Appendix IV

Herring PDT Analysis: Development of Measures to Address River Herring Bycatch

A: July 2010
B: August 30, 2010 (Updated)
C: August 30, 2010 Supplemental Material
D: December 20, 2010 – Final Draft Spatial

DRAFT

Identification of river herring hotspots at sea using multiple fishery dependent and independent datasets

Prepared for the Atlantic Herring PDT

by

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Background

At its May 2010 meeting, the New England Fisheries Management Council Herring Oversight Committee tasked the Plan Development Team (PDT) with identifying river herring hotspots as part of the analysis for Amendment 5 to the Atlantic Herring fishery management plan (FMP). Specifically, one of the objectives for Amendment 5 of the FMP is to address river herring bycatch in the Atlantic herring, *Clupea harengus*, fishery.

Here, the term "river herring" refers to alewife, *Alosa pseudoharengus*, and blueback herring*, Alosa aestivalis*. This analysis combines available data on both species to identify river herring hotspots. Furthermore, this work differs from other studies on the bycatch of river herring in ocean fisheries (Shepherd 1986, Cieri et al. 2008, Wigley et al. 2009) because it incorporates fishery dependent and independent data. The following is a summary of the method and analysis developed by the PDT to identify river herring hotspots.

Study Area

The study area includes the Atlantic herring fishery management plan areas that overlap the Eastern US Continental shelf (Fig. 1).

Datasets and Data Selection

Multiple data sources are used in this analysis to identify river herring hotspots at sea. These sources include fishery dependent (Vessel Trip Reports, VTR and Northeast Fishery Observer Program, NEFOP) and fishery independent (National Marine Fisheries Service, NMFS bottom-trawl surveys) datasets (Tables 1-3). The most recent 5 years (2005-2009) of fishery dependent data and 15 years (1994-2008) of fishery independent are pooled separately by dataset in the analysis.

Data from directed herring trips were selected from VTR and NEFOP databases and grouped by quarter: 1, 2, 3, and 4 (Tables 1 and 2). Here, directed herring trips were defined as 2,000 lbs of kept Atlantic herring on a trip. Data from other non-directed trips is not included in the analysis, but may become the scope of future examination. In addition, fishery dependent data included three broad gear categories: bottom otter-trawl, purse seine, and mid-water trawl (combining single and pair mid-water trawls).

River herring data from observed directed herring trips (NEFOP) were presence/absence and weight (lbs) from each haul or set. Data from the Massachusetts Division of Marine Fisheries and the Maine Department of Marine Resources portside surveys were excluded because spatial information was not available for all years and all trips.

Selected river herring data from NMFS bottom-trawl surveys included presence/absence and the number of individuals found at each sampling location. Surveys were separated by season: winter, spring, and fall (Tables 3 and 4).

Methods

Fishing Effort and River Herring Bycatch

To understand where and when the directed herring fishery operated throughout the fishing year, quarterly maps and tables of the number of trips per statistical area were constructed using VTRs (Figs. 2-5, Appendix Tables A.1-A.4). Fishing effort was approximated by the number of trips within a statistical area. Quarterly maps of fishing effort by statistical areas were color-coded from hot (red) to cool (blue) to identify fishing effort concentration areas.

These maps were overlaid with quarterly NEFOP data on river herring bycatch events from observed hauls and sets. Circles of increasing size represent the magnitude of the bycatch event. These bycatch events were binned into circles of increasing size using all years and quarters combined and then mapped separately by quarter.

Hotspots

Seasonal NMFS bottom-trawl surveys were used to identify river herring "hotspot" areas (Appendix Figure A.1). Analyses for the winter, spring, and fall surveys were conducted separately for two spatial stratification schemes:

- fisheries statistical areas (Fig. 1) and
- survey strata (Appendix Figs. A.2- A.5).

Regardless of the spatial stratification scheme, at least 10 tows per strata were required for inclusion in the analysis. Strata with less than 10 tows were omitted from the analysis.

For each seasonal survey and stratification scheme, two metrics were used to determine hotspots:

- percent occurrence and
- median Q index.

Within each spatial stratum, percent occurrence was defined as the count of tows with river herring present divided by the total tows. For example if for a given area, the number of tows was 100, and out of those 100 tows 66 tows detected river herring. The percent occurrence for that area was 66%. The percent occurrence for each spatial strata was used for ranking.

The Q index standardizes the number of river herring caught per tow to reduce the effect of annual sampling variation and differences in sample size among years. The Q index can be interpreted as reflecting the density of river herring within a given spatial strata. Because the NMFS bottom trawl survey has predefined survey strata, results for the Q index that ignore the survey strata (i.e., results of the Q index for each statistical area) should be interpreted cautiously and may not reflect river herring density in a

given area because such methods violate assumptions of the a priori survey sampling design. The median of the Q-index for each spatial strata was used for ranking hotspots.

The strata for each stratification scheme (i.e., statistical areas or survey strata) were ranked using each metric and recorded in respective tables, plots and maps (Figs.6-8, Appendix Tables A.5-A.10, Figs. A.6- A.14). Maps of ranked areas were color-coded from hot (red) to cool (blue or purple) to identify river herring hotspot areas. These maps were overlaid with quarterly NEFOP data on river herring bycatch from observed hauls and sets based on the timing of the NMFS bottom-trawl surveys (Table 4).

Results

Fishing Effort and River Herring Bycatch

Visual differences in the spatial and temporal distribution of directed herring trips were evident from maps of fishing effort (Figs. 2-5). In general, fishing effort shifted from the northern Mid-Atlantic Bight and southern New England waters in quarter 1 to southern New England waters and the Gulf of Maine in quarter 2 (Figs. 2-3). In quarter 3, fishing effort concentrated in the Gulf of Maine and Georges Bank (Fig. 4). Then during quarter 4, fishing effort spanned the Gulf of Maine and southern New England waters (Fig. 5).

Using NEFOP haul and set data, river herring bycatch events were inspected by quarter. River herring bycatch events in quarter 1 included areas in Ipswich Bay, off the back of Cape Cod, and in the northern Mid-Atlantic Bight (Fig.2). In quarter 2, river herring bycatch events occurred in the northern Gulf of Maine, off the back of Cape Cod, and the Mid-Atlantic Bight (Fig. 3). In quarter 3, bycatch events included areas in the northern Gulf of Maine (Fig. 4). For quarter 4, bycatch events included the northern Gulf of Maine, Ipswich Bay, Massachusetts Bay, the back of Cape Cod, south of Martha's Vineyard, and near Block Island (Fig. 5).

Hotspots

Results include river herring hotspot areas ranked in tables, plots, and maps:

- percent occurrence by statistical area (Figs. 6-8, Appendix Tables A.5-A.7)
- percent occurrence by survey strata (Appendix Figs. A.6-A.8, Tables A.8-A.10
- median Q index by statistical area (Appendix Figs. A.9-A.11, Tables A.5-A.7)
- median Q index by survey strata (Appendix A.12-A.14, Tables A.8-A.10).

Each of these above combinations produced different hotspot maps. These seasonal maps were overlaid with observed river herring bycatch events by quarters. Although the timing of the quarterly observed river herring bycatch events did not perfectly match the timing of the seasonal NMFS bottom-trawl surveys (Table 4), they could be used to reference identified hotspot areas and in future analysis.

Tables

Q1-4	Gear Category			
Year	OT	PR	PS	ALL
2005	77	774	200	1051
2006	150	739	175	1064
2007	414	389	365	1168
2008	109	304	246	659
2009	203	406	225	834
ALL	953	2612	1211	**4776**

Q1	Gear Category			
Year	OT	PR	PS	ALL
2005	14	127	0	141
2006	67	160	0	227
2007	154	176	0	330
2008	63	128	0	191
2009	99	171	0	270
ALL	397	762	0	**1159**

Q2	Gear Category			
Year	OT	PR	PS	ALL
2005	8	161	25	194
2006	4	177	27	208
2007	1	105	52	158
2008	0	42	53	95
2009	7	30	53	90
ALL	20	515	210	**745**

Q3	Gear Category			
Year	OT	PR	PS	ALL
2005	16	294	142	452
2006	32	265	136	433
2007	224	7	258	489
2008	23	18	191	232
2009	42	75	156	273
ALL	337	659	883	**1879**

Q4	Gear Category			
Year	OT	PR	PS	ALL
2005	39	192	33	264
2006	47	137	12	196
2007	35	101	55	191
2008	23	116	2	141
2009	55	130	16	201
ALL	199	676	118	**993**

Table 1: Number of directed herring trips separated by gear, year and quarter. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Q1-4	Gear Category			
Year	OT	PR	PS	ALL
2005	15	465	95	575
2006	64	120	0	184
2007	59	75	27	161
2008	8	209	69	286
2009	35	437	97	569
ALL	181	1306	288	**1775**

Q1	Gear Category			
Year	OT	PR	PS	ALL
2005	0	56	0	56
2006	36	75	0	111
2007	37	35	0	72
2008	4	63	0	67
2009	27	91	0	118
ALL	104	320	0	**424**

Q2	Gear Category			
Year	OT	PR	PS	ALL
2005	0	65	5	70
2006	0	6	0	6
2007	0	9	0	9
2008	0	50	25	75
2009	0	56	39	95
ALL	0	186	69	**255**

Q3	Gear Category			
Year	OT	PR	PS	ALL
2005	13	175	75	263
2006	16	28	0	44
2007	11	3	24	38
2008	4	18	38	60
2009	4	122	54	180
ALL	48	346	191	**585**

Q4	Gear Category			
Year	OT	PR	PS	ALL
2005	2	169	15	186
2006	12	11	0	23
2007	11	28	3	42
2008	0	78	6	84
2009	4	168	4	176
ALL	29	454	28	**511**

Table 2: Observed hauls from directed herring trips separated by gear, year and quarter. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Source: NEFOP Database 2005-2009.

	Season			
Year	Winter	Spring	Fall	ALL
1994	79	299	288	666
1995	120	288	298	706
1996	114	291	263	668
1997	109	293	287	689
1998	116	321	294	731
1999	121	291	296	708
2000	107	292	294	693
2001	146	280	283	709
2002	138	274	289	701
2003	70	271	281	622
2004	119	285	278	682
2005	82	261	279	622
2006	103	292	306	701
2007	117	316	295	728
2008		297	306	603
ALL	1541	4351	4337	**10229**

Table 3: Number of tows from seasonal research surveys separated by year and season. Source: NMFS bottom-trawl surveys 1994-2008.

		NMFS BTS Seasons		
Month	Fishing Quarter	Winter	Spring	Fall
1	1	16		
2	1	1498	9	
3	1	27	2402	
4	2		1916	
5	2		24	
6	2			
7	3			
8	3			
9	3			2262
10	4			1970
11	4			105
12	4			

Table 4: Number of tows from seasonal research surveys separated month, fishing quarter, and survey season. Note that spring and fall surveys overlap multiple fishing quarters. Source: NMFS bottom-trawl surveys 1994-2008.

