Summary of Harbor Porpoise Bycatch in Waters off New Jersey

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SUMMARY
Harbor porpoise bycatch in winter (January to April) in waters off New Jersey and in the Mudhole increased dramatically in the last few years, particularly 2005 and 2006. This manuscript documents bycatch patterns and attempts to identify why the bycatch increased.

Since the implementation of the Harbor Porpoise Take Reduction Plan (TRP) on January 1, 1999, 43 harbor porpoises were observed taken in gillnets in the waters off of New Jersey and in the Mudhole. Most of harbor porpoise bycatch occurred in and around Hudson Canyon. All the takes were in large-mesh nets that were targeting monkfish.

The majority (60%) of the large mesh nets observed were out-of-compliance with the TRP, with strings too long being the most common factor out-of-compliance. The level of compliance during 2007 improved markedly over the previous 4 years. The bycatch rate of net strings greater than 4000 feet was 3x greater than the rate for strings less than 4000 feet. Nearly all of the observed small mesh nets were in compliance with the TRP.

A bycatch rate model was developed using stepwise regression methods. The best model was determined by investigating three models that were based on different variables which were included as the first variable in the stepwise regression method. These three models resulted in models with similar significant variables that included fixed environmental variables (bottom depth, and distance to the 50m depth contour), annually varying environmental factors (surface and bottom water temperature, and winter North Atlantic Oscillation (NAO) value), and fishery characteristics (ships gross tonnage, anchor weight, number of anchors, and duration of time the net was in the water – soak duration). One interpretation of these models is that the fixed environmental factors indicate where the majority of the takes (and fishing effort) are (i.e., around Hudson Canyon), the annually varying environmental variables help explain the inter-annual differences, and the fishing characteristics indicate the types of strings with higher bycatch within a particular area-year.

Investigating the fishing characteristic variables in these models further showed the bycatch rate of the hauls that used 4 anchors was 100x larger than that for hauls that used 2 anchors. The hauls that used 4 anchors were hauls that had long soak durations (greater than 6.5 days) and when the soak duration was shorter than 6.5 days, the wind speeds were fairly high (greater than 13.5 knots). The string lengths were not related to the number of anchors.

All of the observed takes were in hauls that soaked for 48 or more hours, where 63% of the observed hauls and 81% of the landings (in metric tons (mtons)) came from hauls that soaked for 48 or more hours. The bycatch rate of hauls that soaked for more than 1 week was 5x greater than for hauls that soaked for less than 1 week.

INTRODUCTION

For the waters off New Jersey (Figure 1), the Harbor Porpoise Take Reduction Plan (TRP) divides the waters into the "New Jersey Mudhole" and "Waters off New Jersey (excluding the Mudhole) . The TRP also divides gillnets into "large mesh" [7-18 inches] and "small mesh" [>5-<7 inches]. The TRP management measures for these areas are in Table 1.

This paper investigates the harbor porpoise bycatch in the gillnet fishery off of New Jersey after the TRP went into effect which was January 1, 1999 (63 FR 66464, December 2, 1998). Using data collected by the Northeast Fisheries Observer Program (NEFOP), the patterns in the harbor porpoise bycatch are described, and the levels of compliance to the TRP mitigation measures are documented. In addition, the bycatch patterns are related to gear characteristics, fishing practices and environmental factors to aid in explaining the patterns in the bycatch and to suggest potential management measures to reduce the harbor porpoise bycatch in this area.

DATA

The variables collected by the NEFOP that were used in these investigations are described in Appendix 1. In addition to these variables for the data collected during 1999 to 2006, a variety of environmental variables which are associated with the location and date of the haul were added (Appendix 1). Data from 2007 are still preliminary and so have not been processed as completely as the older data.

GENERAL BYCATCH PATTERNS

In the waters off New Jersey during 1999 to 2007, harbor porpoise bycatch was observed only in the months of January to April, the time period corresponding to the TRP mitigation measures for the Mid-Atlantic gillnets. Thus, the rest of this investigation will concentrate only on these months during 1999 to 2007. Only bycatch of dead harbor porpoises are explored in this investigation.

During the years 2000 to 2003 there were fewer than 10 trips observed per year (Table 2). For each of the years 1999, 2006 and 2007, there were over 100 observed hauls, which were from over 20 trips and 17 vessels (Table 2).

Most of the harbor porpoise bycatch was near Hudson Canyon, both inside and out of the Mudhole (Figure 1). Takes from the different years are located in overlapping areas (Figure 2). Of the 721 hauls observed in this time-area, 691 hauls did not have any harbor porpoise bycatch, 22 hauls had 1 take, 4 hauls had 2 takes, 3 hauls had 3 takes, and 1 haul had 4 harbor porpoise takes. Most of the hauls that took more than one harbor porpoise were in deeper waters, 40-50 m (Figure 2).

The bycatch rates were highest in 2005 and 2006 (Table 2). All of the takes were from hauls that were targeting monkfish in large-mesh nets (60% of the observed hauls were targeting monkfish). There were no observed takes in 2007. The bycatch rate in February was considerably higher than the rate in other months (Table 3).

The bycatch rates (number of observed hauls with one or more takes/landings from those hauls) for many variables are in Table 4. Close examination of these tables could suggest potential

mitigation measures to reduce the bycatch. Some of the values of variables with high bycatch rates include: the year of 2006, the month of February, hauls in waters that were 60-100 fathoms deep, monkfish target species, hauls in waters that had a surface water temperature of 2-4ºC, hauls that are over a fairly steeply sloped bottom, have a long soak duration (greater than 200 hours), use long strings (greater than 4000 ft), using tie downs with a length of 3-4 feet, nets using 4 anchors weighing 80-100 pounds, hauls conducted in years with a small winter NAO, and depths of the nets that have their lead lines at 30-50 fathoms, and waters with low amounts of chlorophyll.

COMPLIANCE

Small Mesh

During January 1 to April 30 of 1999 to 2007, 133 observed hauls (from 42 trips and 25 vessels) used small mesh in waters off New Jersey and in the Mudhole (only one observed haul was in the Mudhole). No harbor porpoise takes were observed in small mesh gillnets in waters off New Jersey and in the Mudhole.

Looking only at the gear length requirement, in 1999 there were 23 hauls (12 trips from 6 vessels) that were using small mesh sizes (5.5, 6, and 6.5 inches) and had total gear lengths greater than 3000 ft (the limit set in the TRP). The lengths ranged from 3027 to 4200 ft. Of these 23 hauls, 9 hauls from 6 trips, had total lengths that were 3027 to 3036, which were 3000 ft of netting and the spaces in between the nets. I am considering these 9 hauls in-compliance for the purposes of this analysis (Table 5). The 23 hauls occurred in January (3), February (1), March (9) and April (10) of 1999.

Looking only at the twine size requirements, during 2004 there were 15 hauls (3 trips and 2 vessels) and during 2006 there was one haul that used small mesh (5.5 inches) and twine sizes less than 0.81 mm (0.4 to 0.7).

Looking only at the closure requirements, in 1999 one small mesh string near the southern border of the Mudhole hauled back on January 16 (closure starts January 15); this string was set before the closure time period, on January 14.

No other observed small mesh gillnets in the waters off New Jersey (including the Mudhole) were out of compliance (Table 5).

Large Mesh

During January 1 to April 30 of 1999 to 2007, 119 observed hauls (from 36 trips and 21 vessels) used large mesh in the Mudhole, and 316 observed hauls (from 108 trips and 54 vessels) used large mesh in waters off New Jersey (excluding the Mudhole). Overall, the level of compliance increased marked in 2007 over that from the previous 4 years.

Looking only at the gear length requirements, in the Mudhole there were 62 hauls (23 trips and 14 unique vessels) that used large mesh and floatline lengths greater than 3900 ft (4500 to 8400 ft). These occurred in 2002, 2003, and 2005 through 2007 (Table 6). In the waters off of NJ (excluding the Mudhole), there were 163 hauls (70 trips and 36 unique vessels) that used

floatline lengths greater than 4800 ft (5100 to 12,000). These occurred in 1999, 2001, and 2003 through 2007 (Table 6).

Looking only at the closure requirements, there were only 3 observed hauls in the closed period, April 1-20, which were in 2006, and these hauls caught 3 harbor porpoises (Table 6). This is a very large bycatch rate per haul.

Over all observed large mesh hauls, 261 of the 437 (60%) hauls had at least one gear characteristic or closure requirement out-of-compliance. In addition, 28 out of the 43 (65%) harbor porpoise takes were in large mesh hauls that were out-of-compliance for at least one of the gear characteristics or closures required by the TRP (Table 6).

Most of the hauls that were out of compliance were violating the float line length rules (Table 6). As was demonstrated with the observer data collected before the TRP, the bycatch rate increases as the float line length increases (Figure 3). To illustrate this, the bycatch rate of all large mesh hauls is 0.320 takes/mtons of landings (43 takes; 437 hauls), as compared to the bycatch rate of hauls that used strings less than or equal to 4000 feet was 0.121 takes/mton (3 takes; 139 hauls) and 0.368 takes/mton (40 takes; 295 hauls) for strings greater than 4000 feet.

