	NA
2000	60.1	22.3	35.8	65.9	25.8
2001	58.8	16.0	25.7	47.3	18.5
2002	50.7	13.5	21.6	39.7	15.5
2003	42.8	15.4	24.6	45.4	17.7
2004	31.0	8.2	13.2	24.3	9.5
2005	23.7	9.3	15.0	27.5	10.8
2006	23.3	20.2	32.5	59.8	23.3
2007	22.3	17.7	28.5	52.4	20.5
2008	22.8	15.9	25.4	46.8	18.3
2009	22.4	9.4	15.1	27.7	10.8
2010	18.1	9.6	15.5	28.5	11.1
2011	15.3	3.2	5.1	9.3	3.7
2012	17.8	4.1	6.6	12.2	4.8

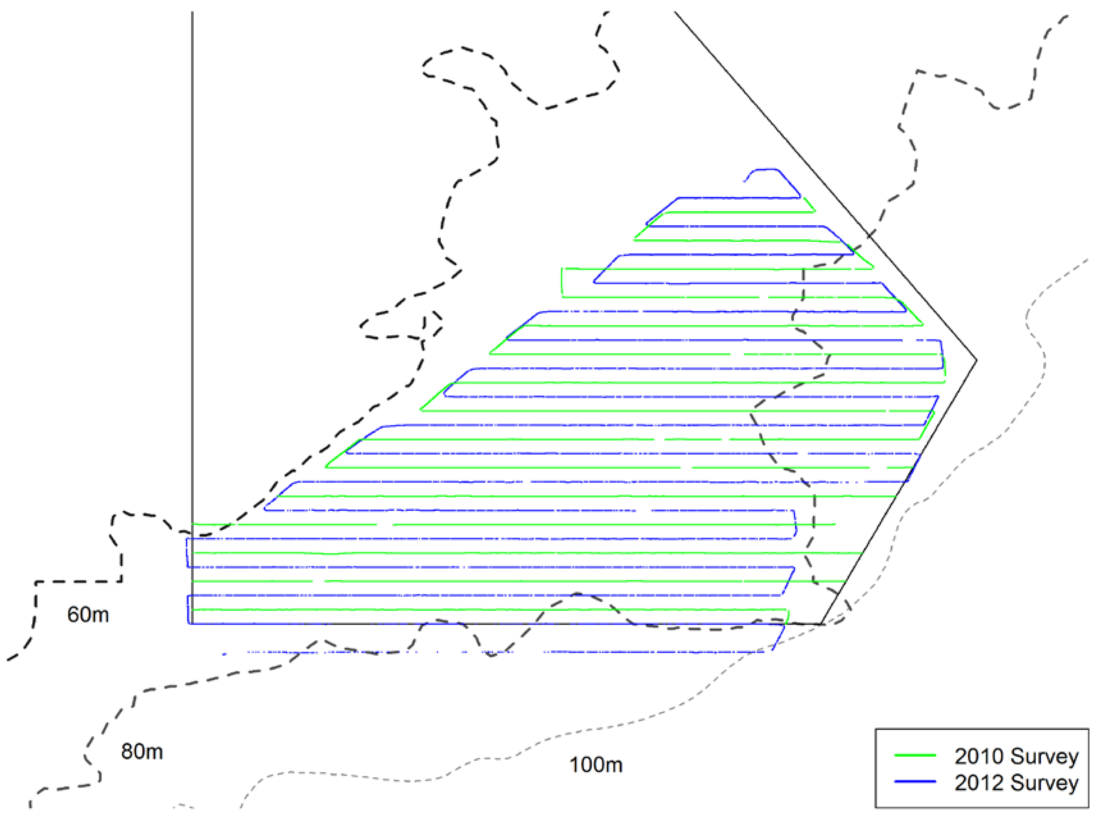

Figure 1. Map of the southern portion of Closed Area II on Georges Bank with the survey tracks for the 2010 and 2012 HabCam RSA survey.