Figures

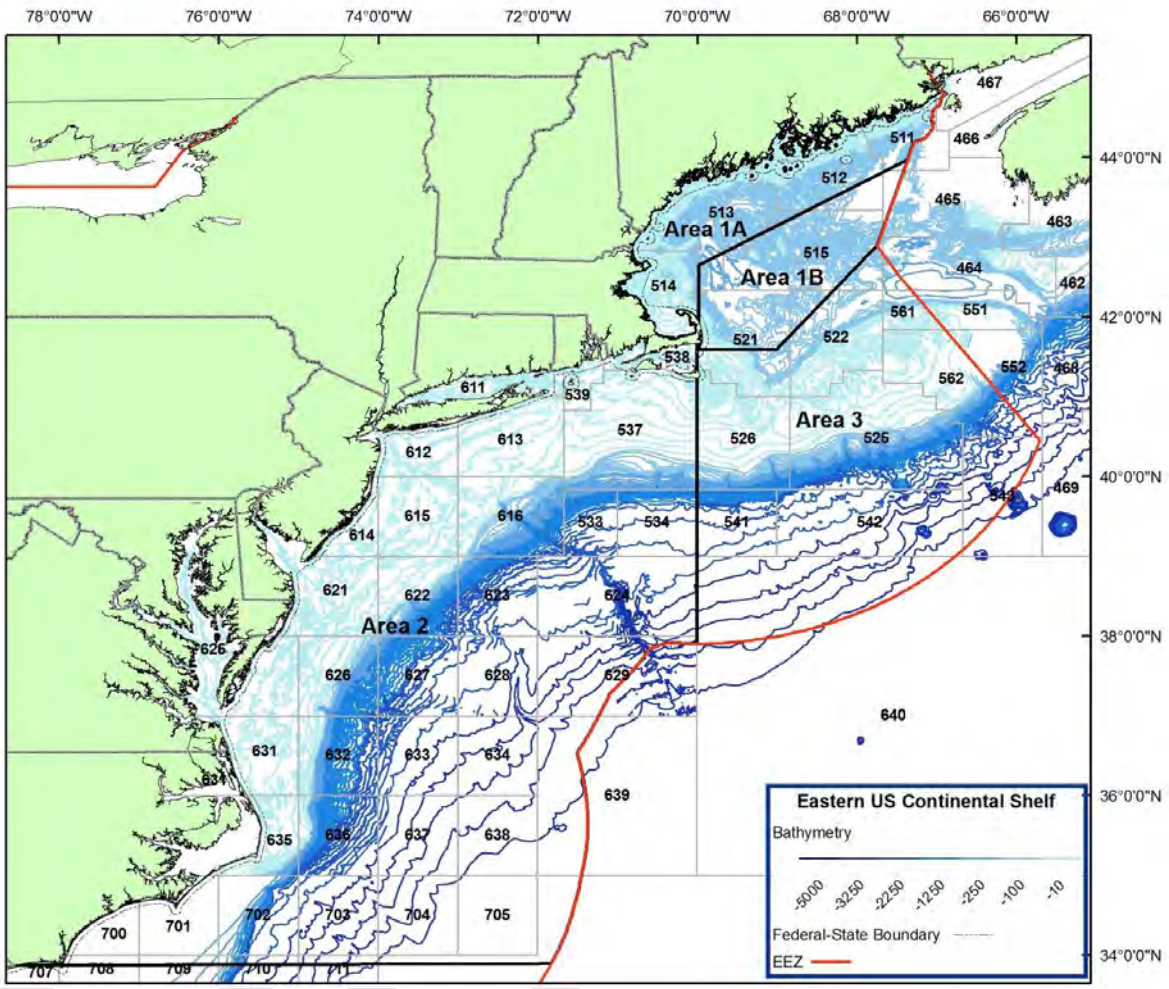

Figure 1: Study area of the Eastern US Continental Shelf. Overlapping Atlantic herring fishery management plan areas (Area 1A, 1B, 2, and 3) and fisheries management statistical areas (400-700s) indicated.

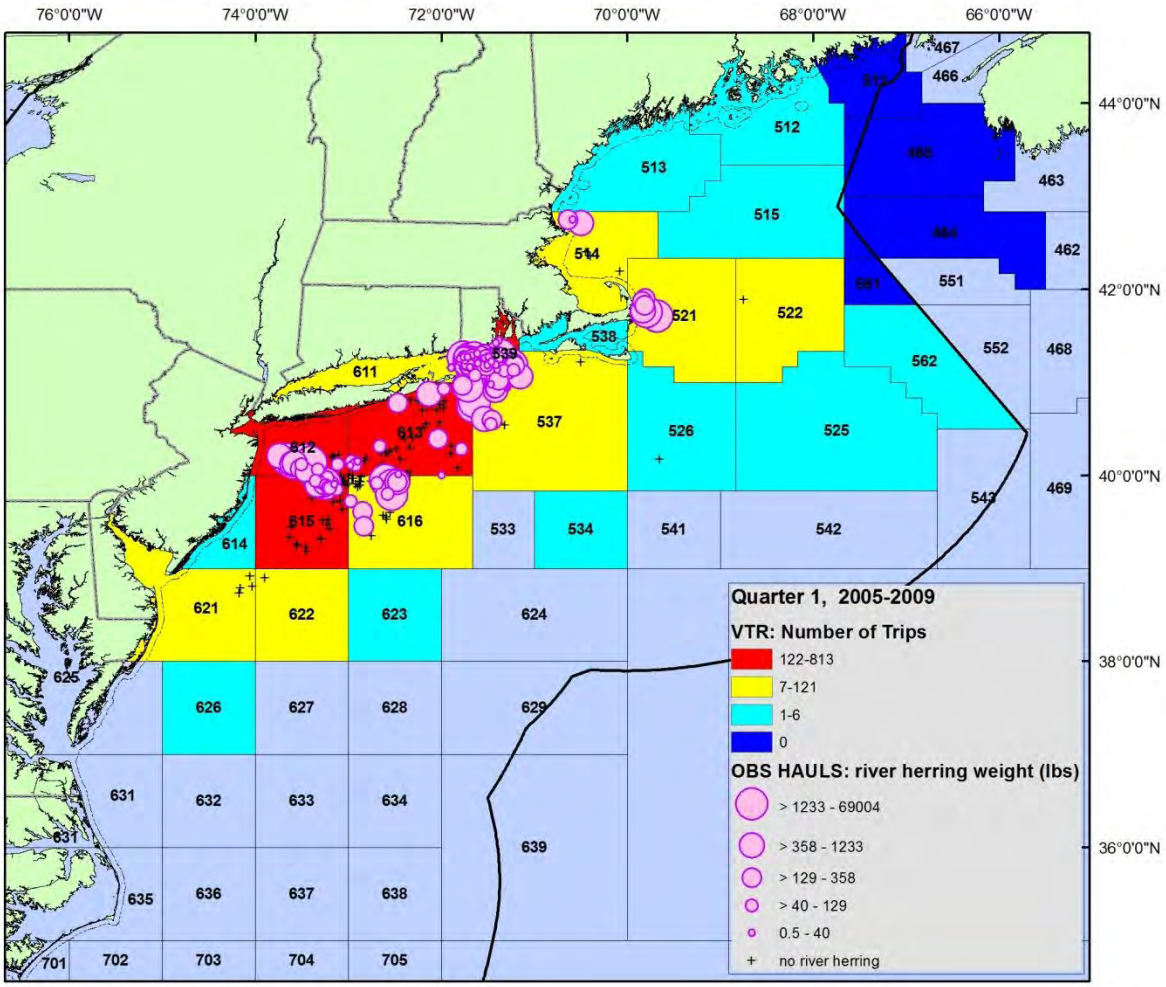

Figure 2: Reported trips (VTR) and observed hauls and sets (OBS HAULS) from quarter 1, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 122-813 (red), 7-121 (yellow), 1-6 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

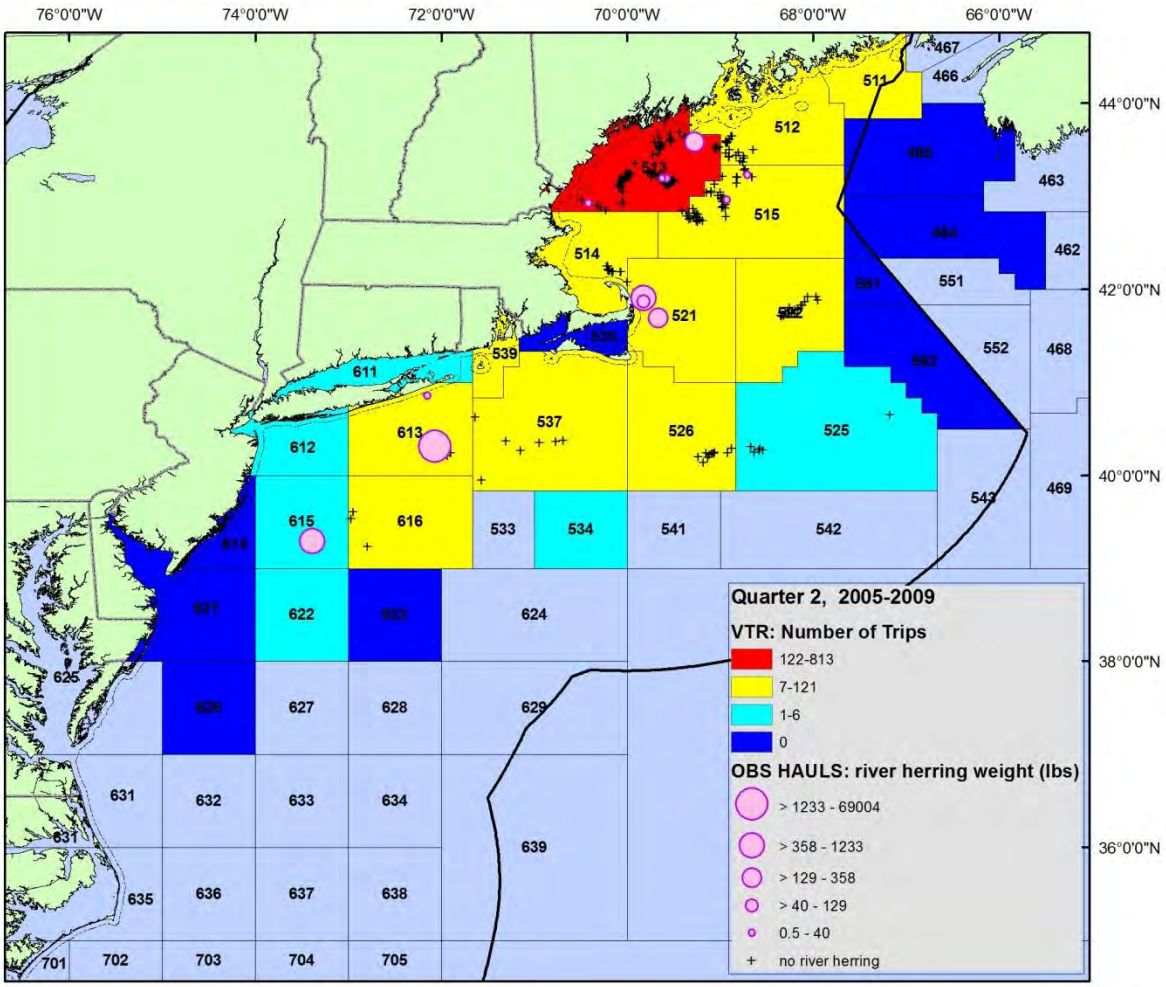

Figure 3: Reported trips (VTR) and observed hauls and sets (OBS HAULS) from quarter 2, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 122-813 (red), 7-121 (yellow), 1-6 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

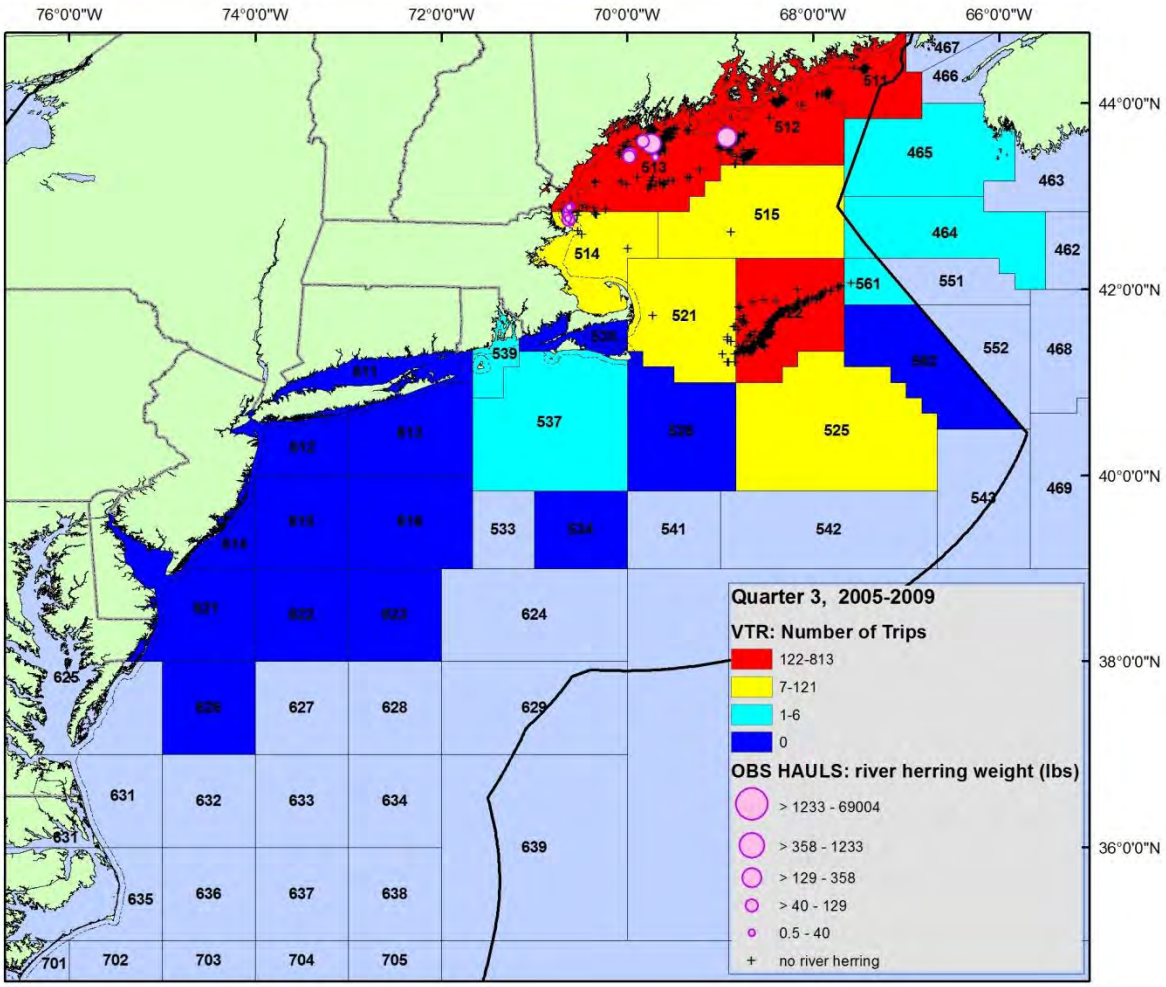

Figure 4: Reported trips (VTR) and observed hauls and sets (OBS HAULS) from quarter 3, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 122-813 (red), 7-121 (yellow), 1-6 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