BYCATCH RATES AS RELATED TO OTHER FACTORS

To suggest other possible mitigation actions to reduce the bycatch in this time-area, the following is an investigation into which gear characteristics, fishing practices, and environmental factors were most highly correlated to the bycatch rate. Fishing and environmental factors were regressed against the bycatch rate using generalized additive models (if the factor is continuous) and using generalized linear models (if the factor is categorical), assuming a quasi Poisson distribution[1]. The bycatch rate was defined as total observed takes per total observed landings, where landings were measured as metric tons[2] + 0.001[3]. Generalized additive models allow a non-linear relationship between the factor and the bycatch rate, if the data support a non-linear relationship. See Orphanides' manuscript on the bycatch estimates for more details on this type of regression bycatch estimation method and the observer data. A forward stepwise selection method was employed, using the Akaike Information Criterion (AIC) criterion as the selection criterion. That is, a model with a lower AIC fits the data better than a model with a larger AIC. The forward stepwise selection method is as follows: first, all variables were individually regressed against the bycatch rate. The variable most highly significant was then identified and added to the model to create a 1-variable model. Then all other variables were individually added to the 1-variable bycatch rate model to identify the next most significant variable. The

[1] A Poisson distribution is used because the numbers of observed takes are counts ranging from 1 to 4. A quasi distribution is used to properly account for dispersion, if it is needed. The Poisson distribution assumes the variance of the bycatch is equal to the mean of the bycatch. If the variance is greater than the mean, then the data are called over-dispersed. The quasi distribution calculates correct variances of the model parameter estimates, if there is dispersion.

[2] Metric tons of landings is the only variable that is available that can be used as a unit of effort for gillnet fisheries. See separate paper on this topic for more details.

[3] Add 0.001 metric tons of landings to landings recorded for each haul to ensure the amount of landings for each haul is greater than zero.

next most significant variable was then added to the model to create a 2-variable model. The final model is the model resulting from the stepwise selection method that could not be improved further, that is the AIC did not decrease by at least 2%.

When developing the 1-variable model, three variables were the most highly significant, where it was not possible to tell which variable was better because the AIC values were so similar. Those variables were bottom depth, distance to the 50m depth contour, and number of anchors. Thus, best fitting models using each of these variables as the first variable were developed. These three attempts resulted in two distinct models, both of which include similar variables (Table 7). The significant factors in the final models included fixed environmental variables (bottom depth, and distance to the 50m depth contour), annually varying environmental factors (surface and bottom water temperature, and winter North Atlantic Oscillation (NAO) value), and fishery characteristics (ships gross tonnage, anchor weight, number of anchors, and duration of time the net was in the water – soak duration).

For both final models, the values of each variable that are most highly correlated to the bycatch rate are values of the variable (x-axis) that have a y-axis value greater than zero, that is, above the red line (Figures 4 and 5).

A description and discussion about the variables follows.

Fixed environmental variables

One interpretation of the fixed environmental variables is these variables define the area of highest bycatch (around Hudson Canyon), which is also the area with the most fishing effort (Figures 6 and 7).

Annually varying environmental variables

One interpretation of the inclusion of the annually varying environmental factors is these factors provide a reason as to why the annual bycatch rates vary so much. That is, all of observed bycatch was when the winter NAO value was small (less than about 0.25), that is when the surface and bottom water temperatures were slightly warmer (Figure 8). The average surface water temperatures for years with small versus large winter NAO values was 7.2 versus 6.6, respectively. The average bottom water temperatures for years with small versus large winter NAO values was 6.3 versus 5.7, respectively.

These results could lead to a hypothesis that due to environmental factors, the spatial distribution of fish (and/or fisherman) and harbor porpoises may overlap more in some years (small NAO values) than in other years (large NAO values). However, we do not have enough fishery-independent sighting surveys in the winter in this area, to investigate this hypothesis.

Interestingly, the year with the smallest winter NAO value (-0.29) was 2001, when only 26 hauls (4.6 mtons landings) were observed in this time-area, of which there were no observed harbor porpoise takes. The year with the second smallest winter NAO (-0.24) was 2006, when 201 hauls (50.9 mtons landed) were observed with 22 observed takes. Thus, in 2006 the resulting bycatch rate was 0.43 takes per mton landed, that is, 1 take per 2.3 mtons. So, if there is a relationship between the winter NAO and the bycatch rate, and only 4.6 mtons were observed in

2001, it is difficult to confidently estimate the bycatch of harbor porpoises in 2001 because the number of observed hauls is so small.

Gear/fishing characteristics

The gear/fishing characteristics that were most significantly correlated with the bycatch rate were the number of anchors used, the total weight of the anchors, soak duration and gross tonnage of the vessel.

Most (93%) of the observed hauls used 2 anchors, an additional 6% used 4 anchors, and a few hauls used 1, 3 or 6 anchors. As the number of anchors increased so did the total weight of the anchors; thus, these two variables are related to each other. The bycatch rate of the hauls that used 4 anchors (usually 88 total pounds) was 100x larger than that for hauls that used 2 anchors (usually 44 total pounds). For hauls that used 4 anchors, there were 11 takes in 26 hauls, which resulted in a bycatch rate of 0.423 takes per haul. For hauls that used 2 anchors, there were 18 takes in 401 hauls, which resulted in a bycatch rate of 0.045 takes per haul. Only observed monkfish hauls used 4 anchors, though only 8.3% of the observed monkfish hauls used 4 anchors. This should not be interpreted that using 4 anchors caused the higher bycatch. The higher bycatch rate could be related to why it was decided to use 4 anchors or related to some other factor that happened to be statistically correlated with the number of anchors.

To investigate possible reasons why 4 anchors were used instead of the usual 2 anchors, a classification tree analysis was used to determine which fishing practices and gear characteristics were most commonly used for hauls with 4 anchors. This analysis showed that the hauls which used 4 anchors were hauls that had long soak durations (greater than 6.5 days) or if the haul had a shorter soak duration, the wind speeds were fairly high (greater than 13.5 knots) (Figure 9). The average (and median) string lengths were not different for strings with 2 versus 4 anchors (2 anchors: 4074 (4500) versus 4 anchors: 4569 (4500) feet. The monkfish hauls with 4 anchors were on average in an area where the bottom slope was steeper than the average slope of hauls with 2 anchors (Figure 10). So perhaps, more anchors are used when the captain knew the soak duration would be long or the weather was predicted to be poor or the bottom slope was steep. Or it could just be a personal preference since only 2 of the 63 vessels targeting monkfish used 4 anchors.

Soak duration was another variable that was included in the bycatch rate model (Table 7) and it appears to be at least partially related to the number of anchors used (see last paragraph). All of the observed takes were in hauls that soaked for 48 or more hours, where 63% of all observed hauls and 81% of the landings came from hauls that soaked for 48 or more hours. Half of the takes were from hauls that soaked for more than 1 week. However, only 11% of the observed hauls and 15% of the landings were from hauls that soaked for more than 1 week. The bycatch rate from hauls that soaked for more than 1 week was 0.53 takes/mton (=15 takes/28.2 mtons) as compared to 0.10 takes/mton (=15/155.349) for hauls that soaked for less than 1 week. This means that if there is a relationship between bycatch and soak duration, and if the soak duration of all hauls was less than 1 week it might be possible to reduce the bycatch rate by about 5 times. Yet the amount of landings per haul were about the same for hauls that soaked less than 1 week,

0.30 mtons/haul on monkfish hauls versus 0.35 mtons/haul on monkfish hauls that soaked for more than 1 week.

The relationship between soak time and bycatch rate still holds when looking only at the 2006 data. That is, for 2006 only (the year with the most takes and a low winter NAO), the bycatch rate for hauls that soaked less than 1 week was 0.31 takes/mtons as compared to 0.99 takes/mton for hauls that soaked more than 1 week.

All of the takes were from vessels which were either small vessels, less than or equal to 20 tons (10 takes from 67 hauls), or from vessels which did not have the tonnage reported (33 takes from 300 hauls). Until the tonnage of all the vessels is identified, this variable does not provide much information about what fishery characteristics are related to the bycatch.

Appendix 1. Variables investigated for the bycatch rate model.

Variable Name	Description
LOCATION/TIME VARIABLES	
Day of year	Day of year: 1 = Jan. 1 for each year
Year	Year: 1999 to 2007
Month	Month: January to April
Longitude	Longitude
Latitude	Latitude
Steam time	Time spent steaming to fishing grounds from port
Bottom depth	Bottom depth (fathoms)
Distance to 50m	Distance to the 50 m depth contour
Distance to 100m	Distance to the 100 m depth contour
Distance to 200m	Distance to the 200 m depth contour
Distance to 500m	Distance to the 500 m depth contour
Distance to the coast	Distance to the nearest coastline (m)
N. Atlantic Oscillation	N. Atlantic Oscillation (NAO) monthly value
NAO - 1	NAO value including a 1 year lag
NAO - 2	NAO value including a 2 years lag
Winter NAO	Winter NAO monthly value
Winter NAO - 1	Winter NAO monthly value with 1 year lag
Winter NAO - 2	Winter NAO monthly value with 2 years lag
SST	Sea surface temperature (celcius)
Bottom water temperature	Bottom water temperature (celcius)
Bottom slope	Bottom slope
Chlorophyll	Chlorophyll level (from satellite)
log10(Chlorophyll)	log10(Chlorophyll level) (from satellite)
Sediment	Type of bottom sediment
FISHING PRACTICES	
Soak duration	Time net in the water (hrs)
Target species	Species captain said they were trying to get
Temporary home port	Temporary home port
Vessel gross tonnage	Vessel gross tonnage
Vessel length	Length of fishing vessel
Haul duration	Length of time of haul back (hrs)
Days absent	Number of days absent from a port
State landed	State that catch were landed in
Weather	Weather conditions
Wave height	Wave height

Appendix 1. continued. Variables investigated for the bycatch rate model.