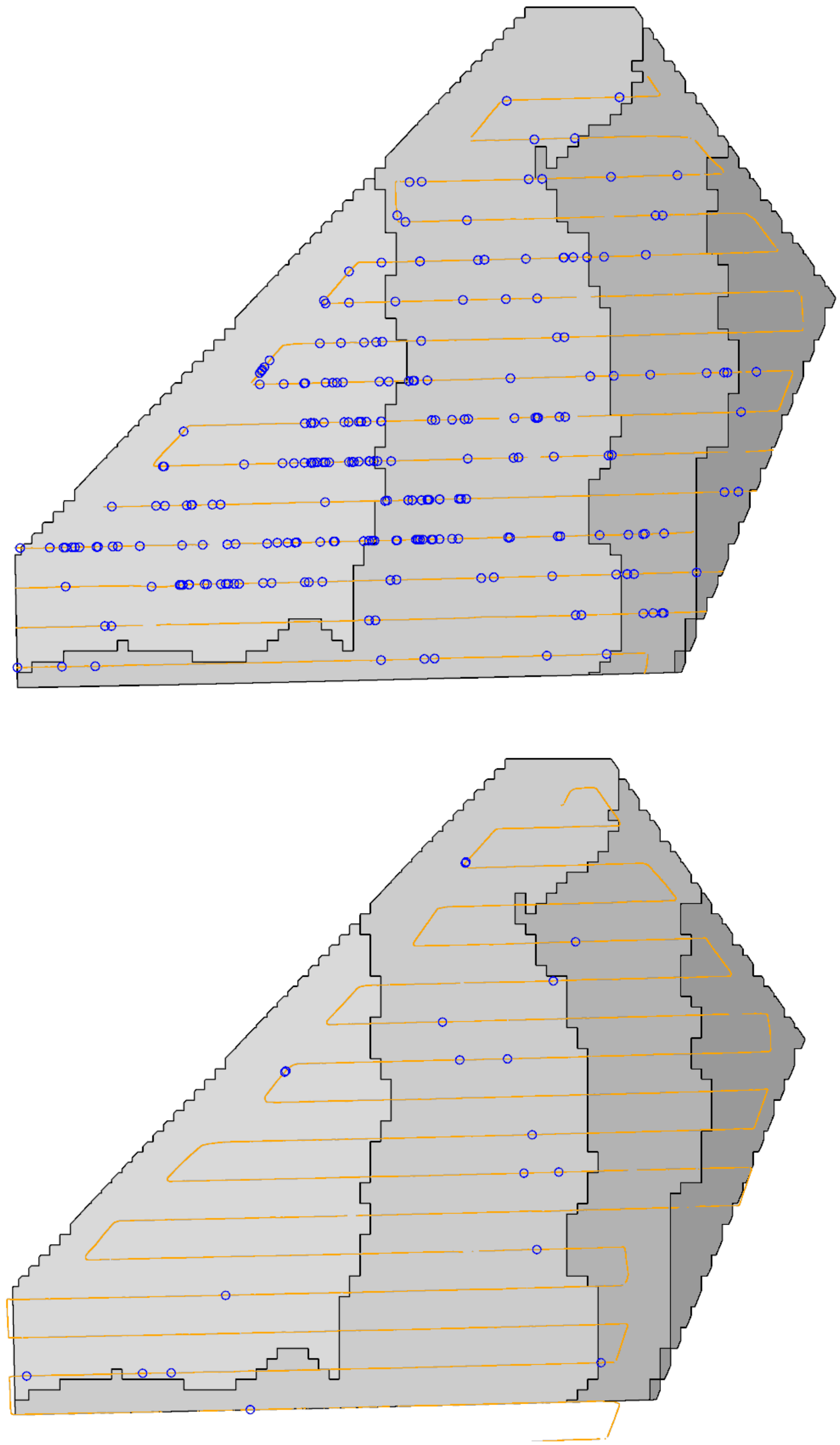

Figure 2. Occurrence of yellowtail flounder in the 2010 (top) and 2012 (bottom) surveys. Sampled images are represented by the orange line. Blue circles indicate the presence of yellowtail in images. Shaded areas represent depth strata (<70m, 70-80m, 80-90m, and 90-100m left to right).