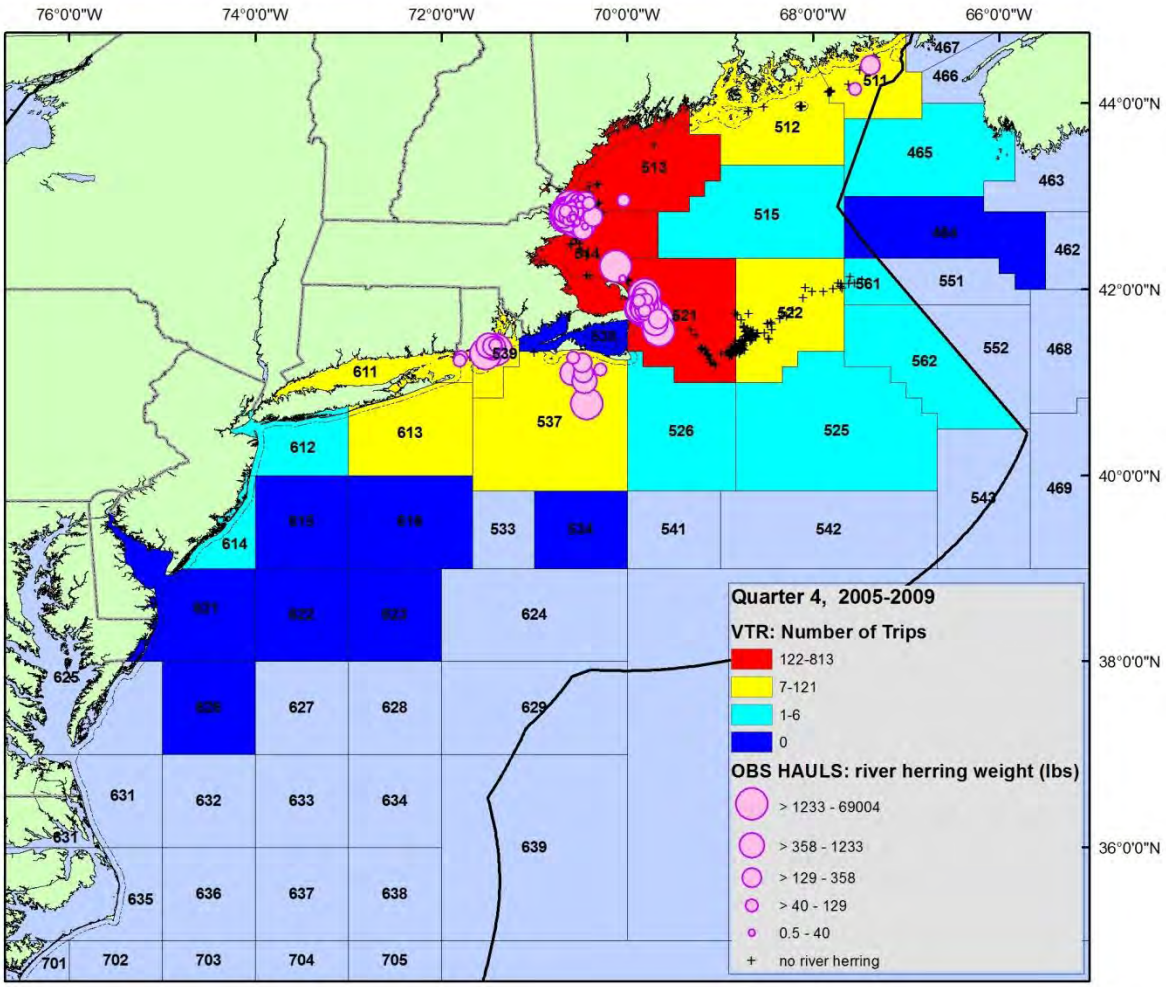

Figure 5: Reported trips (VTR) and observed hauls and sets (OBS HAULS) from quarter 4, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 122-813 (red), 7-121 (yellow), 1-6 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

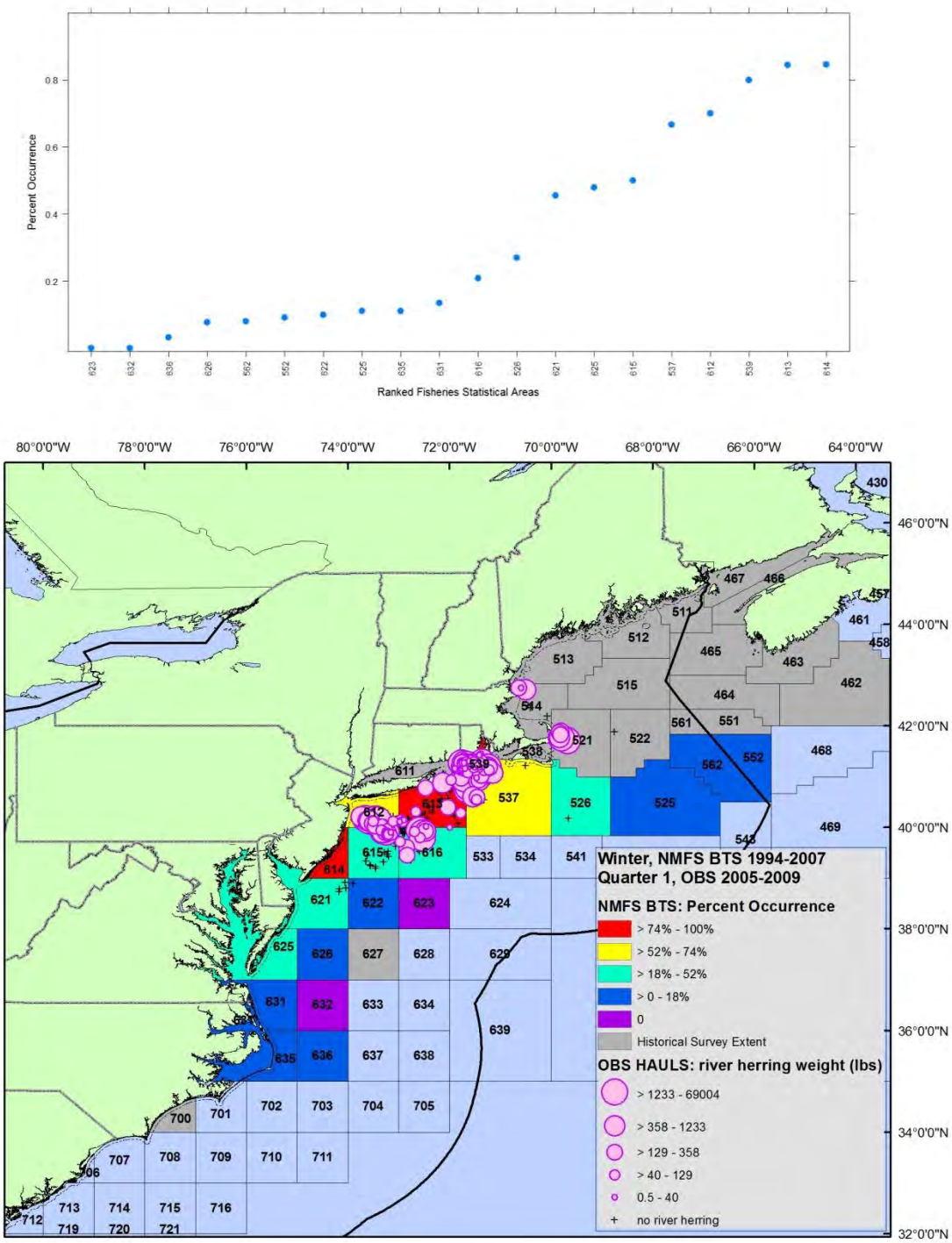

Figure 6: Percent occurrence of river herring in winter research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by statistical area grouped from >74-100% (red), >52-74% (yellow), >18-52% (aqua), >0-18% (dark blue) and 0% (purple) (bottom). Ranks are based on river herring percent occurrence values in the spring research surveys. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2007 and NEFOP Database 2005-2009.

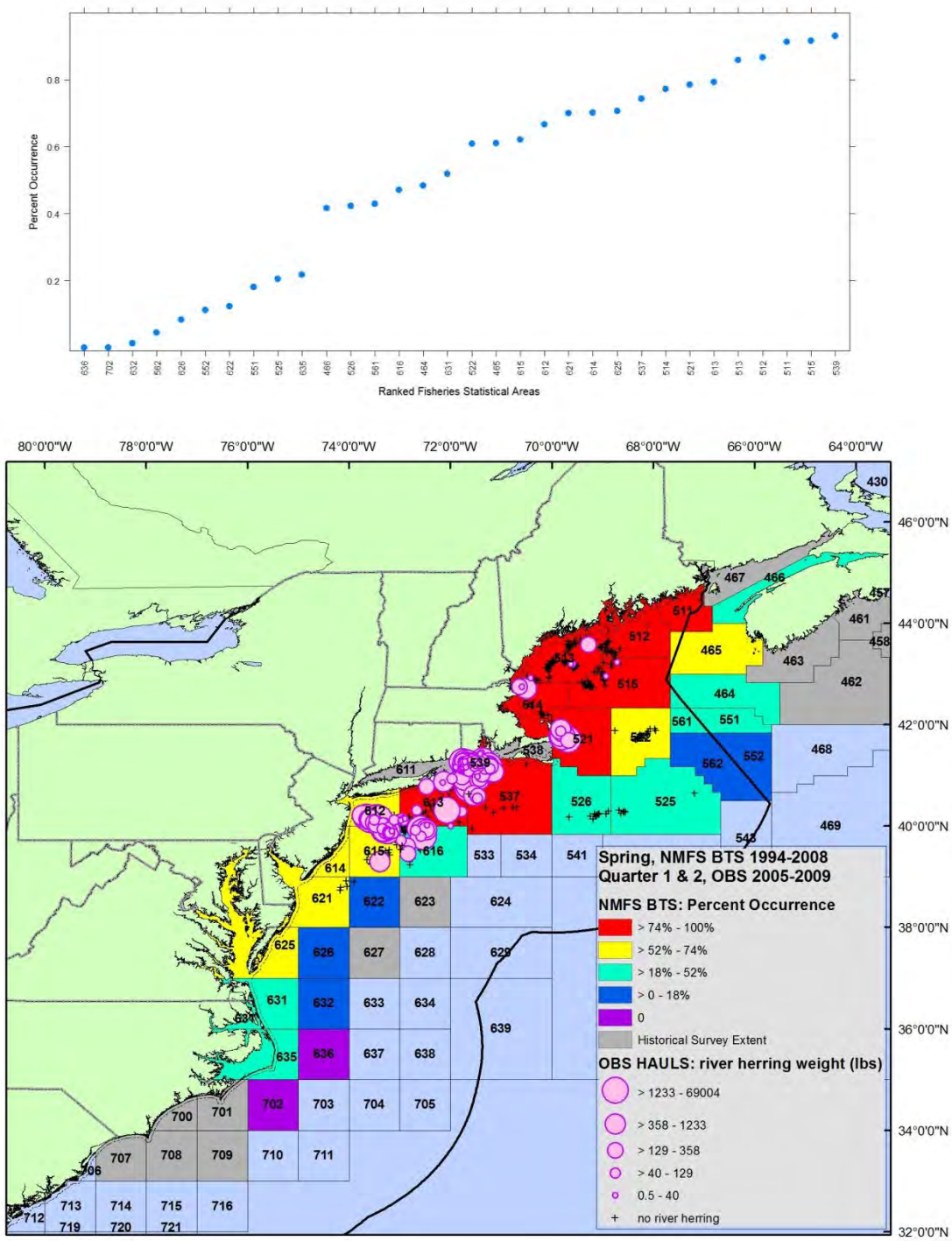

Figure 7: Percent occurrence of river herring in spring research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by statistical area grouped from >74-100% (red), >52-74% (yellow), >18-52% (aqua), >0-18% (dark blue) and 0% (purple) (bottom). Ranks are based on river herring percent occurrence values in the spring research surveys. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 and 2 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