Variable Name	Description
GEAR CHARACTERISTICS	
Twine size	Size of the twine (mm)
Mesh count	Number of meshs in the vertical direction of the net
Gear length	Total length of gear and spaces between nets
Net height	Height of net
Average mesh size	Average mesh size (inches)
Hang ratio	Hang ratio
Number of nets set	Number of nets that were set
Number of nets hauled	Number of nets that were hauled back
Used tie downs?	Were tie downs used: yes, no, unknown
Length tie downs	Length of tie downs
Used anchors?	Were anchors used: yes, no, unknown
Number of anchors	Number of anchors used on the string
Type of anchor	Type of anchor used
Anchor weight	Total weight of anchors (pounds)
Used additional weights?	Were additional weights used: yes, no, unknown
Additional weights	Amount of additional weights used (pounds)
Used droplines?	Were droplines used: yes, no, unknown
Lead line depth	Depth the lead line of the net is at (fathoms)
Weight of lead line	Total weight of the lead line
Used spaces?	Were spaces between the nets: yes, no, unknown
Space width	Width of spaces between nets
Number of spaces	Number of spaces between nets
Color of net	Color of net
Float distance	Distance between floats
Total number of floats	Total number of floats
OBSERVER PRACTICE	
Type of trip	Observer protocol: complete, limited

Table 1. Management measures for the large and small mesh gillnet fishery in the Mid-Atlantic.

LARGE MESH FISHERY (7 inches to 18 inches)

Floatline length:	
NJ Mudhole	<= 3,900 ft
NJ waters (excluding the Mudhole)	<= 4,800 ft
Southern Mid-Atlantic waters	<= 3,900 ft
Twine Size	>= 0.90 mm
Tie Downs	Required
Net Number per Vessel	80 nets
Net Size	<= 300 ft
Net Tagging	Required
Number of Nets within a Net String	
NJ Mudhole	<= 13 nets
NJ waters (excluding the Mudhole)	<= 16 nets
Southern Mid-Atlantic waters	<= 13 nets
Time/Area Closures:	
NJ waters (including the Mudhole)	Closed from April 1 - 20
NJ Mudhole	Closed from February 15 - March 15
Southern Mid-Atlantic waters	Closed from February 15 - March 15
Gear Modification Requirements:	
NJ waters (excluding the Mudhole)	January 1 – March 30 and April 21 – 30
NJ Mudhole	January 1 – February 14; March 16 – March 31; and April 21 – 30
Southern Mid-Atlantic waters	February 1 – February 14 and March 16 – April 30

SMALL MESH FISHERY (> 5 inches to < 7 inches)

Floatline length:	
NJ waters (including the Mudhole)	<= 3,000 ft
Southern Mid-Atlantic waters	<= 2,118 ft
Twine Size	>= 0.81 mm
Tie Downs	Prohibited
Net Number per Vessel	45 nets
Net Size	<= 300 ft
Net Tagging	Required
Number of Nets within a Net String	
NJ Waters (including the Mudhole)	<= 10 nets
Southern Mid-Atlantic waters	<= 7 nets
Time/Area Closures:	
NJ Mudhole	Closed from February 15 - March 15
Gear Modification Requirements:	
NJ waters (excluding Mudhole)	January 1 – April 30
NJ Mudhole	January 1 – February 14 and March 16 – April 30
Southern Mid-Atlantic waters	February 1 – April 30

Table 2. Descriptive statistics about the bycatch of harbor porpoises in waters off of New Jersey during January to April.

	Year									Total
	1999	2000	2001	2002	2003	2004	2005	2006	2007	
Number of observed hauls	186	16	26	7	20	66	84	201	115	721
Number of observed trips	61	3	8	2	8	18	27	54	21	202
Number of observed vessels	26	3	4	1	5	14	17	32	17	119
Number of observed hauls with one or more take	0	0	0	0	1	0	7	22	0	30
Total number of observed takes	0	0	0	0	1	0	15	27	0	43
Bycatch rate (observed total takes/observed number of hauls)	0	0	0	0	0.050	0	0.179	0.134	0	0.060
Bycatch rate (observed total takes/observed mt of landings)	0	0	0	0	0.110	0	0.445	0.530	0	0.233

Table 3. By month, the number of observed hauls and takes and resulting bycatch rate (number of observed takes per number of observed hauls)

	Month			
	Jan	Feb	Mar	Apr
Number of observed hauls	328	114	46	233
Number of observed takes	12	28	0	3
Bycatch rate (obs takes/obs hauls)	0.037	0.246	0.000	0.013

Table 4.

Bycatch rates (Byc Rate) and number of observed hauls (Num Obs) with various gear characteristics, fishing practices and environmental factors. The bycatch rate is defined as observed number of hauls with one or more takes per the observed landings in those hauls (in mtons). The overall average bycatch rate is 0.163.

Categories of variables with ** in the Num Obs column have less than 6 mtons of landings (thus, there is a very small chance of observing one take given the overall bycatch rate). Categories of variables with * in the Num Obs column have less than 12 mtons of landings (thus, there is a small chance of observing one take).

Categories of variables with a high bycatch rate (> 0.3) are highlighted.

Category	Num Obs	Byc Rate		Category	Num Obs	Byc Rate		Category	Num Obs	Byc Rate
MONTH				**TARGET SPECIES**				**TOT LENGTH OF STRING (feet)**		
Jan	328	0.109		Monkfish	430	0.225		0-2000	235	0.000
Feb	114	0.443		Bluefish	20**	0.000		2000-4000	174	0.056
Mar	46*	0.000		Herring	2**	0.000		4000-6000	213	0.393
Apr	233	0.070		Am. Mackerel	37*	0.000		6000-8000	74	0.025
				Menhaden	9**	0.000		8000-14000	11**	0.184
YEAR				Weakfish	81**	0.000				
1999	186	0.000		Am. shad	47**	0.000		**HANG RATIO**		
2000	16**	0.000		Spiny dogs	41	0.000		0.33	61	0.080
2001	26**	0.000		Skate, unk	4**	0.000		0.5	648	0.172
2002	7**	0.000		Win. Skate	3**	0.000				
2003	20*	0.110		Strip Bass	24**	0.000		**TWINE SIZE (mm)**		
2004	66	0.000		Groundfish	21**	0.000		0.33	7**	0.000
2005	84	0.208		Mackerel, unk	2**	0.000		0.40	5**	0.000
2006	201	0.432						0.47	1**	0.000
2007	115*	0.000		**SURFACE WATER TEMP (degC)**				0.52	19**	0.000
				2-4	11**	0.524		0.57	41*	0.000
TYPE OF TRIP				4-6	199	0.104		0.62	12**	0.000
FISH	146	0.140		6-8	216	0.284		0.66	18**	0.000
MM (limited)	575	0.170		8-10	155	0.066		0.70	45	0.000
				10-12	17**	0.000		0.74	9**	0.000
STEAM TIME (hrs)								0.81	60	0.054
0-2	377	0.033		**BOTTOM WATER TEMP (degC)**				0.90	375	0.244
2-4	185	0.310		3-4	12**	0.000				
4-6	99	0.200		4-5	115	0.175		**MESH SIZE (inches)**		
6-8	38	0.053		5-6	171	0.257		2-4	70	0.000
8-10	19*	0.213		6-7	139	0.177		4-6	186	0.000
10-14	2**	0.000		7-8	74	0.181		6-8	27*	0.000
				8-9	44	0.000		8-10	3**	0.000
WIND SPEED (knots)				9-10	8**	0.000		10-12	434	0.224
0-10	413	0.171								
10-20	256	0.181		**BOTTOM SLOPE**				**USED TIE DOWNS**		
20-30	27*	0.000		0.00-0.05	213	0.054		no	300	0.000
30-40	3**	0.000		0.05-0.10	238	0.204		yes	407	0.241
				0.10-0.15	99	0.403		unk	14**	0.000
WAVE HEIGHT (feet)				0.15-0.20	28**	0.496				
0-2	291	0.188		0.20-0.25	17**	0.000		**USED SPACES**		
2-4	267	0.221						no	551	0.216
4-6	100	0.059		**SOAK DURATION (hrs)**				yes	166	0.036
6-8	28*	0.000		0-100	540	0.051		unk	9**	0.000
8-10	4**	0.000		100-200	141	0.287				
				200-300	24*	0.749		**USED DROP LINES**		
				300-700	15**	0.339		no	510	0.236
								yes	9**	0.000
								unk	198	0.000

				NET HEIGHT (feet)				**USED ANCHORS**		
				0-5	23	0.000		no	77**	0.000
				5-10	312	0.110		yes	644	0.165
				10-15	221	0.280				
				15-30	91*	0.000				
LENGTH OF TIE DOWN (feet)								**USED ADDED WEIGHTS**		
Categories	Num Obs	Byc Rate		**NUMBER OF SPACES**				Categories	Num Obs	Byc Rate
2-3	216	0.123		Categories	Num Obs	Byc Rate		no	453	0.000
3-4	144	0.405		0-10	76	0.000		yes	66*	0.238
4-5	4**	0.000		10-20	75	0.042		unk	198	0.166
5-6	8**	0.000		20-40	11*	0.000				
				30-40	1**	0.000		**ANCHOR WEIGHT TYPE**		
NUMBER OF ANCHORS				**ANCHOR WEIGHT (pounds)**				0	80**	0.000
1	1**	0.000		0-20	2**	0.000		1	278	0.064
2	401	0.166		20-40	89	0.163		2	363	0.275
3	1**	0.000		40-60	424	0.114				
4	26	1.070		60-80	39**	0.000		**LEAD LINE DEPTH**		
6	4**	0.000		80-100	40	0.925		0-10	194	0.000
				100-160	41**	0.000		10-20	132	0.134
GROSS TONNAGE								20-30	95	0.132
0-20	80	0.365		**MTONS LANDED**				30-40	61	0.438
20-40	84	0.000		0-0.5	602	0.227		40-50	22*	0.715
40-60	23**	0.000		0.5-1	82	0.125		50-60	8**	0.000
60-120	20*	0.000		1-1.5	15	0.000				
				1.5-3	7	0.071		**AMT OF CHLOROPHYLL**		
AMT FISH DISCARDED								0-10	210	0.422
0-200	120	0.103		**WINTER N. ATL OSCILLATION**				10-20	35**	0.000
200-400	14*	0.185		-0.4 to -0.2	227	0.396		20-30	3**	0.000
400-1400	8**	0.000		-0.2 - 0.0	0	0.000		30-60	3**	0.000
				0.0 - 0.2	20**	0.110				
SEDIMENT TYPE				0.2 - 0.4	157	0.133		**LOG10(AMT OF CHLOROPHYLL)**		
Clay – Silt/Sand	105	0.295		0.4 - 0.6	186	0.000		-0.5-0	17**	0.520
Gravel	24	0.000		0.6 - 1.2	16**	0.000		0-0.5	86	0.331
Gravel – Sand	97	0.078						0.5-1	107	0.556
Sand	367	0.174		**NORTH ATLANTIC OSCILLATION**				1-1.5	38**	0.000
Sand – Clay/Silt	5	0.000		-1 to -0.5	83	0.318		1.5-2	3**	0.000
				-0.5 to 0	88	0.215				
DIST TO 50 M DEPTH CONTOUR				0 - 0.5	77	0.000		**DEPTH (fathoms)**		
0-2000	83	0.280		0.5 - 1.0	99	0.033		0-20	238	0.000
2000-4000	73	0.498		1.0 - 1.5	198	0.330		20-40	243	0.061
4000-6000	45	0.325		1.5 - 2.0	61	0.043		40-60	145	0.091
6000-8000	42	0.366						60-80	73	0.666
8000->	356	0.000						80-100	18**	0.386