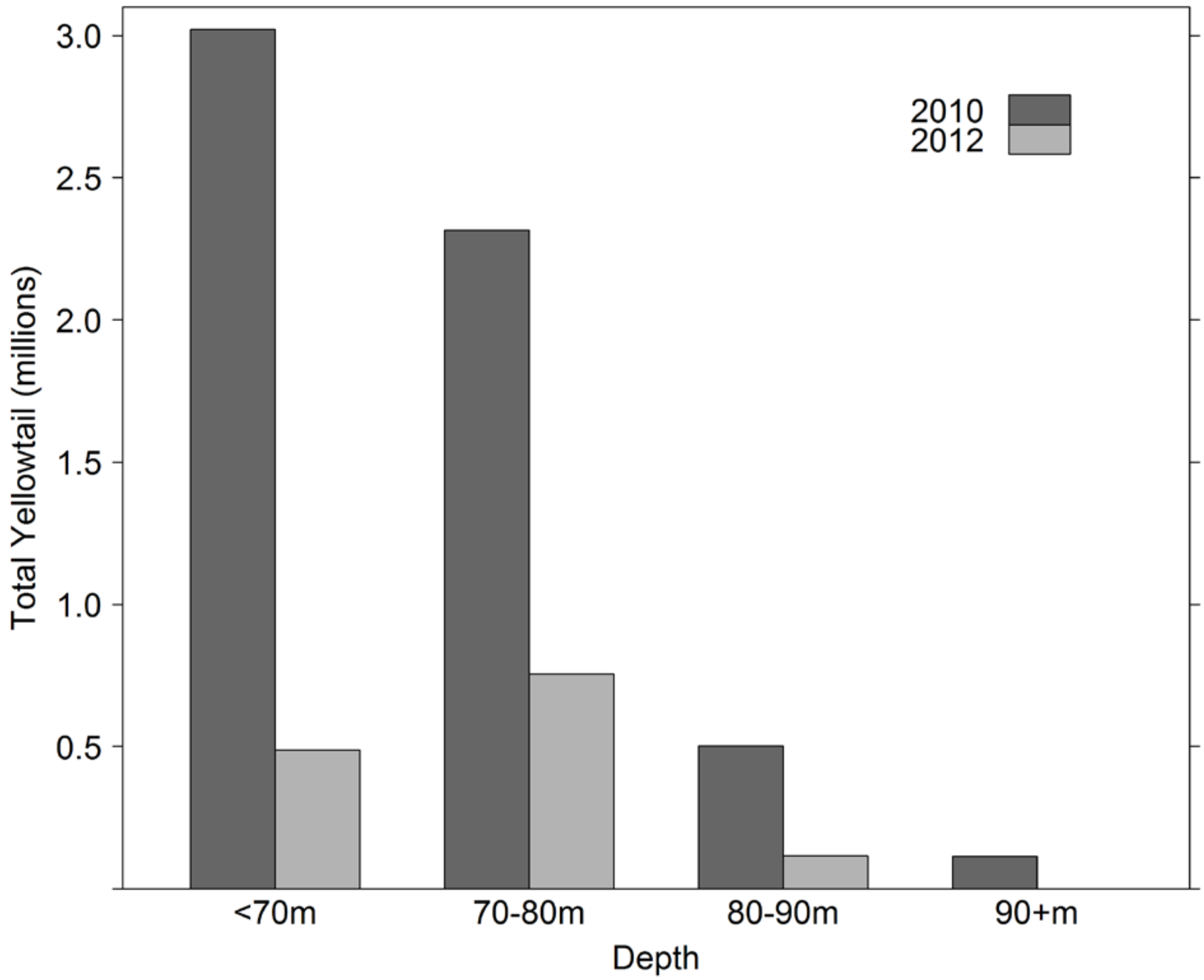

Figure 3. Estimated yellowtail abundance by depth strata for 2010 and 2012.