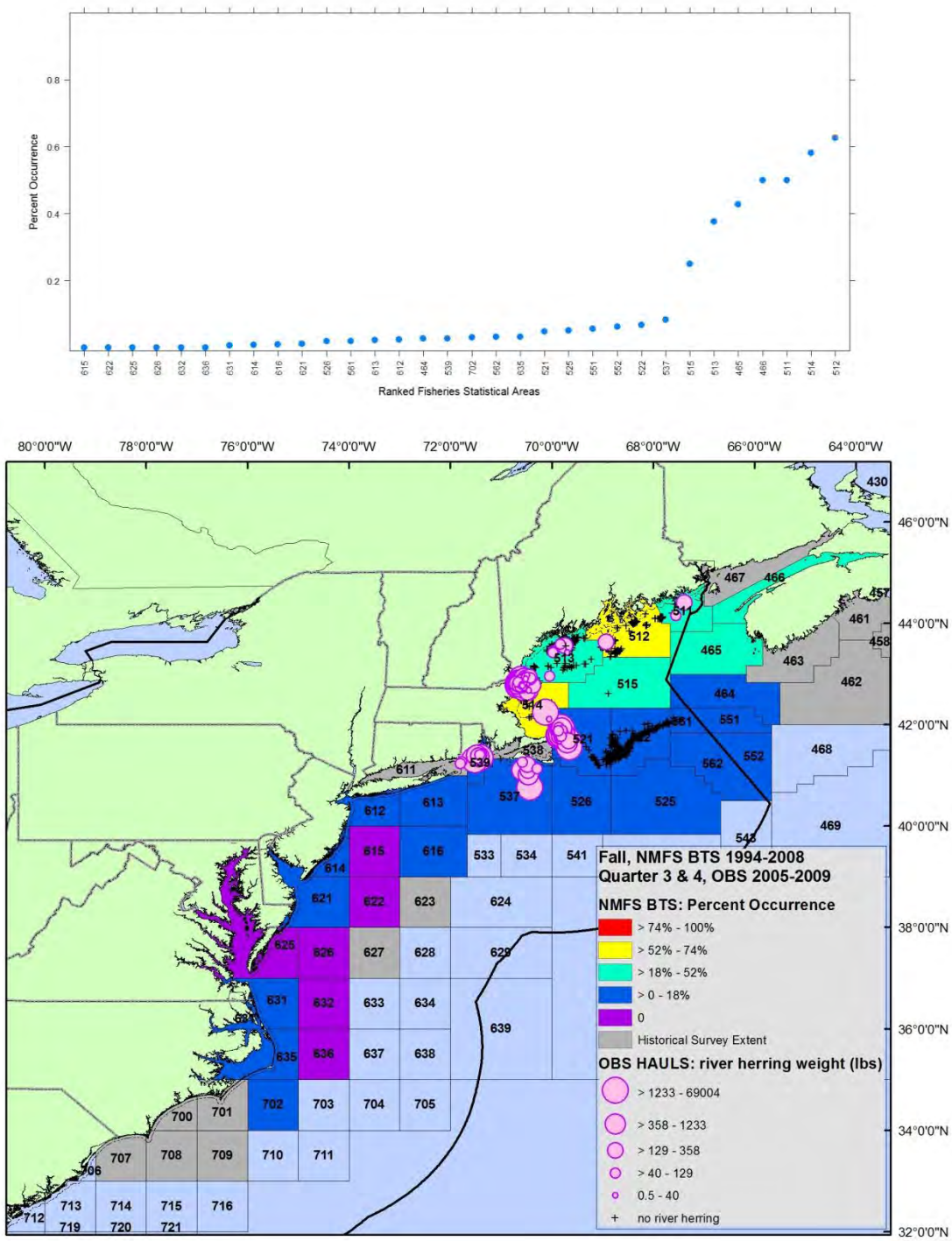

Figure 8: Percent occurrence of river herring in fall research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by statistical area grouped from >74-100% (red), >52-74% (yellow), >18-52% (aqua), >0-18% (dark blue) and 0% (purple) (bottom). Ranks are based on river herring percent occurrence values in the spring research surveys. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 3 and 4 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

References

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Shepherd, G. 1986. Evaluation of the river herring by-catch in the mackerel fishery. *Woods Hole Laboratory Reference Document* 86-10. US Department of Commerce.

Wigley, S. E. , J. Blaylock, P. J. Rago. 2009. River herring discard estimation, precision and sample size analysis. *Northeast Fish Science Center Reference Document* 09-20. US Department of Commerce.

Appendix

Tables

Q1	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	0	0	0
511	0	0	0	0
512	0	1	0	1
513	0	5	0	5
514	0	18	0	18
515	0	1	0	1
521	1	23	0	24
522	0	8	0	8
525	0	1	0	1
526	0	1	0	1
534	1	1	0	2
537	56	49	0	105
538	2	2	0	4
539	161	114	0	275
561	0	0	0	0
562	0	2	0	2
611	80	32	0	112
612	8	132	0	140
613	32	126	0	158
614	0	1	0	1
615	25	124	0	149
616	24	81	0	105
621	2	10	0	12
622	5	23	0	28
623	0	1	0	1
626	0	6	0	6

Table A.1: Number of directed herring trips separated by gear and statistical area for quarter 1. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Q2	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	0	0	0
511	0	8	2	10
512	0	10	76	86
513	1	278	121	400
514	0	36	1	37
515	0	35	8	43
521	0	40	2	42
522	0	21	0	21
525	0	2	0	2
526	1	11	0	12
534	0	1	0	1
537	4	50	0	54
538	0	0	0	0
539	9	5	0	14
561	0	0	0	0
562	0	0	0	0
611	1	1	0	2
612	1	0	0	1
613	1	6	0	7
614	0	0	0	0
615	0	4	0	4
616	2	6	0	8
621	0	0	0	0
622	0	1	0	1
623	0	0	0	0
626	0	0	0	0

Table A.2: Number of directed herring trips separated by gear and statistical area for quarter 2. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Q3	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	1	1
465	0	0	2	2
511	0	18	119	137
512	3	150	406	559
513	247	242	324	813
514	85	28	8	121
515	0	11	20	31
521	0	14	0	14
522	2	181	3	186
525	0	7	0	7
526	0	0	0	0
534	0	0	0	0
537	0	1	0	1
538	0	0	0	0
539	0	1	0	1
561	0	6	0	6
562	0	0	0	0
611	0	0	0	0
612	0	0	0	0
613	0	0	0	0
614	0	0	0	0
615	0	0	0	0
616	0	0	0	0
621	0	0	0	0
622	0	0	0	0
623	0	0	0	0
626	0	0	0	0

Table A.3: Number of directed herring trips separated by gear and statistical area for quarter 3. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Q4	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	1	0	1
511	0	15	53	68
512	0	16	31	47
513	8	106	25	139
514	33	222	8	263
515	0	2	1	3
521	7	199	0	206
522	1	55	0	56
525	1	0	0	1
526	0	1	0	1
534	0	0	0	0
537	2	19	0	21
538	0	0	0	0
539	93	21	0	114
561	0	1	0	1
562	0	1	0	1
611	43	10	0	53
612	2	1	0	3
613	8	6	0	14
614	1	0	0	1
615	0	0	0	0
616	0	0	0	0
621	0	0	0	0
622	0	0	0	0
623	0	0	0	0
626	0	0	0	0

Table A.4: Number of directed herring trips separated by gear and statistical area for quarter 4. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

NMFS BTS Winter 1994-2007					
AREA	TOWS	Percent Occurrence	Ranked	Median Q Index	Ranked
614	13	0.846153846	1	0.805448788	1
613	128	0.84375	2	-0.083656329	15
539	10	0.8	3	-0.487278536	20
612	30	0.7	4	0.142164949	8
537	225	0.666666667	5	-0.022998617	10
615	102	0.5	6	-0.035149298	12
625	48	0.479166667	7	-0.469611988	19
621	99	0.454545455	8	-0.361947445	17
526	119	0.268907563	9	-0.031869313	11
616	125	0.208	10	0.060962733	9
631	82	0.134146341	11	-0.036515113	13
525	117	0.111111111	12	-0.210428394	16
635	27	0.111111111	12	-0.372659733	18
622	130	0.1	14	0.201160655	6
552	11	0.090909091	15	0.795905513	2
562	25	0.08	16	0.402988721	5
626	131	0.076335878	17	-0.061931623	14
636	32	0.03125	18	0.161388547	7
623	10	0	19	0.642275966	3
632	68	0	19	0.439684587	4

Table A.5: Ranked statistical areas (AREA) using percent occurrence and median Q index calculated from river herring presence/absence and number of individuals, respectively, in winter research surveys. The number of survey tows (TOWS) by statistical area is provided. Statistical areas with less than 10 survey tows were excluded from the analysis. Source: NMFS bottom-trawl surveys 1994-2007.

NMFS BTS Spring 1994-2008					
AREA	TOWS	Percent Occurrence	Ranked	Median Q Index	Ranked
539	43	0.930232558	1	0.048223074	12
515	166	0.915662651	2	0.185106619	6
511	69	0.913043478	3	0.41081519	4
512	83	0.86746988	4	0.030680333	14
513	113	0.85840708	5	-0.092156843	24
613	246	0.792682927	6	-0.136116442	27
521	191	0.785340314	7	-0.103550876	26
514	185	0.772972973	8	0.004382231	19
537	241	0.742738589	9	0.013147031	16
625	191	0.706806283	10	-0.326634116	30
614	151	0.701986755	11	0.009249683	17
621	273	0.6996337	12	0.004444391	18
612	219	0.666666667	13	0.02287269	15
615	119	0.621848739	14	0.111339016	9
465	100	0.61	15	-0.075776668	22
522	207	0.608695652	16	0.034462192	13
631	179	0.519553073	17	-0.202880679	28
464	89	0.483146067	18	-0.096883651	25
616	119	0.470588235	19	-0.048907631	20
561	49	0.428571429	20	0.269207792	5
526	156	0.423076923	21	-0.05188503	21
466	12	0.416666667	22	0.471084801	3
635	156	0.217948718	23	-0.548940546	32
525	230	0.204347826	24	0.066841291	11
551	111	0.18018018	25	0.127428325	8
622	122	0.12295082	26	0.655564103	1
552	71	0.112676056	27	-0.243404178	29
626	120	0.083333333	28	0.146788992	7
562	134	0.044776119	29	0.081239939	10
632	78	0.012820513	30	0.486129946	2
636	39	0	31	-0.337694765	31
702	53	0	31	-0.085072957	23

Table A.6: Ranked statistical areas (AREA) using percent occurrence and median Q index calculated from river herring presence/absence and number of individuals, respectively, in spring research surveys. The number of survey tows (TOWS) by statistical area is provided. Statistical areas with less than 10 survey tows were excluded from the analysis. Source: NMFS bottom-trawl surveys 1994-2008.