Table 5. During January to April 1999 to 2007, the number of observed hauls and number of takes that were in gillnets that were in and out of compliance with the harbor porpoise TRP for Mid-water gillnets. Note, any one haul could be out of compliance for one or more of the requirements.

Large mesh is 7-18 inches, small mesh is >5 to <7 inches, and extra small mesh (not regulated in TRP) is ≤ 5 inches.

ALL HAULS	In compliance?	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	No	25	0	9	7	19	43	63	115	11	292
	Yes	161	16	17	0	1	23	21	86	104	429
	% compliant	0.87	1.00	0.65	0.00	0.05	0.35	0.25	0.43	0.90	0.60
	TOTAL	186	16	26	7	20	66	84	201	115	721
Number of takes	No	0	0	0	0	1	0	9	18	0	28
	Yes	0	0	0	0	0	0	6	9	0	15
	TOTAL	0	0	0	0	1	0	15	27	0	43

SMALL MESH	In compliance?	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	No	15	0	0	0	0	15	0	1	0	31
	Yes	28	0	0	0	0	1	0	25	48	102
	% compliant	0.65	0.00	0.00	0.00	0.00	0.06	0.00	0.96	1.00	0.77
	TOTAL	43	0	0	0	0	16	0	26	48	133
Number of takes	No	0	0	0	0	0	0	0	0	0	0
	Yes	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	0	0	0	0	0	0	0	0	0

LG MESH	In compliance?	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	No	10	0	9	7	19	28	63	114	11	261
	Yes	89	7	4	0	1	5	21	32	17	176
	% compliant	0.90	1.00	0.31	0.00	0.05	0.15	0.25	0.22	0.61	0.40
	TOTAL	99	7	13	7	20	33	84	146	28	437
Number of takes	No	0	0	0	0	1	0	9	18	0	28
	Yes	0	0	0	0	0	0	6	9	0	15
	TOTAL	0	0	0	0	1	0	15	27	0	43

EXTRA SMALL	In compliance?	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	Yes	44	9	13	0	0	17	0	29	39	151
Number of takes	Yes	0	0	0	0	0	0	0	0	0	0

Table 6. During January to April 1999 to 2007, a description of the numbers of hauls, trips and vessels that were out of compliance with the LARGE MESH management measures in the harbor porpoise TRP as applied to (A) the Mudhole (B) the waters off the New Jersey (excluding the Mudhole) and (C) all the waters off of New Jersey, including the Mudhole. Also, the number of observed takes are also listed.

(A) MUDHOLE

FLOAT LINE LENGTH GREATER THAN 3900 FEET

	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	0	0	0	7	2	0	15	34	4	62
Number of trips	0	0	0	2	1	0	6	12	2	23
Number of vessels	0	0	0	1	1	0	4	9	2	17
Number of HP takes	0	0	0	0	0	0	1	3	0	4

HAULED NETS DURING THE CLOSED PERIOD FEB 15 TO MAR 15

	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	0	0	0	0	0	0	0	0	1	1
Number of trips	0	0	0	0	0	0	0	0	1	1
Number of vessels	0	0	0	0	0	0	0	0	1	1
Number of HP takes	0	0	0	0	0	0	0	0	0	0

(B) WATERS OFF OF NEW JERSEY (EXCLUDING THE MUDHOLE)

FLOAT LINE LENGTH GREATER THAN 4800 FEET

	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	7	0	6	0	17	24	37	65	7	163
Number of trips	5	0	4	0	7	9	16	26	3	70
Number of vessels	5	0	3	0	4	7	12	16	3	50
Number of HP takes	0	0	0	0	1	0	8	14	0	23

Table 6 (continued). During January to April 1999 to 2007, a description of the numbers of hauls, trips and vessels that were out of compliance with the LARGE MESH management measures in the harbor porpoise TRP as applied to (A) the Mudhole (B) the waters off the New Jersey (excluding the Mudhole) and (C) all the waters off of New Jersey, including the Mudhole. Also, the number of observed takes are also listed.

(C) WATERS OFF OF NEW JERSEY (INCLUDING THE MUDHOLE)

TWINE SIZE LESS THAN 0.90MM

	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	0	0	0	0	0	12	16	20	0	48
Number of trips	0	0	0	0	0	4	7	5	0	16
Number of vessels	0	0	0	0	0	4	5	4	0	13
Number of HP takes	0	0	0	0	0	0	0	1	0	1

TIED DOWNS NOT USED

	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	3	0	0	0	0	3	11	0	6	23
Number of trips	1	0	0	0	0	1	4	0	2	8
Number of vessels	1	0	0	0	0	1	1	0	2	5
Number of HP takes	0	0	0	0	0	0	0	0	0	0

HAULED NETS DURING THE CLOSED PERIOD APRIL 1-20

	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Number of hauls	0	0	3	0	0	0	0	3	0	6
Number of trips	0	0	1	0	0	0	0	2	0	3
Number of vessels	0	0	1	0	0	0	0	1	0	2
Number of HP takes	0	0	0	0	0	0	0	3	0	3

Table 7. Final models using three different variables as the best 1-variable model. Inclusion of variables in the model is in the order within each column.

Model 1			**Model 2**			**Model 3**	
Variable	**AIC**		**Variable**	**AIC**		**Variable**	**AIC**
None	249.27		None	249.27		None	249.27
Bottom depth	185.65		Dist to 50m depth	185.28		Number of anchors	186.49
Surface water temp	158.74		Number of anchors	151.86		Dist to 50m depth	151.86
Winter NAO	136.01		Bottom water temp	137.47		Bottom water temp	137.47
Dist to 50m depth	127.99		Winter NAO	129.61		Winter NAO	129.61
Vessel gross tons	121.44		Vessel gross tons	120.96		Vessel gross tons	120.96
Anchor weight	118.00		Soak duration	118.98		Soak duration	118.98

Figure 1. By year, the location of observed hauls (colored circles) and harbor porpoise takes (red crosses) during January to April 1999 to 2007. The "Mudhole" is shaded in green and the "waters off of New Jersey" are shaded in blue. Depth contours are 10, 30, 40, 50, 100, and 200m.