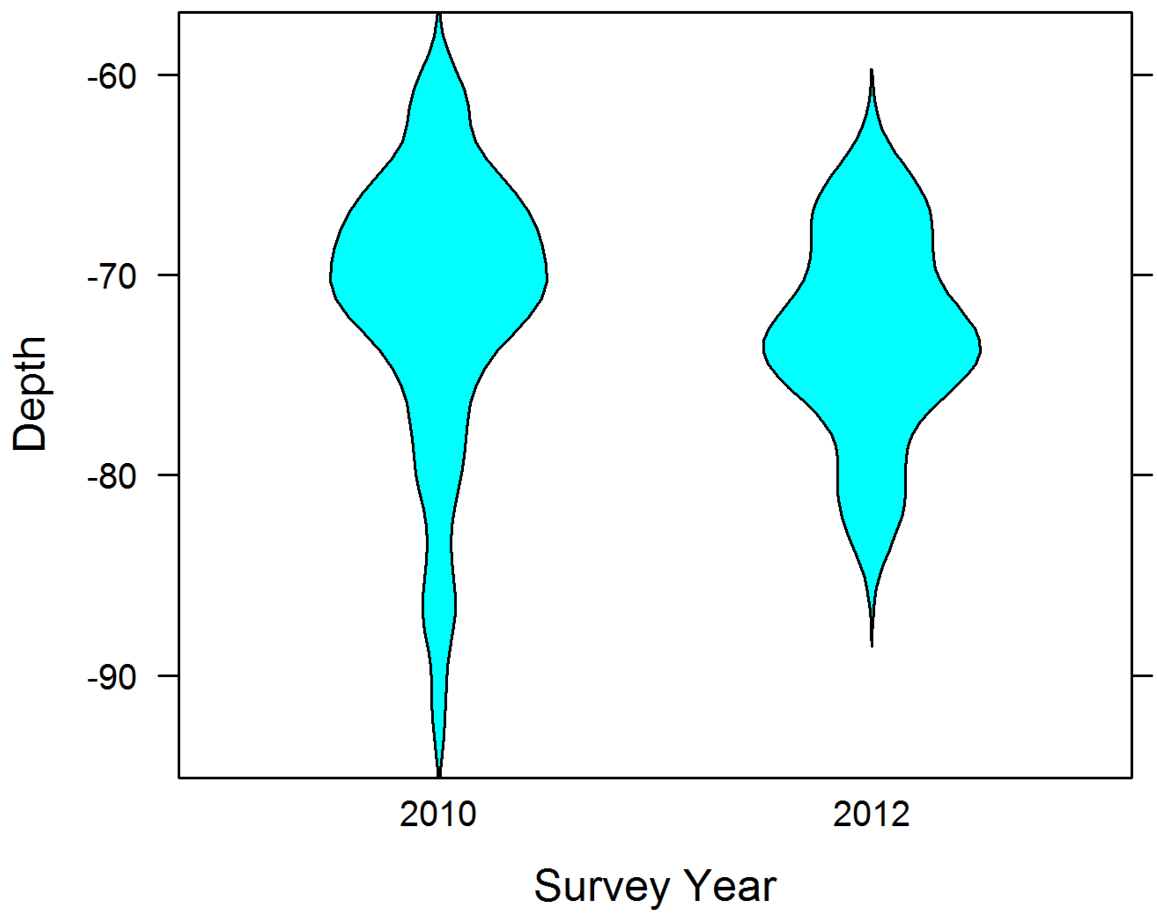

Figure 4. Yellowtail depth distributions in the survey area for 2010 and 2012.