NMFS BTS Fall 1994-2008					
AREA	TOWS	Percent Occurrence	Ranked	Median Q Index	Ranked
512	91	0.626373626	1	0.955824637	2
514	160	0.58125	2	0.497206356	6
466	14	0.5	3	0.229886445	12
511	62	0.5	3	0.594104648	4
465	110	0.427272727	5	-0.275132304	20
513	122	0.37704918	6	-0.366110161	24
515	156	0.25	7	-0.120340473	19
537	228	0.083333333	8	0.347935696	8
522	208	0.067307692	9	0.43719754	7
552	81	0.061728395	10	-1.061954751	31
551	125	0.056	11	0.304046913	10
525	233	0.051502146	12	0.064427119	16
521	208	0.048076923	13	-0.341945975	21
635	158	0.03164557	14	-0.488781686	26
562	128	0.03125	15	0.147723364	13
702	66	0.03030303	16	0.793263683	3
539	36	0.027777778	17	-0.362844938	23
464	74	0.027027027	18	-1.129410073	32
612	209	0.023923445	19	-0.347490311	22
613	273	0.021978022	20	-0.031337982	17
561	52	0.019230769	21	-0.677302761	28
526	164	0.018292683	22	-0.458971258	25
621	269	0.011152416	23	-0.036204706	18
616	114	0.00877193	24	0.287512246	11
614	138	0.007246377	25	0.555480202	5
631	171	0.005847953	26	0.120887594	14
615	119	0	27	-0.618119832	27
622	114	0	27	-0.887163123	30
625	198	0	27	0.09910871	15
626	118	0	27	-0.83185715	29
632	70	0	27	1.267479015	1
636	33	0	27	0.314304904	9

Table A.7: Ranked statistical areas (AREA) using percent occurrence and median Q index calculated from river herring presence/absence and number of individuals, respectively, in fall research surveys. The number of survey tows (TOWS) by statistical area is provided. Statistical areas with less than 10 survey tows were excluded from the analysis. Source: NMFS bottom-trawl surveys 1994-2008.

NMFS BTS Winter 1994-2008					
STRATUM	TOWS	Percent Occurrence	Ranked	Median Q Index	Ranked
1050	50	0.84	1	6.93889E-17	15
1060	109	0.80733945	2	0.035478596	13
1010	89	0.741573034	3	-0.017905444	16
1090	61	0.524590164	4	-0.155907169	22
1070	37	0.513513514	5	0.410531734	8
1690	98	0.5	6	-0.086548458	19
1020	87	0.482758621	7	0.012051389	14
1730	60	0.466666667	8	-0.086979627	20
1080	11	0.454545455	9	-1.13437527	29
1110	40	0.4	10	0.257752174	10
1100	96	0.395833333	11	-0.235850851	25
1650	126	0.285714286	12	-0.027856228	17
1740	58	0.275862069	13	-0.660812928	27
1130	72	0.180555556	14	-0.214475284	23
1040	12	0.166666667	15	-0.750797253	28
1030	37	0.135135135	16	0.426406974	5
1610	68	0.088235294	17	-0.36073455	26
1160	29	0.034482759	18	0.389125787	9
1750	43	0.023255814	19	-0.09910786	21
1700	55	0.018181818	20	-0.23131104	24
1140	33	0	21	0.426406974	5
1190	10	0	21	0.620106139	4
1620	29	0	21	0.168490797	12
1630	24	0	21	-1.220873863	30
1640	10	0	21	1.146046614	1
1660	41	0	21	-0.053739318	18
1670	36	0	21	0.791649478	3
1710	39	0	21	0.23131104	11
1720	10	0	21	0.804026489	2
1760	13	0	21	0.418695621	7

Table A.8: Ranked survey strata (STRATUM) using percent occurrence and median Q index calculated from river herring presence/absence and number of individuals, respectively, in winter research surveys. The number of survey tows (TOWS) by survey strata is provided. Survey strata with less than 10 survey tows were excluded from the analysis. Source: NMFS bottom-trawl surveys 1994-2007.

NMFS BTS Spring 1994-2008

STRATUM	TOWS	Percent Occurrence	Ranked	Median Q Index	Ranked
3590	10	1	1	0.98392021	2
1240	89	0.95505618	2	0.223246262	33
1370	74	0.932432432	3	0.100069653	49
1380	59	0.93220339	4	-0.425750232	81
3050	27	0.925925926	5	-0.111339016	64
3600	23	0.913043478	6	0.605991274	10
3450	22	0.909090909	7	0.117136801	46
1400	32	0.90625	8	0.149316234	42
3020	29	0.896551724	9	0.556287714	12
1351	27	0.888888889	10	0.197099084	35
3660	16	0.875	11	0.828594137	5
1050	63	0.873015873	12	0.305303336	27
3360	29	0.862068966	13	-0.782222878	91
1060	106	0.858490566	14	-0.884740393	94
1390	42	0.857142857	15	0.201154176	34
3300	14	0.857142857	15	0.337011254	26
1280	105	0.847619048	17	0.090882184	50
3270	13	0.846153846	18	-0.636722591	89
3210	12	0.833333333	19	-1.024235236	96
3280	30	0.833333333	19	-0.421201932	80
1360	112	0.821428571	21	-0.09588692	61
3240	28	0.821428571	21	-0.277764259	74
3350	27	0.814814815	23	-1.140641133	97
3340	30	0.8	24	-1.402562283	106
3250	29	0.793103448	25	0.690971688	6
3140	24	0.791666667	26	0.551356512	13
3130	28	0.785714286	27	-0.849977935	93
3220	31	0.774193548	28	-1.441988721	107
1270	57	0.771929825	29	-0.099565033	62
1340	69	0.768115942	30	-0.43550702	82
1220	53	0.754716981	31	0.174848423	39
3060	12	0.75	32	-0.592992878	88
3180	12	0.75	32	-0.336583687	77
1090	67	0.746268657	34	-0.403730172	79
3160	31	0.741935484	35	0.975207456	3
1070	27	0.740740741	36	0.256053654	31
3170	27	0.740740741	36	-0.446773288	83
1010	99	0.737373737	38	-0.965170421	95
3330	15	0.733333333	39	-1.872819983	108
3260	29	0.724137931	40	1.267823155	1

3460	18	0.722222222	41	0.439552304	19
3200	28	0.714285714	42	0.117473003	45
3610	27	0.703703704	43	0.669111025	7
3150	10	0.7	44	0.251872066	32
3580	10	0.7	44	-0.822222227	92
3110	29	0.689655172	46	-1.358142081	105
3320	25	0.68	47	0.129317899	44
1020	96	0.677083333	48	-0.059313664	59
1250	37	0.675675676	49	0.178130245	37
1290	106	0.660377358	50	-0.271242146	72
1230	57	0.649122807	51	-0.110929914	63
3230	28	0.642857143	52	-1.150390295	98
3310	28	0.642857143	52	0.008703763	54
1260	53	0.641509434	54	-0.169355223	69
3040	30	0.633333333	55	-0.466113337	84
3290	27	0.62962963	56	-0.188232439	71
3400	31	0.612903226	57	-0.336711484	78
3370	30	0.6	58	0.378768747	24
3080	29	0.586206897	59	0.274516216	29
3120	12	0.583333333	60	-1.174267118	100
3190	31	0.580645161	61	-0.161000479	67
3100	28	0.571428571	62	0.285591522	28
3390	14	0.571428571	62	-0.49048516	86
1690	86	0.569767442	64	-0.177319148	70
1730	71	0.563380282	65	0.06968492	51
1100	111	0.54954955	66	0.175575848	38
3070	28	0.535714286	67	-0.044458845	58
3090	15	0.533333333	68	-0.330351013	76
3380	29	0.517241379	69	0.921262905	4
3550	49	0.489795918	70	-1.184282207	101
1030	27	0.481481481	71	0.386232718	23
1300	42	0.476190476	72	0.34623796	25
3410	25	0.44	73	-0.161902497	68
3420	14	0.428571429	74	0.132054335	43
1080	12	0.416666667	75	0.453304692	18
3030	12	0.416666667	75	0.581798938	11
1650	97	0.371134021	77	-0.275296784	73
1740	55	0.327272727	78	0.102399329	47
3440	29	0.310344828	79	0.405802856	22
1180	10	0.3	80	-0.663761088	90
1210	55	0.290909091	81	0.150809258	41
1040	15	0.266666667	82	0.261225105	30
1330	24	0.25	83	0.652803781	9

1140	43	0.23255814	84	0.510421643	15
3430	28	0.214285714	85	0.652876207	8
1110	29	0.206896552	86	-1.305749876	103
1130	132	0.204545455	87	-0.030573692	56
1170	40	0.2	88	0.051529331	52
1190	119	0.18487395	89	0.185623879	36
1150	11	0.181818182	90	-0.14902602	66
1200	72	0.180555556	91	-1.207827251	102
1610	43	0.162790698	92	-0.032260003	57
1700	53	0.132075472	93	0.415497455	21
1750	33	0.090909091	94	-1.316687896	104
1760	13	0.076923077	95	0.425856017	20
7510	19	0.052631579	96	-0.48635946	85
7520	20	0.05	97	-0.323161627	75
1670	30	0.033333333	98	0.167895865	40
1160	161	0.02484472	99	-0.116149263	65
8500	43	0.023255814	100	0.457571568	17
1660	45	0.022222222	101	0.462974908	16
1620	31	0	102	-1.159325505	99
1630	26	0	102	0.102028247	48
1640	13	0	102	0.525458197	14
1710	30	0	102	-0.009284042	55
1720	13	0	102	-0.583942112	87
8510	21	0	102	-0.081641868	60
8520	19	0	102	0.047231444	53

Table A.9: Ranked survey strata (STRATUM) using percent occurrence and median Q index calculated from river herring presence/absence and number of individuals, respectively, in spring research surveys. The number of survey tows (TOWS) by survey strata is provided. Survey strata with less than 10 survey tows were excluded from the analysis. Source: NMFS bottom-trawl surveys 1994-2008.

NMFS BTS Fall 1994-2008

STRATUM	TOWS	Percent Occurrence	Ranked	Median Q Index	Ranked
3660	17	0.882352941	1	1.539239575	2
1390	43	0.813953488	2	-0.837880357	85
3590	10	0.8	3	-0.36418973	70
3600	17	0.705882353	4	-0.254212876	67
3610	22	0.545454545	5	-0.130311289	59
1351	27	0.518518519	6	-0.871442581	87
1340	73	0.479452055	7	-1.122502735	95
1400	23	0.47826087	8	-0.47769524	74
1330	31	0.419354839	9	0.628904218	23
1260	55	0.418181818	10	0.161718192	43
1380	70	0.414285714	11	-1.163226259	98
1270	61	0.360655738	12	0.679963176	20
1360	111	0.36036036	13	-0.180664628	64
1370	68	0.279411765	14	0.450533597	30
1280	99	0.181818182	15	-0.949118092	92
3060	13	0.153846154	16	0.982187822	8
1210	55	0.127272727	17	0.0260233	51
1230	68	0.117647059	18	0.732832448	16
3130	29	0.103448276	19	-0.183321897	65
1060	109	0.091743119	20	-0.766634312	83
7520	23	0.086956522	21	0.228319336	39
3030	12	0.083333333	22	0.208084426	42
3390	13	0.076923077	23	2.00481621	1
1290	105	0.076190476	24	-0.14798711	60
1130	133	0.07518797	25	0.057655565	46
1160	174	0.074712644	26	-0.398668486	73
3460	27	0.074074074	27	-1.148320885	97
3430	28	0.071428571	28	0.779002499	14
3040	30	0.066666667	29	0.410669459	33
3070	30	0.066666667	29	1.100658507	6
1100	111	0.063063063	31	0.72119365	17
1140	43	0.046511628	32	0.893391581	11
1090	69	0.043478261	33	0.252457727	38
3450	24	0.041666667	34	-1.749463555	102
7510	24	0.041666667	34	0.029346272	50
1220	54	0.037037037	36	0.433906575	31
1240	82	0.036585366	37	-0.663612748	80
3160	29	0.034482759	38	0.267491304	37