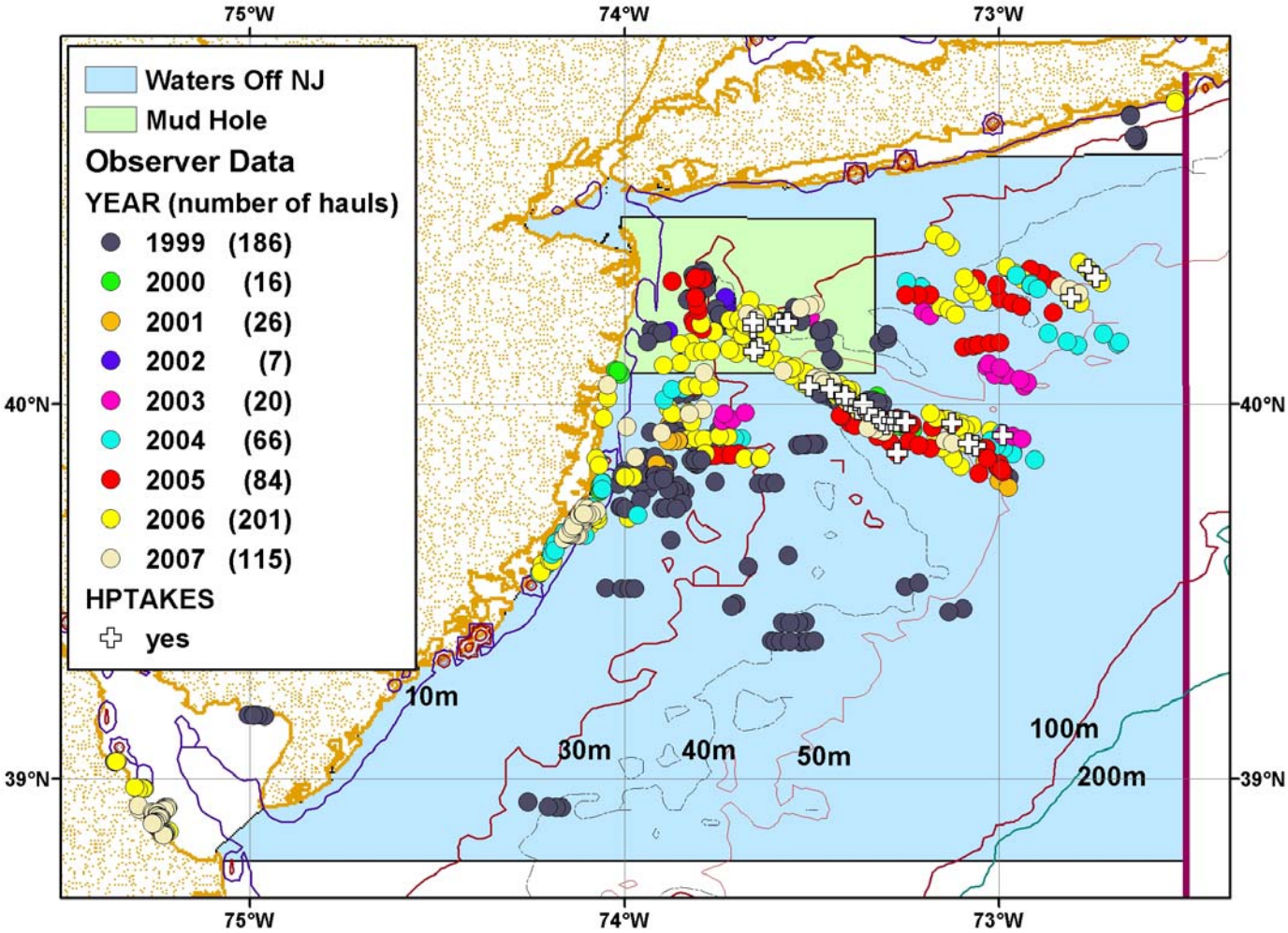


Figure 2. During January to April 1999 to 2007, the location of harbor porpoise takes by year (colored symbols) and number of takes per haul (size of stack: dash is no takes, tallest stack is 4 animals per haul). The "Mudhole" is shaded in pink and the "waters off of New Jersey" are shaded in beige. Depth contours are 10, 20, 30, 40, 50, 100, and 200m.

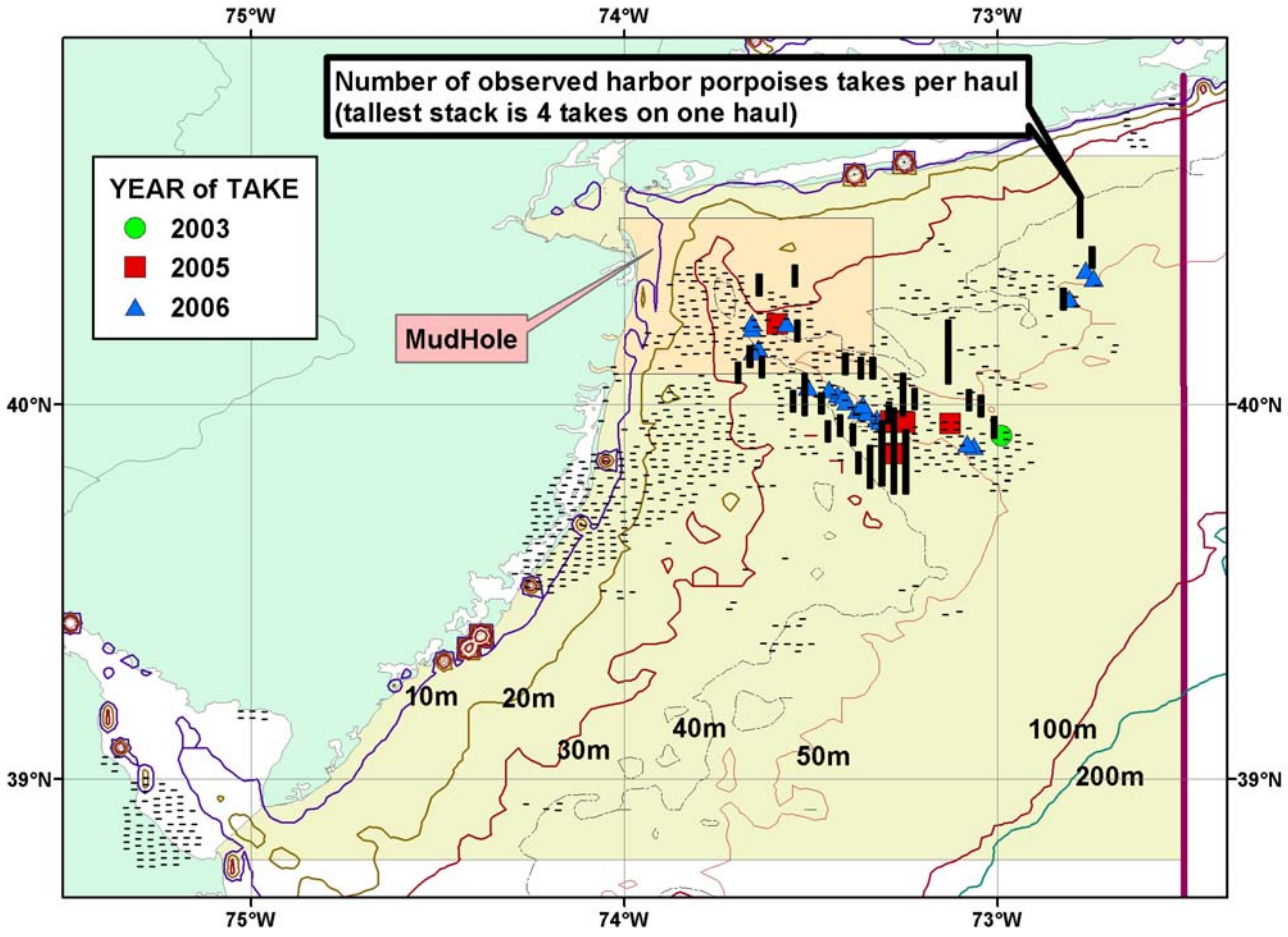


Figure 3. Relationship between the harbor porpoise bycatch rate (total number of observed takes per total landings (mtons)) and gear length (feet) using data from the waters off New Jersey, including the Mudhole collected during January to April 1999 to 2007. Values of the gear length which have a y-value greater than zero (greater than 4000 feet) have higher than average bycatch rates. Tick marks on the x-axis indication the values of the observations, where the tick marks are jittered (spread out) to help display where there are values that are shared by many observations.

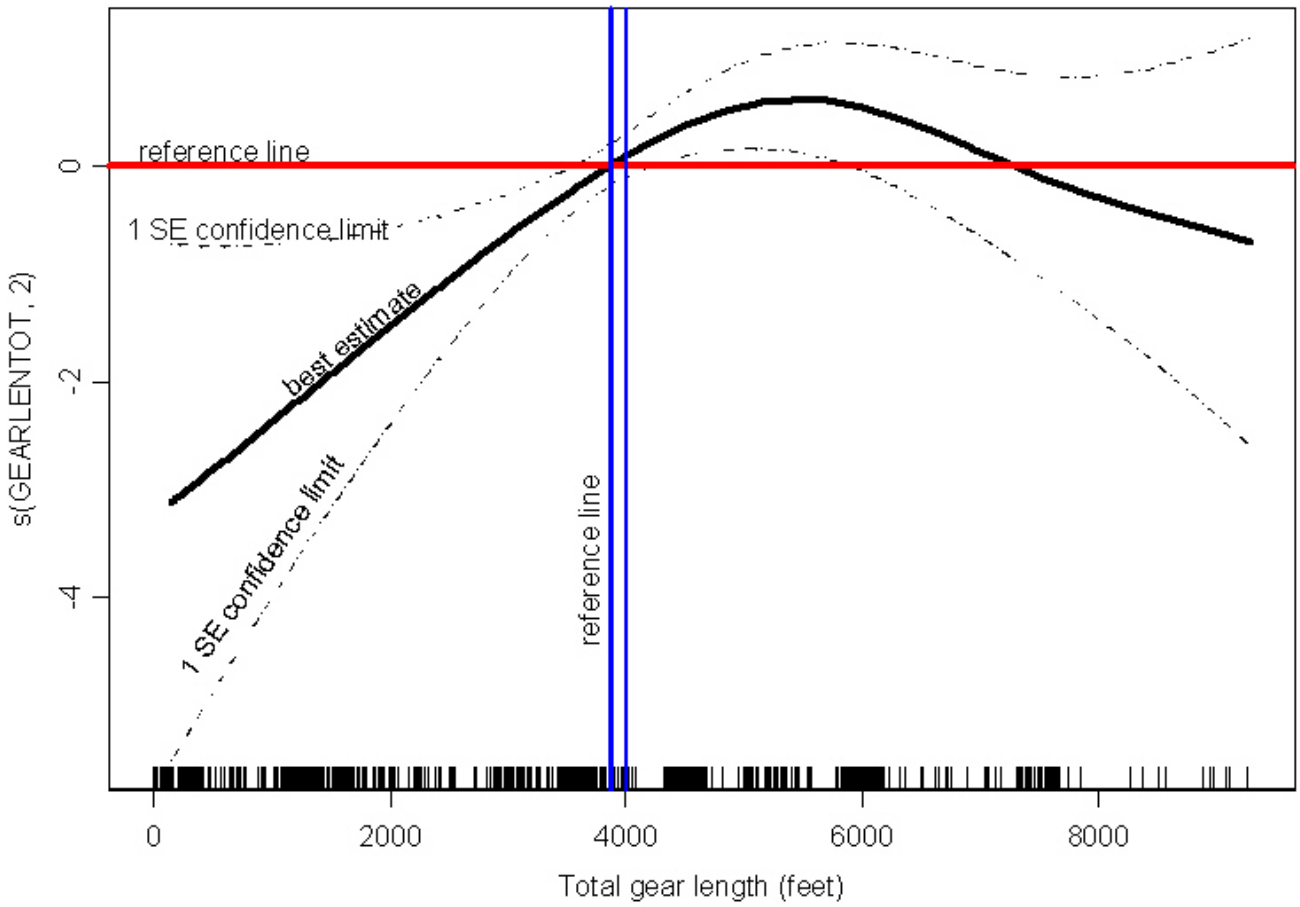


Figure 4. Results of stepwise analysis to model bycatch rates where the first variable used is depth. There is one plot per variable in the model. Values of the variable that are above the red line have a correlation with higher than average bycatch rates. The tick marks on bottom of each plot are the location of the observations, which were jittered to break ties. For more details about the model see Table 7.