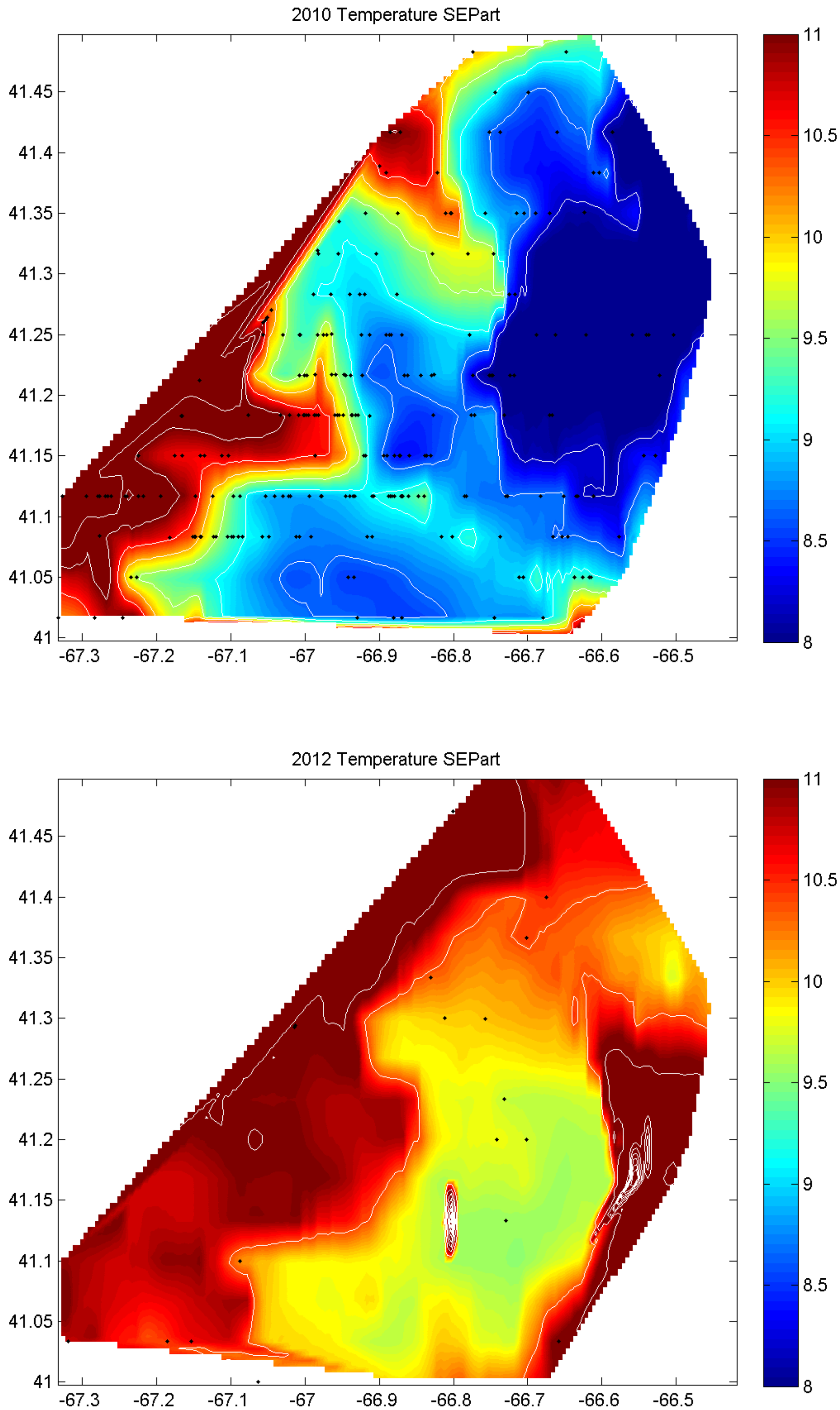

Figure 5. Interpolated bottom temperature maps for 2010 (top panel) and 2012 (bottom panel). Black dots indicate observations of Yellowtail Flounder in HabCam images. Images supplied by S. Gallager.