3290	29	0.034482759	38	0.429204943	32
3280	31	0.032258065	40	0.209718939	41
1200	82	0.024390244	41	-0.396090443	72
1300	41	0.024390244	41	0.281213419	36
8500	43	0.023255814	43	0.5263253	27
1050	56	0.017857143	44	0.95809196	9
1690	86	0.011627907	45	-0.072196593	54
1020	99	0.01010101	46	0.022067181	52
1650	103	0.009708738	47	0.631104762	22
1010	100	0	48	-0.930520742	90
1030	27	0	48	0.481330406	28
1040	12	0	48	0.685622787	19
1070	26	0	48	-0.160038135	62
1080	12	0	48	-0.073283889	55
1110	27	0	48	-0.865119542	86
1120	10	0	48	-0.665486325	81
1150	13	0	48	-1.997465415	103
1170	40	0	48	0.389130196	34
1180	16	0	48	0.674500102	21
1190	106	0	48	-0.902536708	88
1250	38	0	48	-0.148506179	61
1610	44	0	48	-0.176197876	63
1620	31	0	48	0.030680333	49
1630	25	0	48	0.225386874	40
1660	44	0	48	-1.016610625	93
1670	23	0	48	-0.597221192	77
1700	59	0	48	0.462273931	29
1710	26	0	48	0.915935105	10
1730	74	0	48	-1.100658507	94
1740	58	0	48	-0.523354539	76
1750	25	0	48	-0.203393041	66
1760	10	0	48	-0.096559642	58
3020	27	0	48	0.045925081	48
3050	27	0	48	0.718372769	18
3080	27	0	48	-1.281551566	99
3090	14	0	48	-0.936377457	91
3100	27	0	48	-0.677353304	82
3110	29	0	48	-0.382867268	71
3140	25	0	48	-0.036468129	53
3150	10	0	48	0.086702021	45
3170	24	0	48	0.529644281	26
3180	13	0	48	0.735856255	15
3190	28	0	48	1.009544967	7

3200	29	0	48	-1.662834768	101
3220	30	0	48	-1.144354957	96
3230	26	0	48	-0.774676276	84
3240	25	0	48	-0.522490436	75
3250	28	0	48	-0.282700278	68
3260	28	0	48	-0.07919625	56
3270	11	0	48	0.049986821	47
3300	12	0	48	0.605502043	24
3310	29	0	48	0.826293052	13
3320	27	0	48	1.219666404	3
3330	12	0	48	-2.039499792	104
3340	29	0	48	-1.373650623	100
3350	27	0	48	-0.909053665	89
3360	27	0	48	-0.597500894	78
3370	28	0	48	-0.33121538	69
3380	30	0	48	-0.091198392	57
3400	29	0	48	0.121728316	44
3410	29	0	48	0.382052875	35
3420	10	0	48	0.571782999	25
3440	29	0	48	1.178106063	4
3550	51	0	48	-0.656184088	79
8510	20	0	48	0.863339047	12
8520	21	0	48	1.148320885	5

Table A.10: Ranked survey strata (STRATUM) using percent occurrence and median Q index calculated from river herring presence/absence and number of individuals, respectively, in fall research surveys. The number of survey tows (TOWS) by survey strata is provided. Survey strata with less than 10 survey tows were excluded from the analysis. Source: NMFS bottom-trawl surveys 1994-2008.

Figures

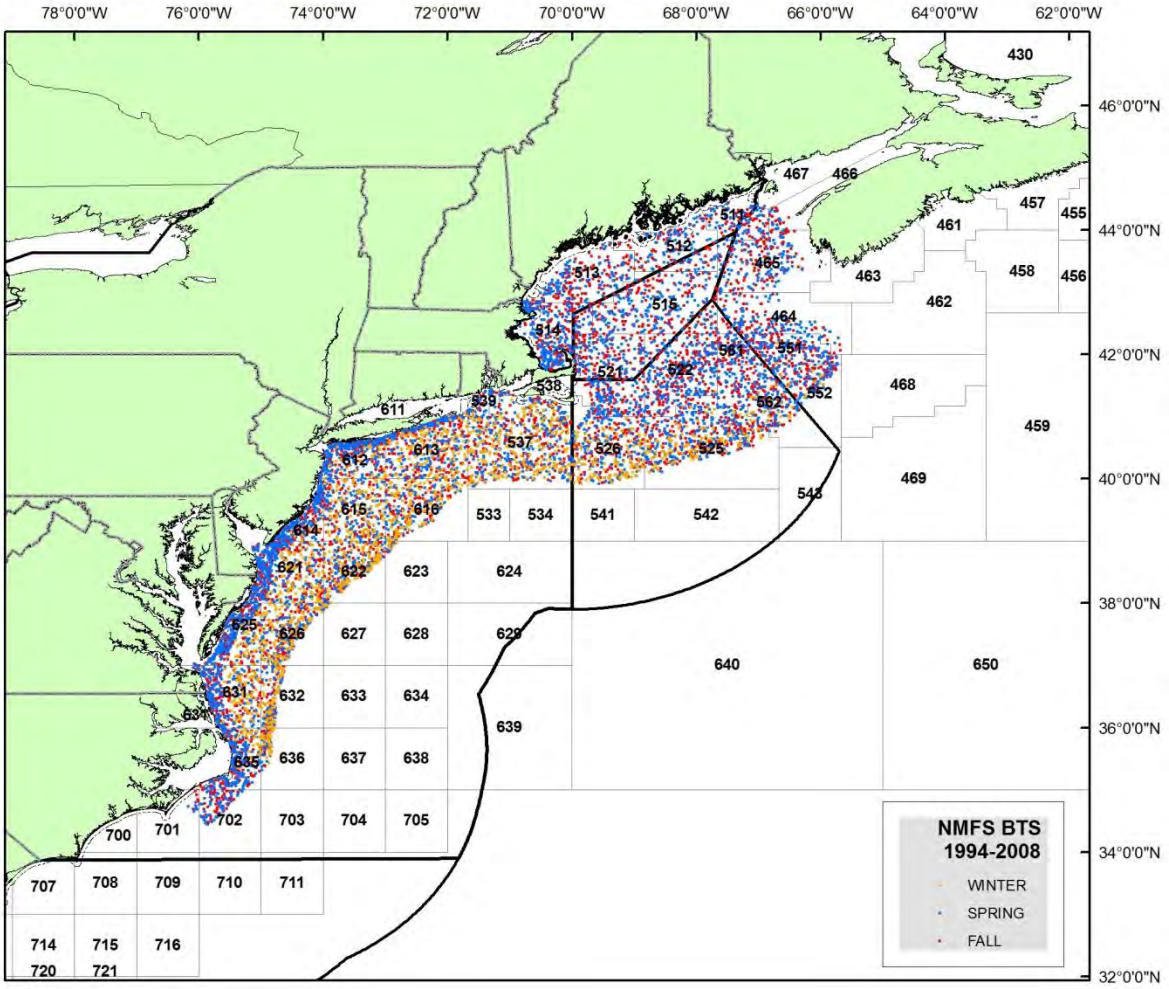

Figure A.1: Map of seasonal research surveys. Source: NMFS bottom-trawl surveys 1994-2008.

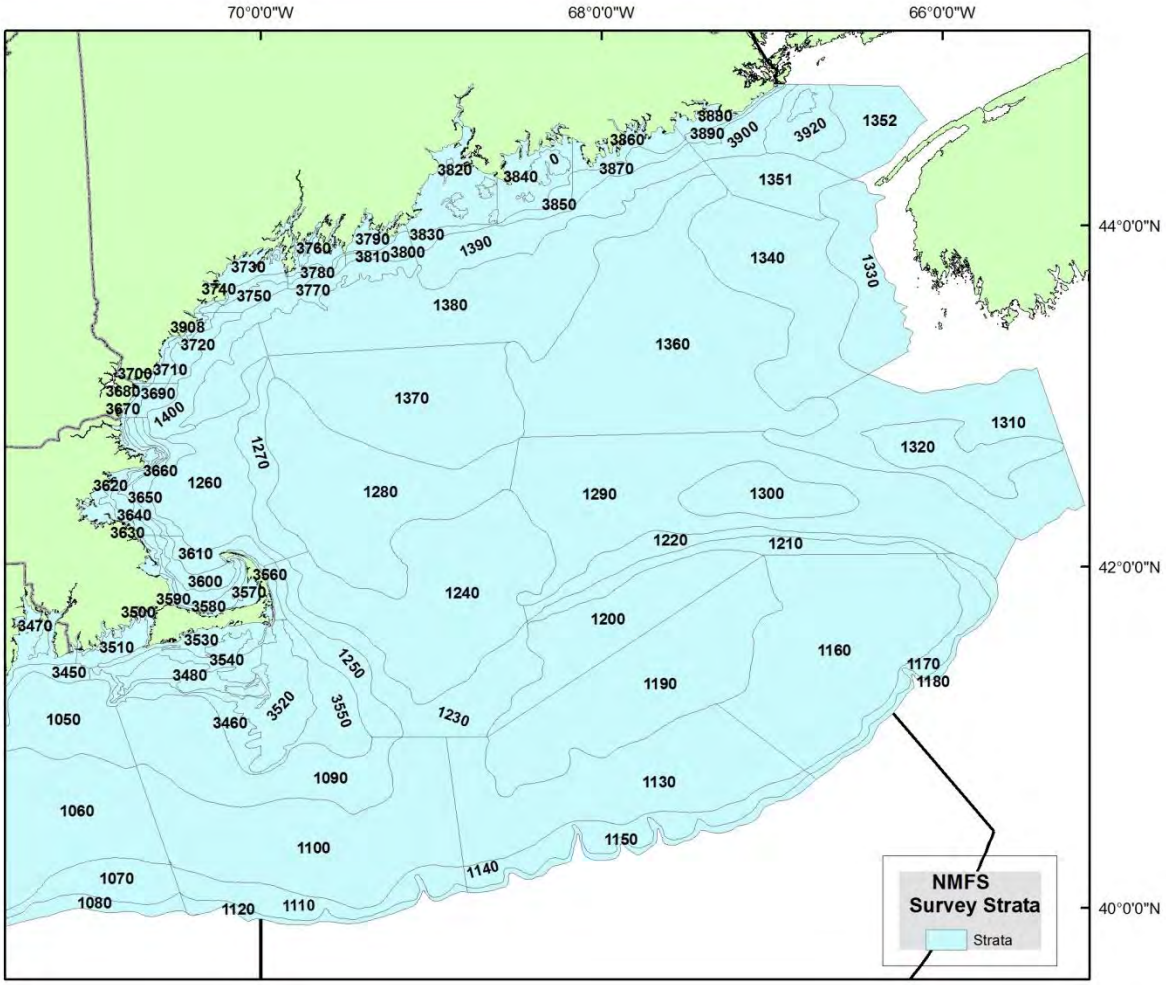

Figure A.2: Map of research survey strata in the Gulf of Maine and Georges Bank. Source: NMFS 2010.

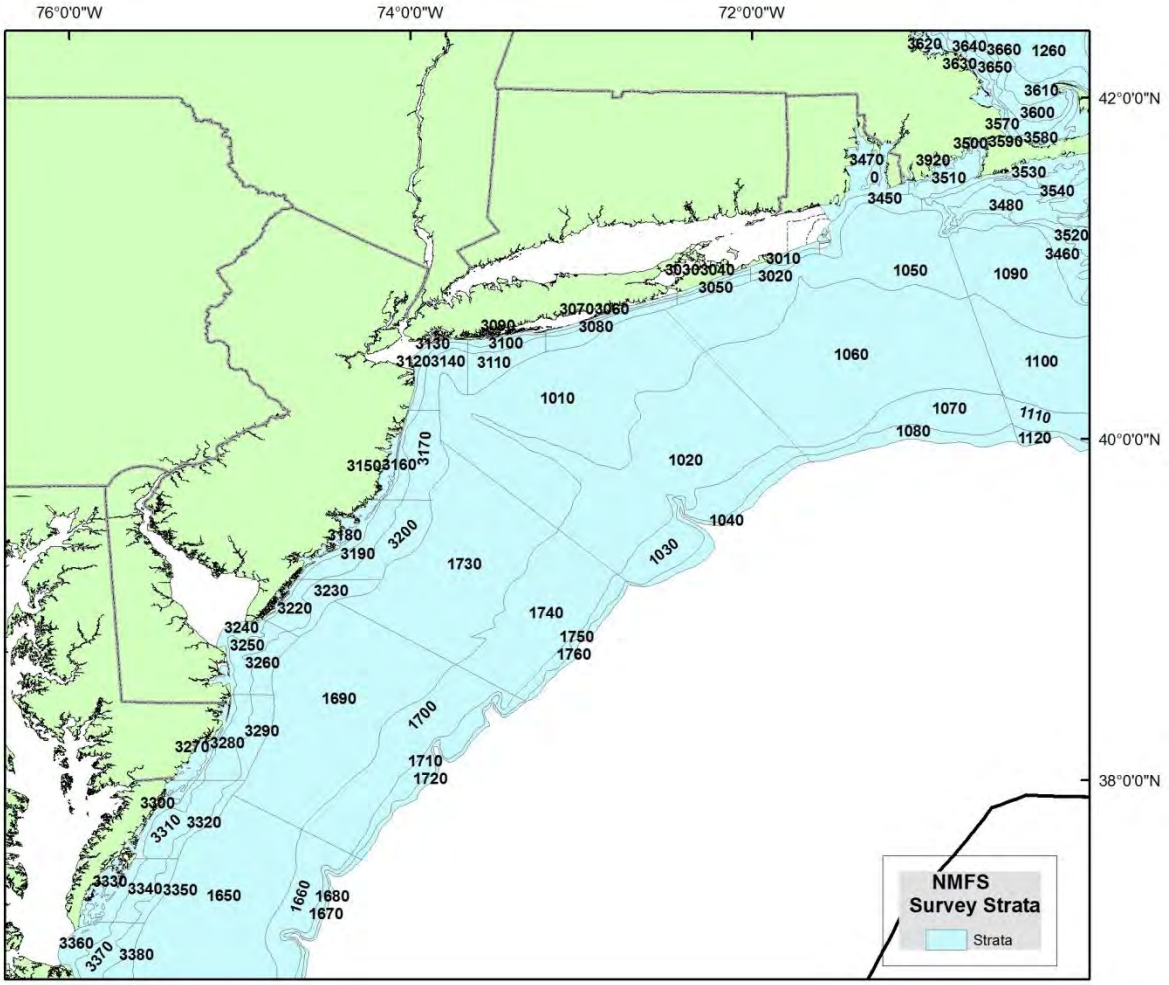

Figure A.3: Map of research survey strata in the northern Mid-Atlantic Bight. Source: NMFS 2010.