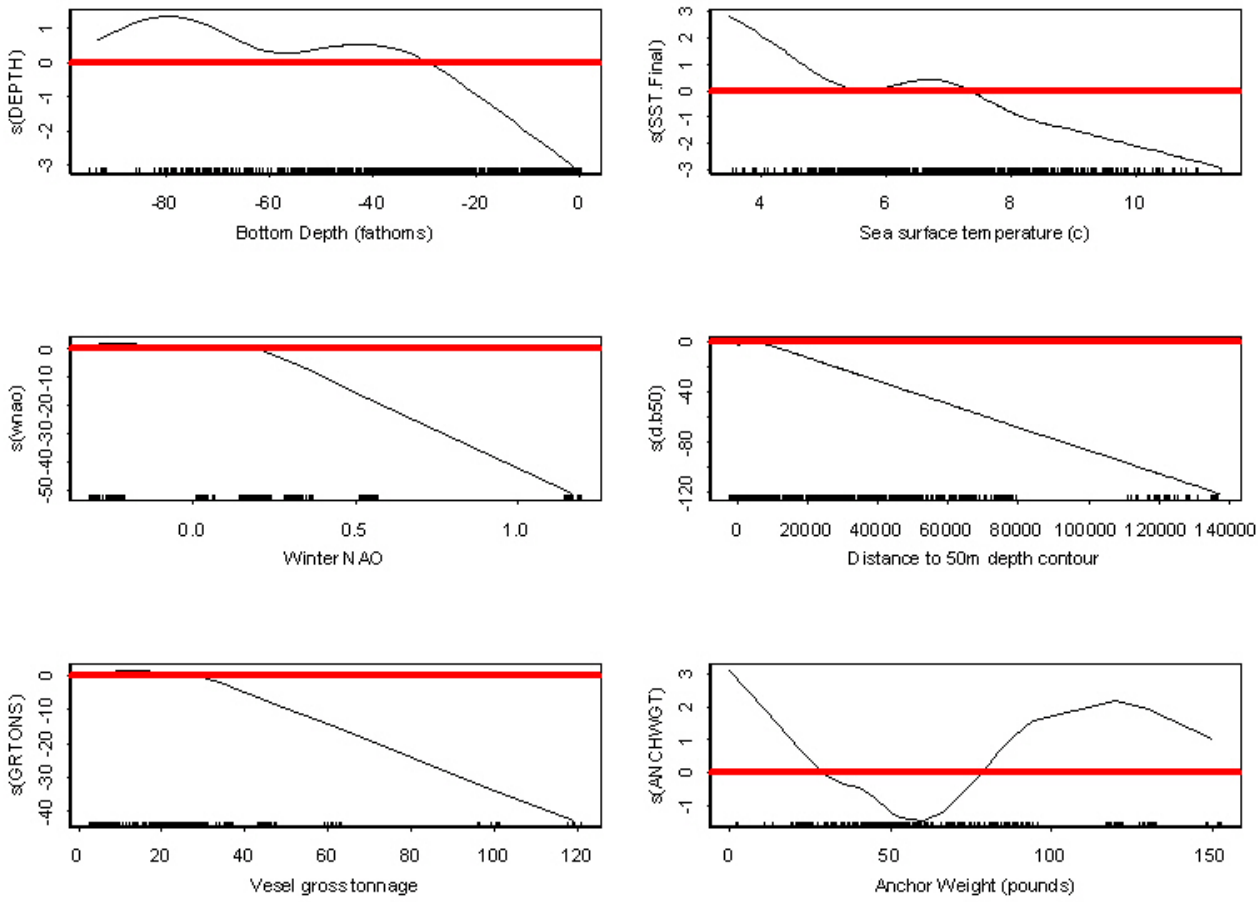


Figure 5. Results of stepwise analysis to model bycatch rates where the first variable used is distance to the 50m depth contour. There is one plot per variable in the model. Values of the variable that are above the red line have a correlation with higher than average bycatch rates. The tick marks on bottom of each plot are the location of the observations, which were jittered to break ties. For more details about the model see Table 7.

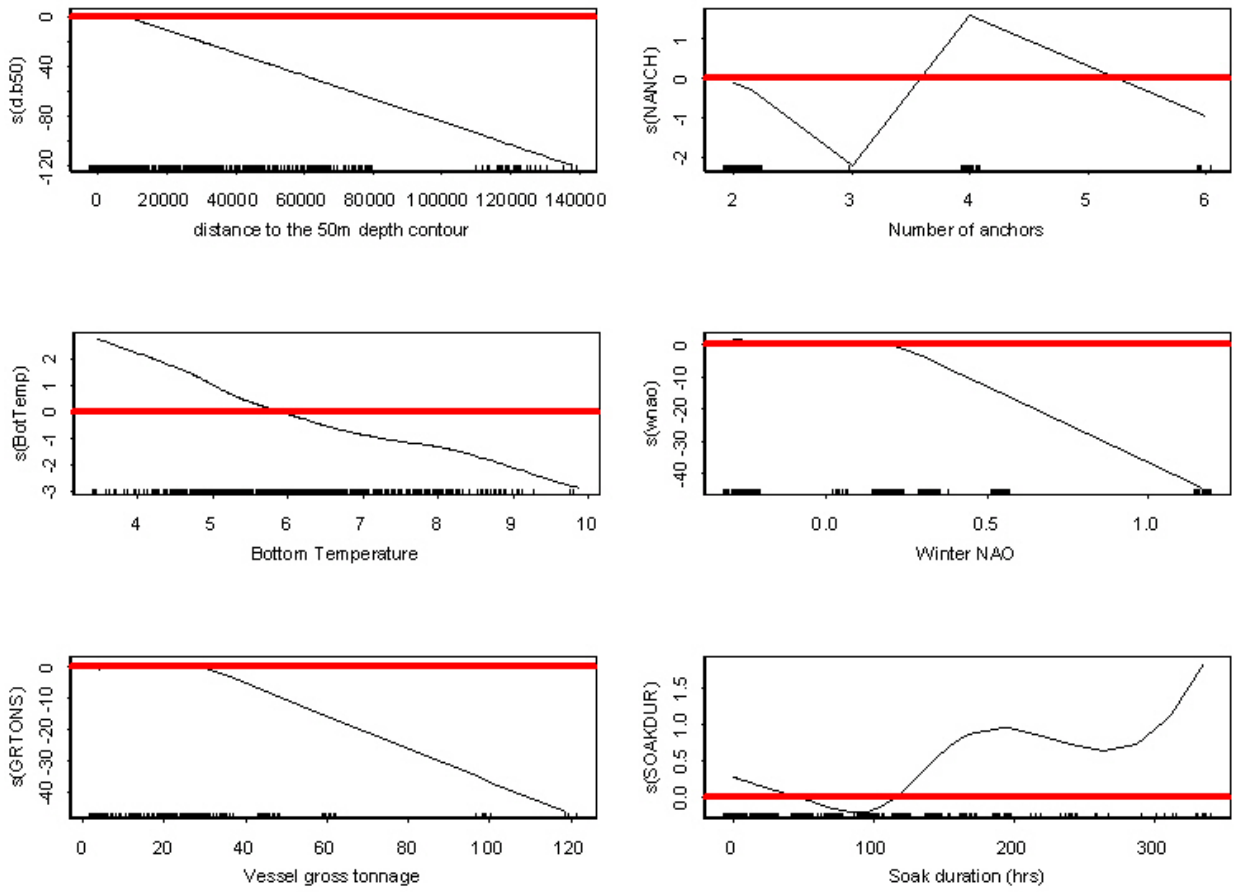


Figure 6. Plots of the location of gillnet VTR trips during January and February from 2004 and 2005.