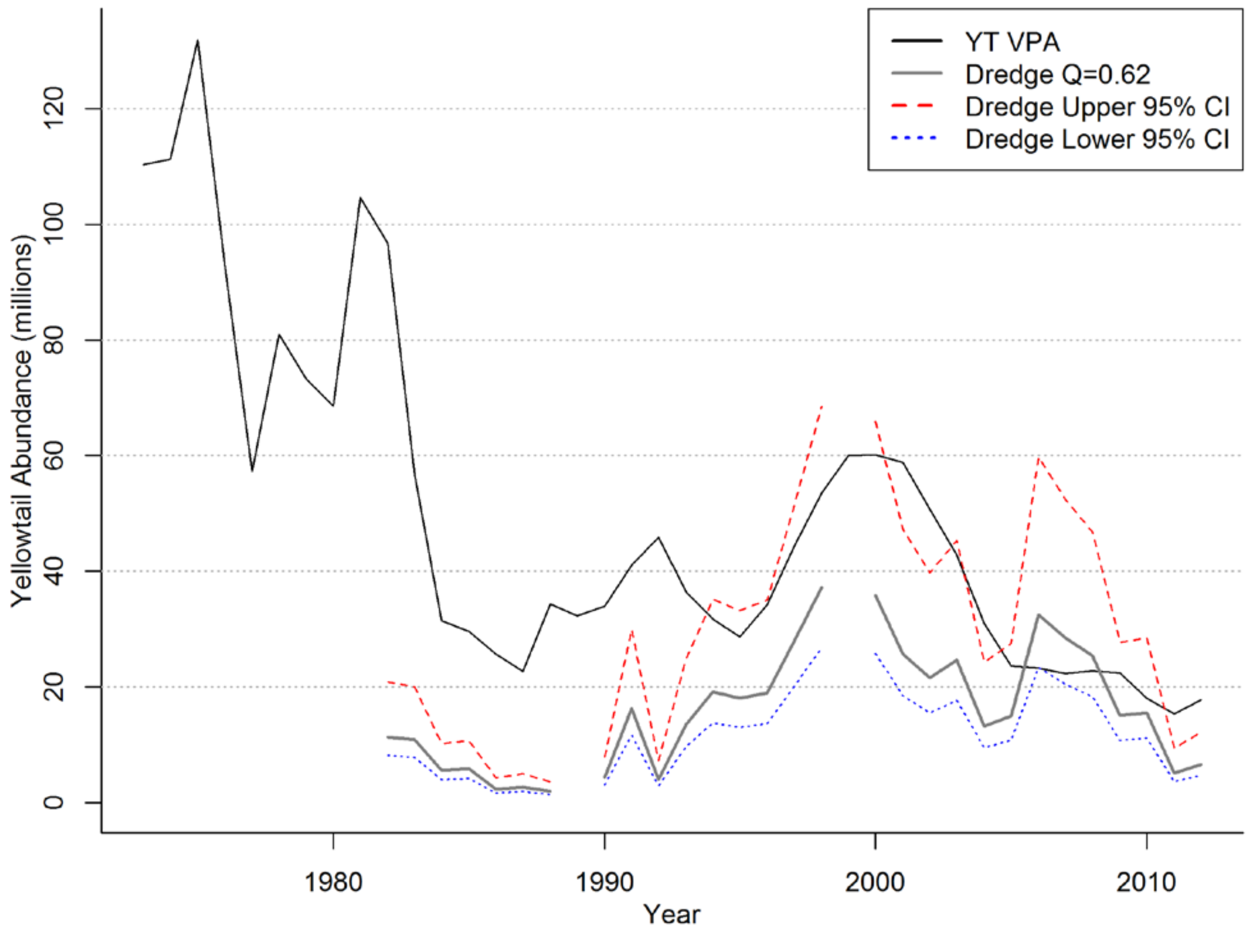

Figure 6. Time series of total yellowtail stock abundance for the assessment model and the expanded scallop survey at different dredge efficiencies.