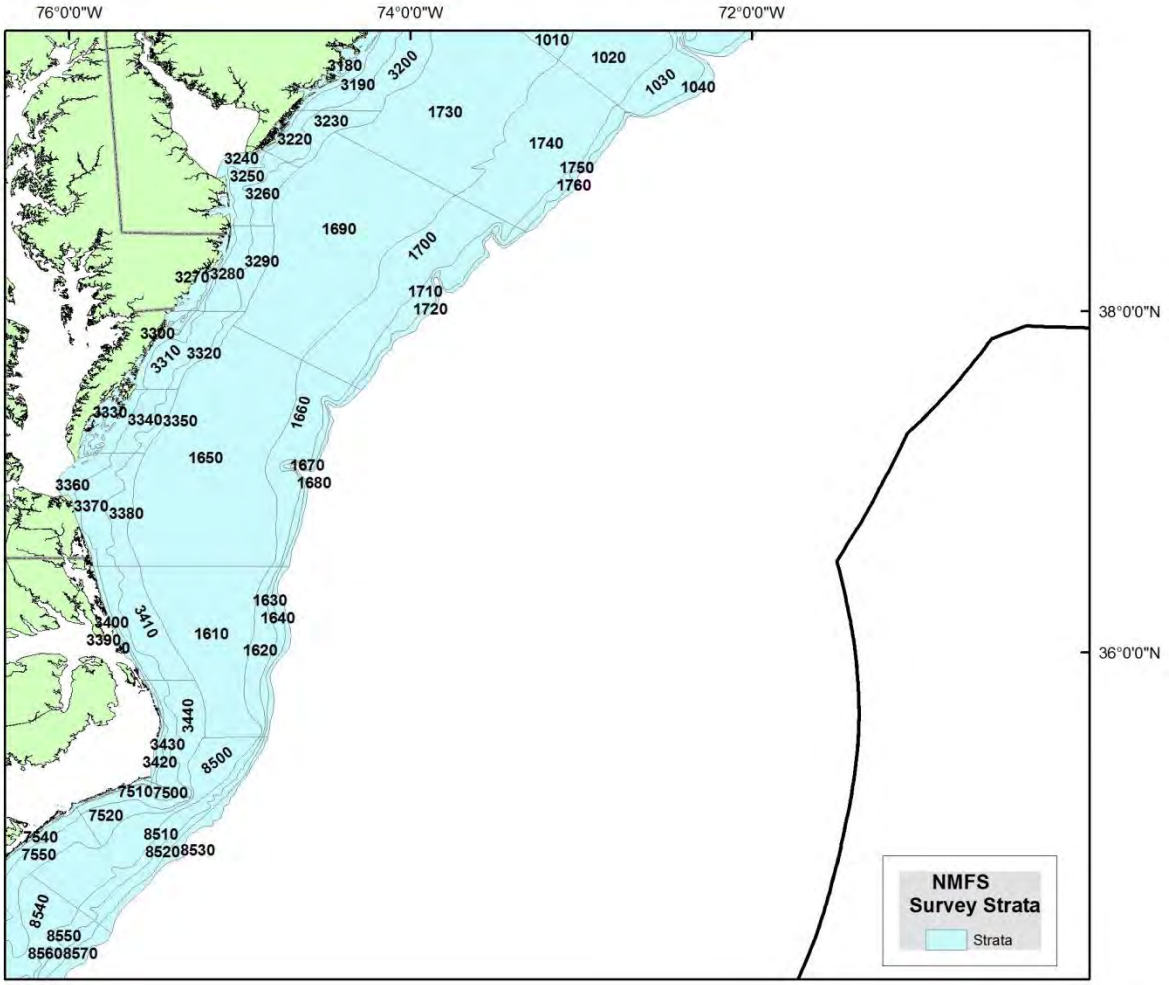

Figure A.4: Map of research survey strata in the central Mid-Atlantic Bight. Source: NMFS 2010.

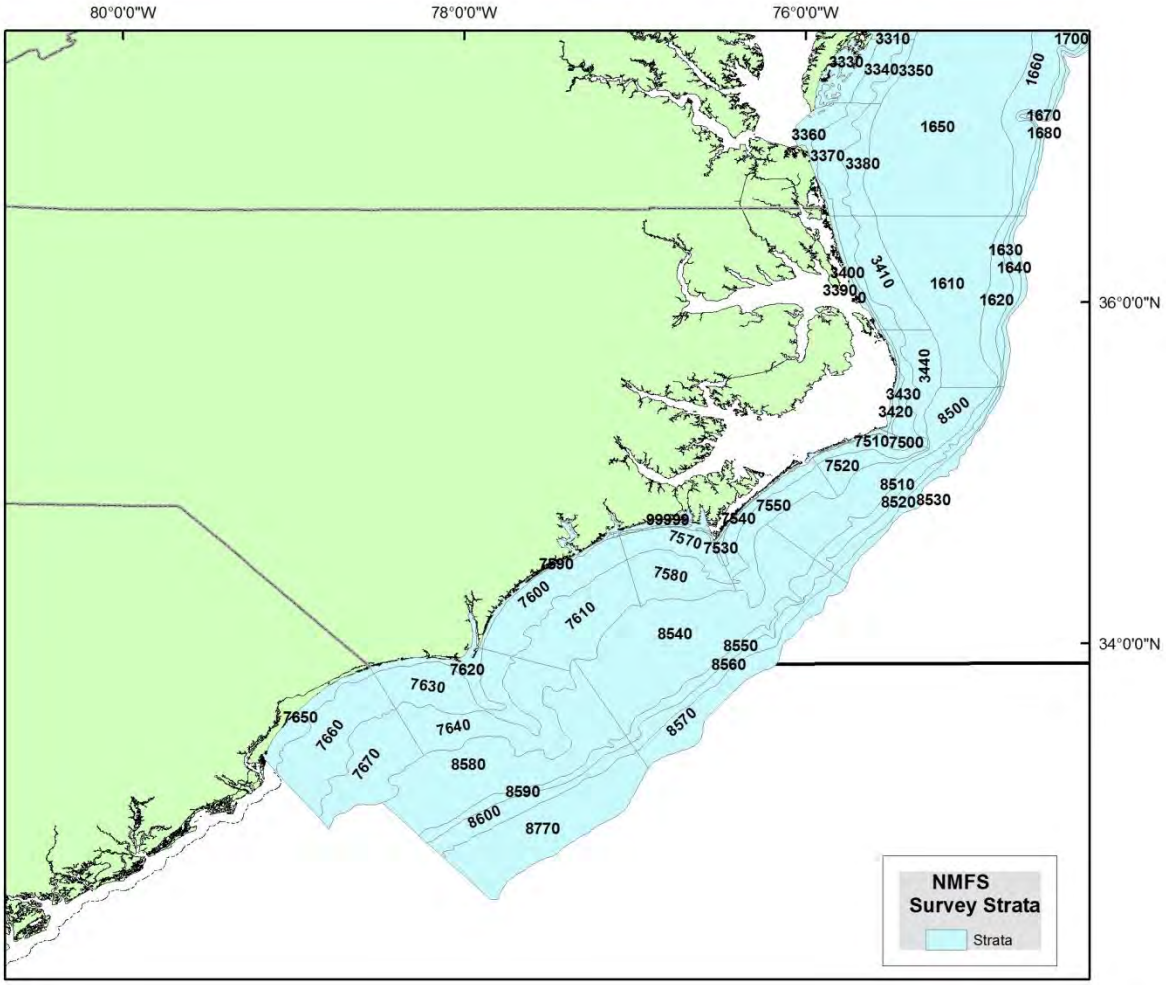

Figure A.5: Map of research survey strata in the southern Mid-Atlantic Bight. Source: NMFS 2010.

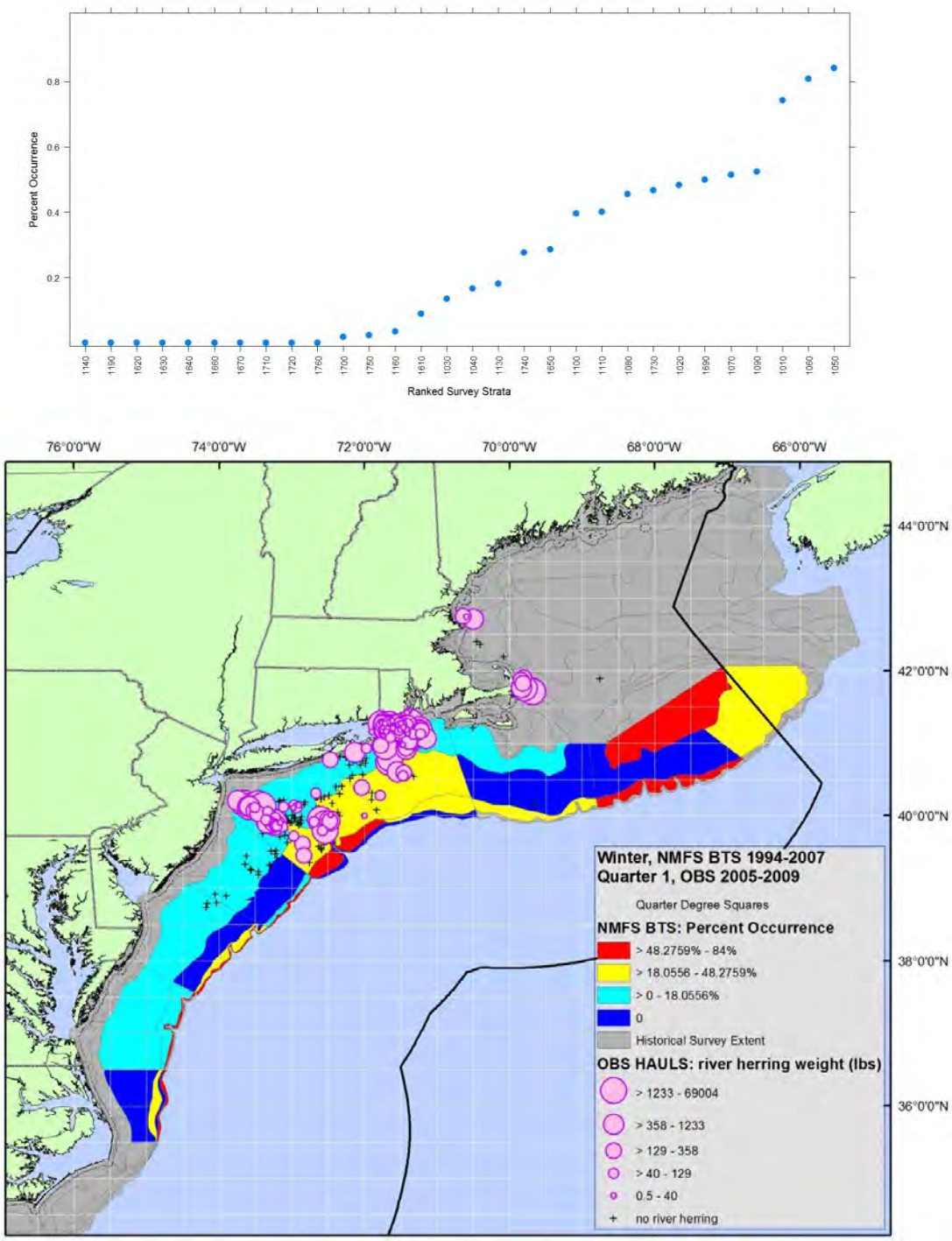

Figure A.6: Percent occurrence of river herring in winter research surveys by survey strata ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by survey strata grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2007 and NEFOP Database 2005-2009.