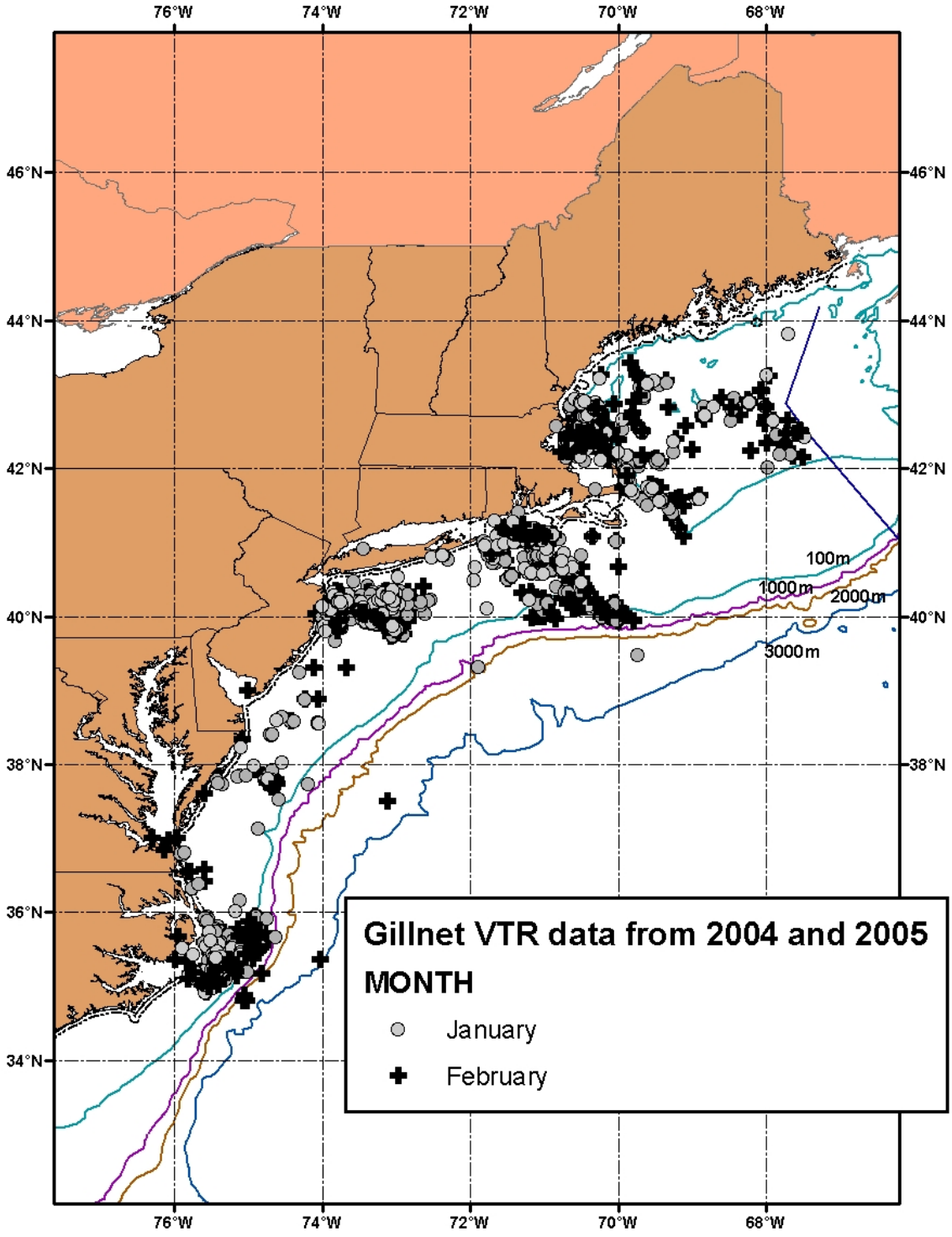


Figure 7. Plots of the location of gillnet VTR trips during March and April from 2004 and 2005.

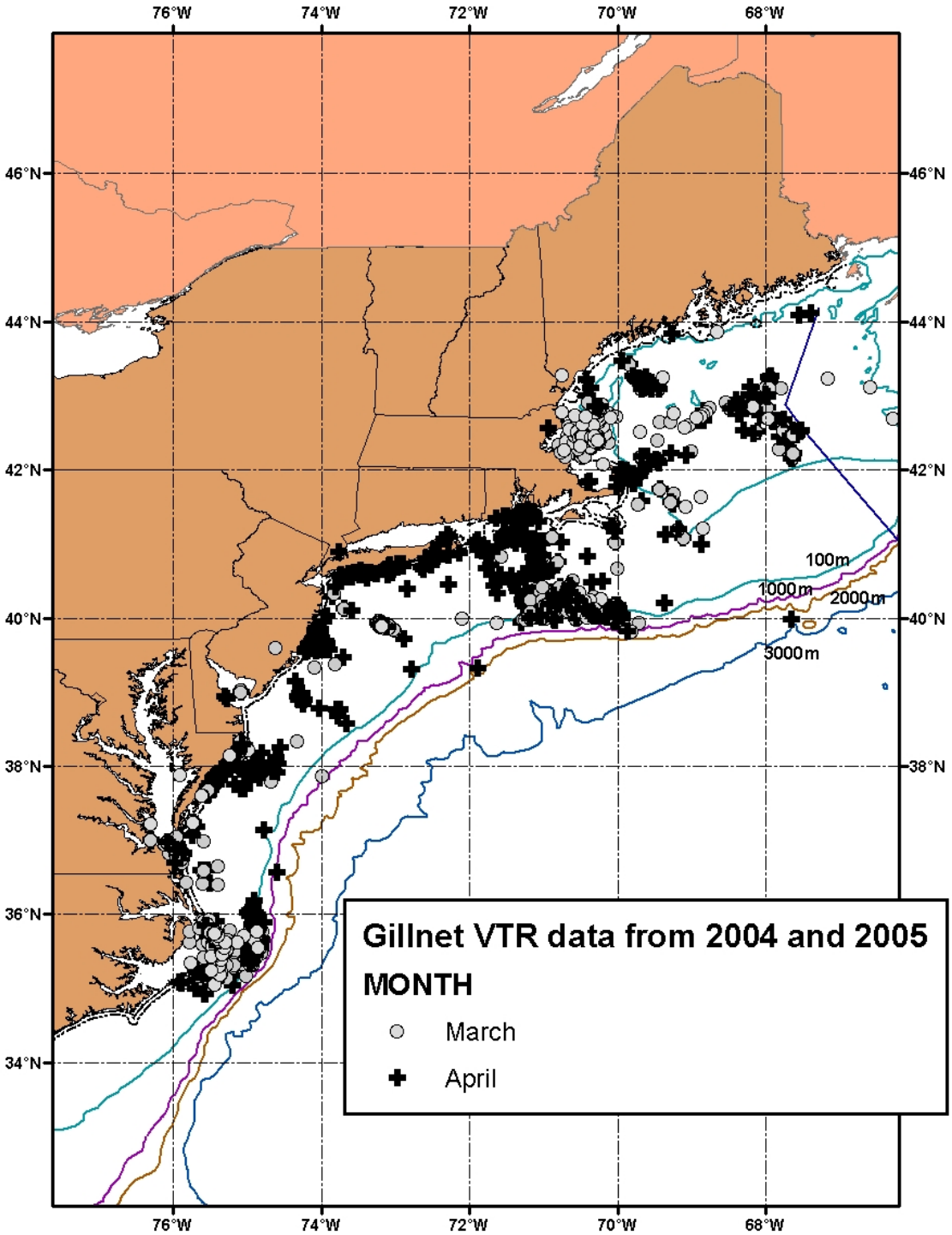


Figure 8. Using data from January to April 1999 to 2007, plots of winter NAO value versus the sea surface and bottom water temperatures. Lines are robust regressions of the data points. Large square symbols are the hauls with a take.

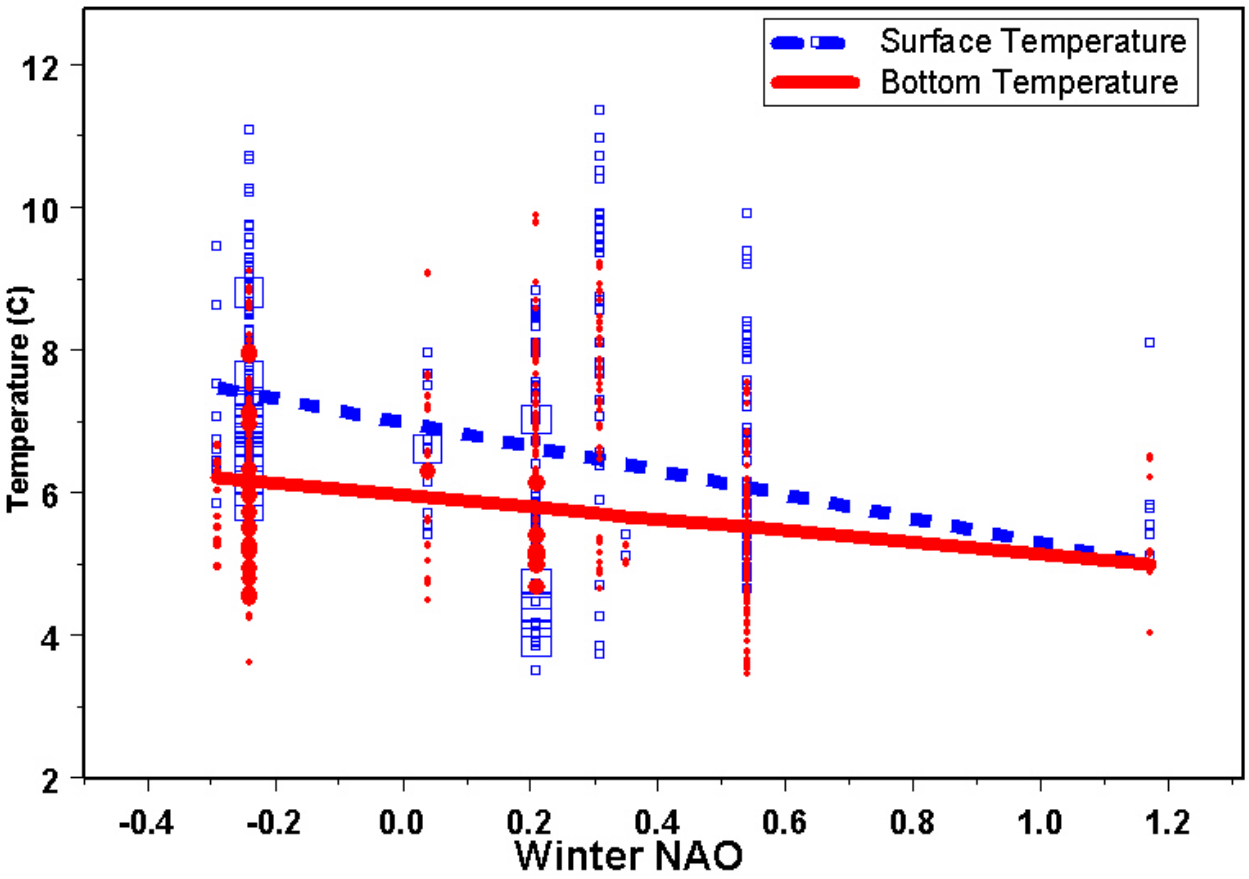


Figure 9. Using data from January to April 1999 to 2007, a classification tree model was used to predict the number of anchors that were used: 2 versus 4 (ignoring the few hauls that used 1, 3, or 6 anchors). To interpret this tree, the top break means hauls that are less than 59.436 fathoms have characteristics that are to the left of the break, and hauls in deeper water used 2 anchors. The predicted number of anchors (2 or 4) is the values at the end of each branch. The longer the vertical branch the more highly correlated is that variable to the number of anchors used during a haul.

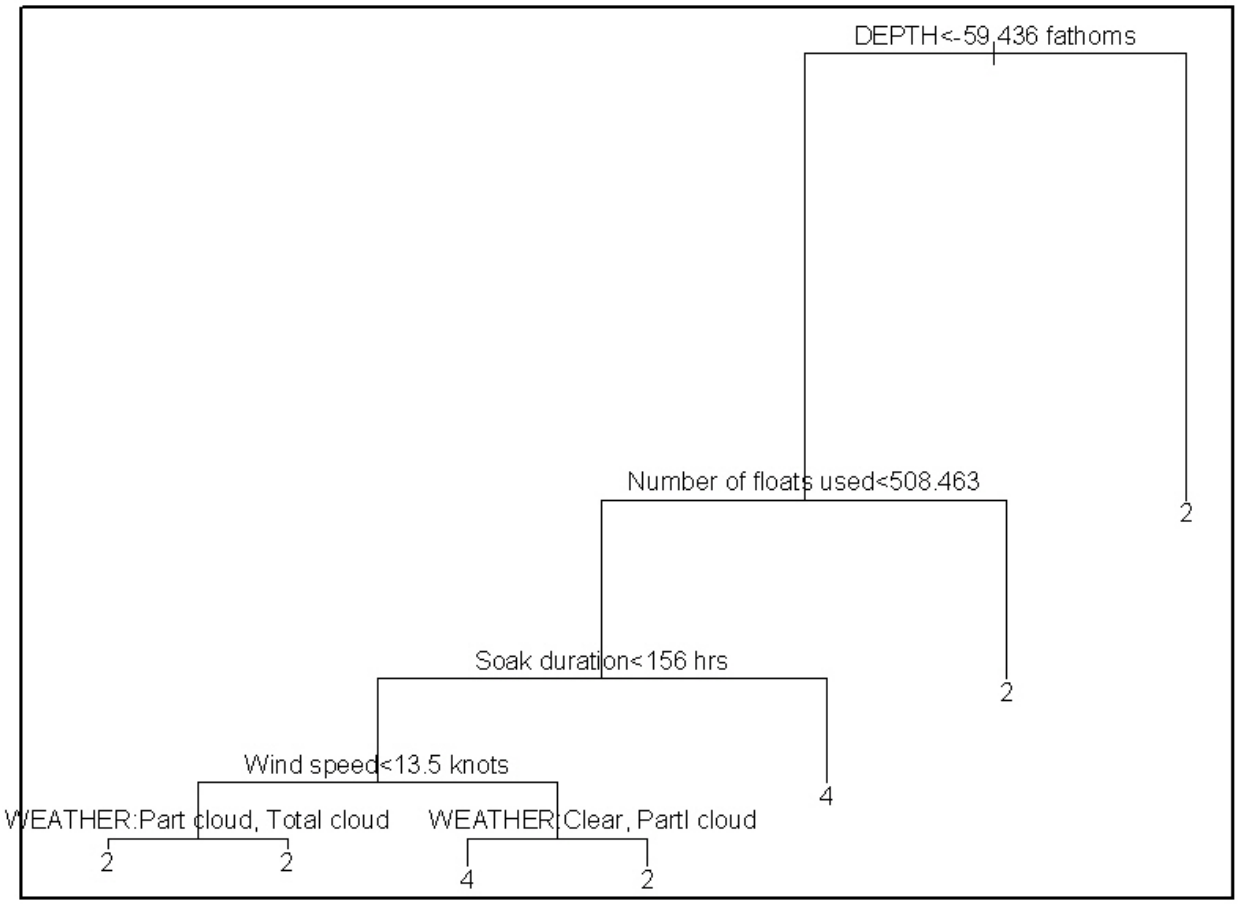
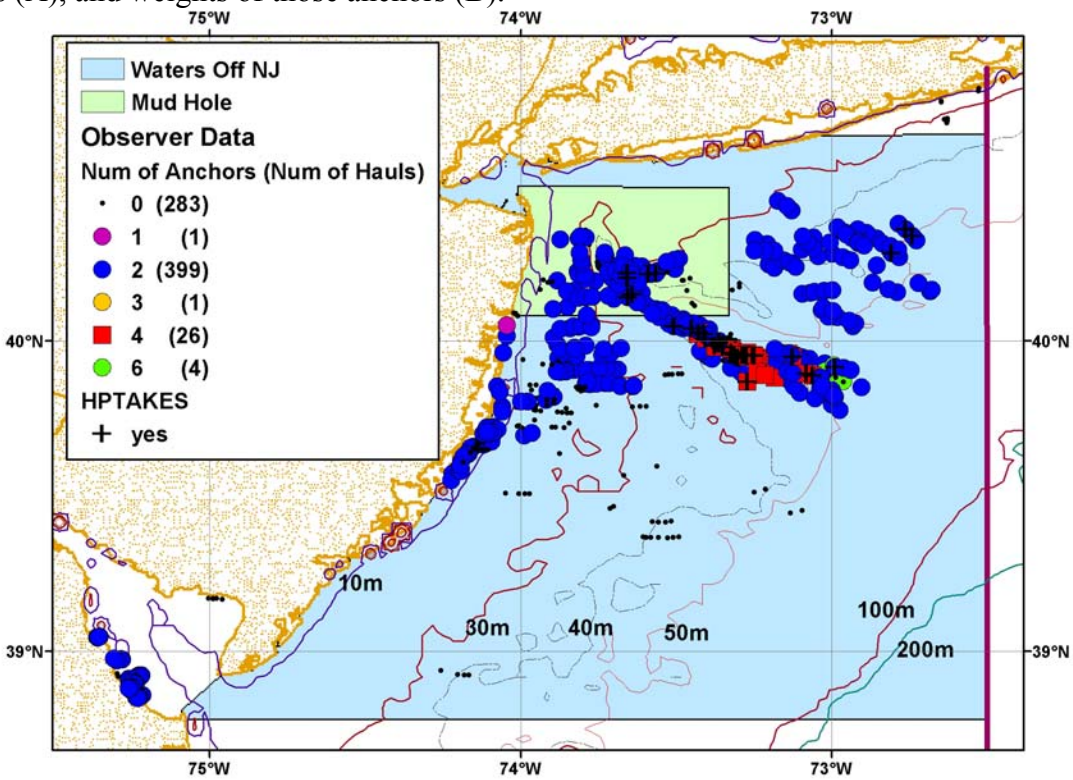
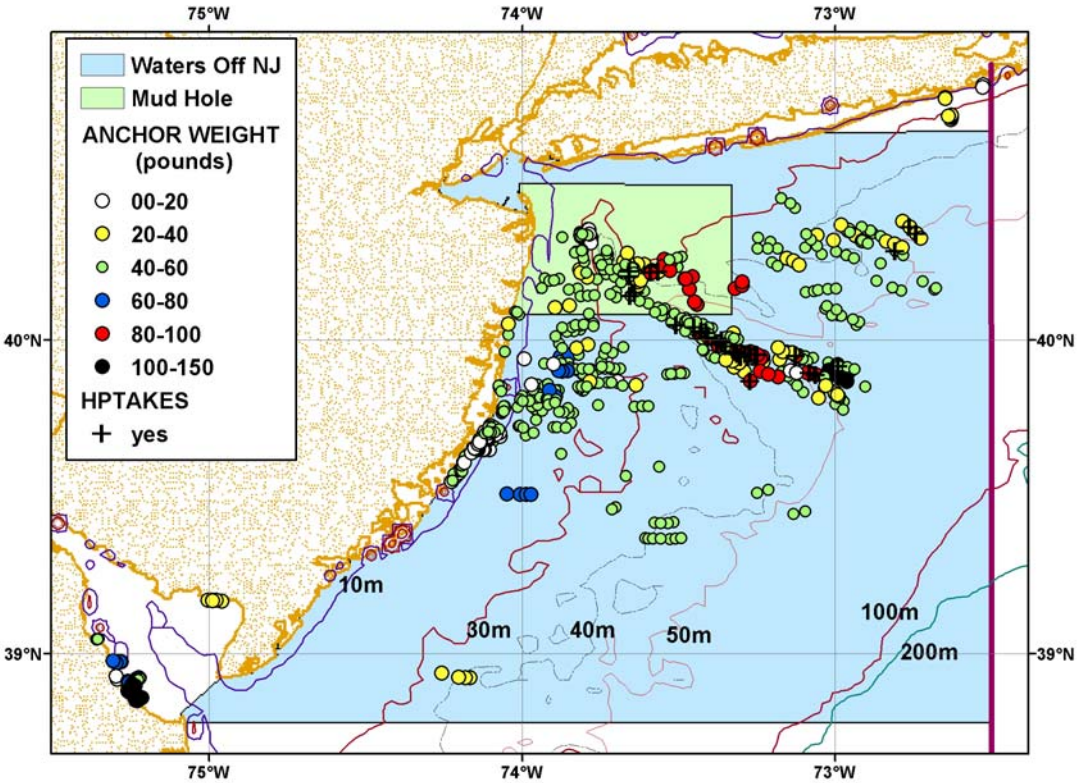


Figure 10. During January to April 1999 to 2007, the location of hauls with various numbers of anchors (A), and weights of those anchors (B).

(A)



(B)