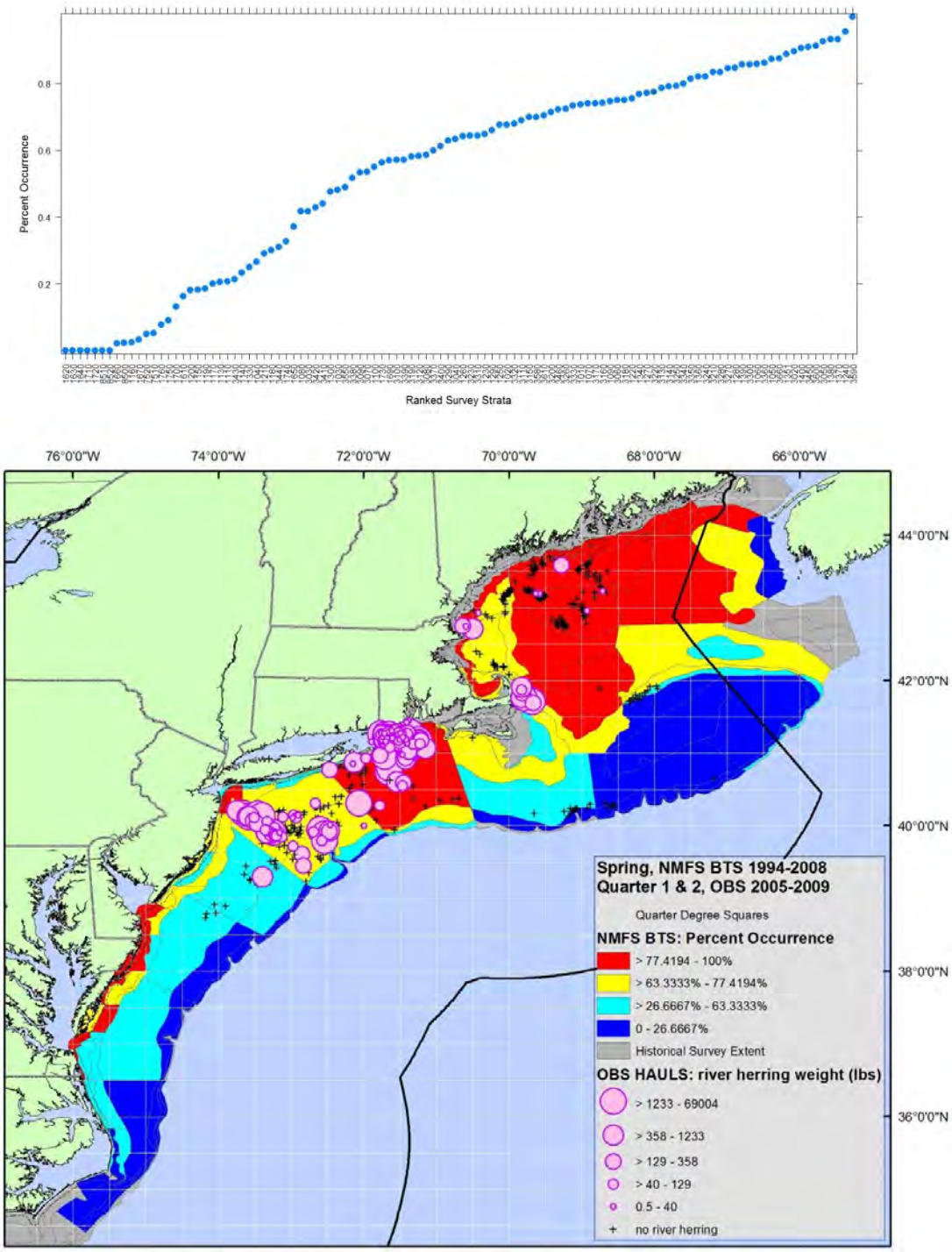

Figure A.7: Percent occurrence of river herring in spring research surveys by survey strata ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by survey strata grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 and 2 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

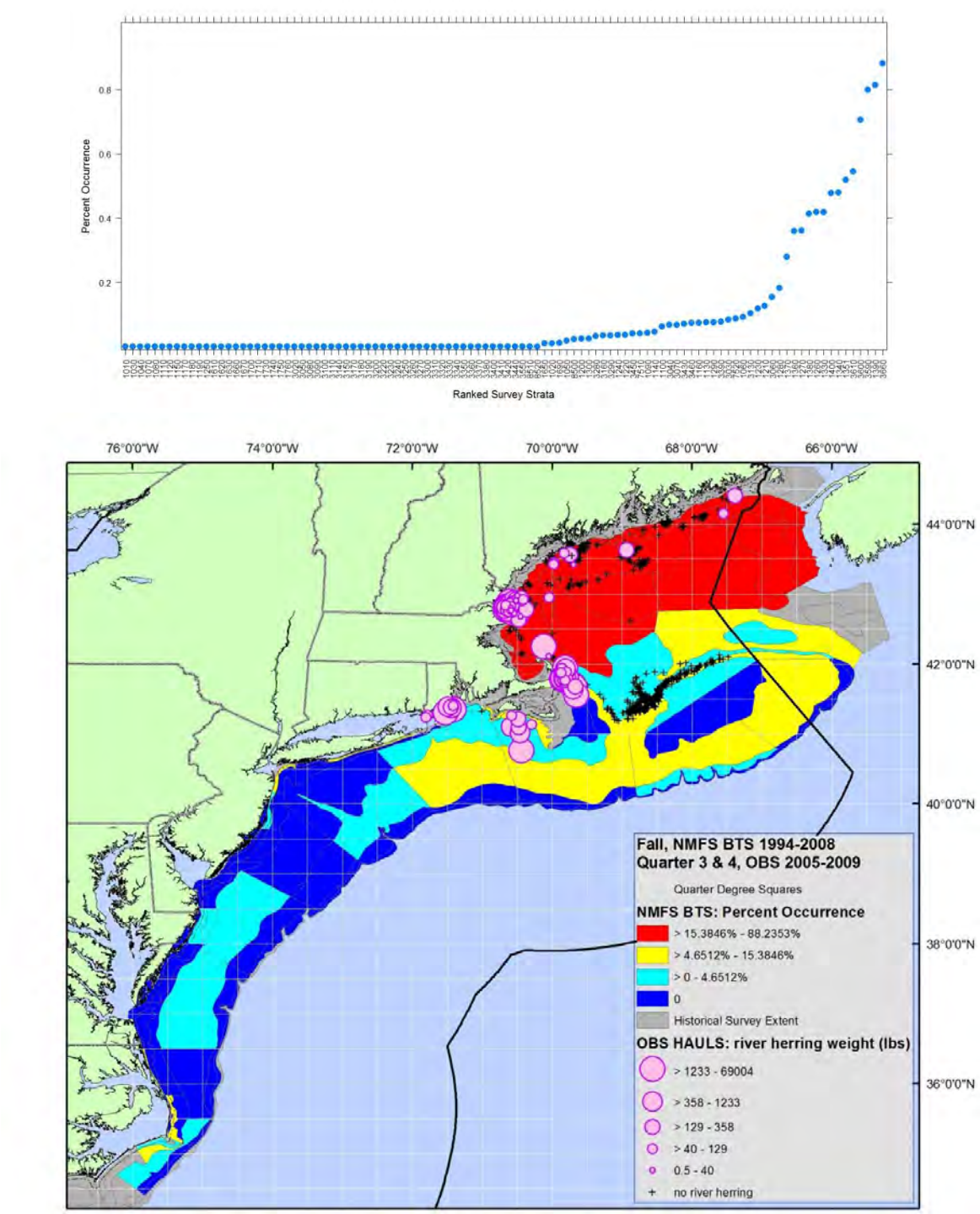

Figure A.8: Percent occurrence of river herring in fall research surveys by survey strata ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by survey strata grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 3 and 4 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

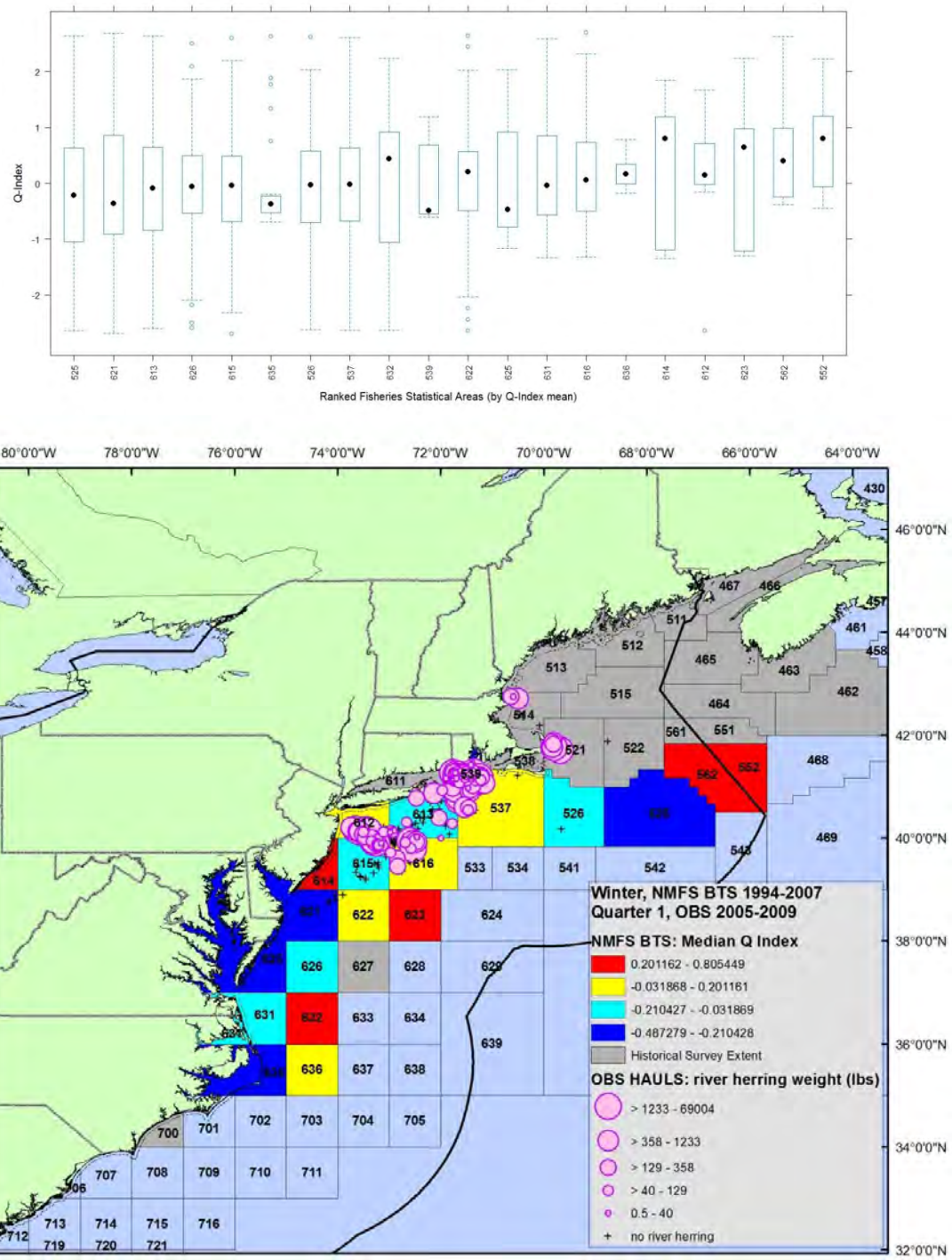

Figure A.9: Median Q index of river herring in winter research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring median Q index by statistical area grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2007 and NEFOP Database 2005-2009.

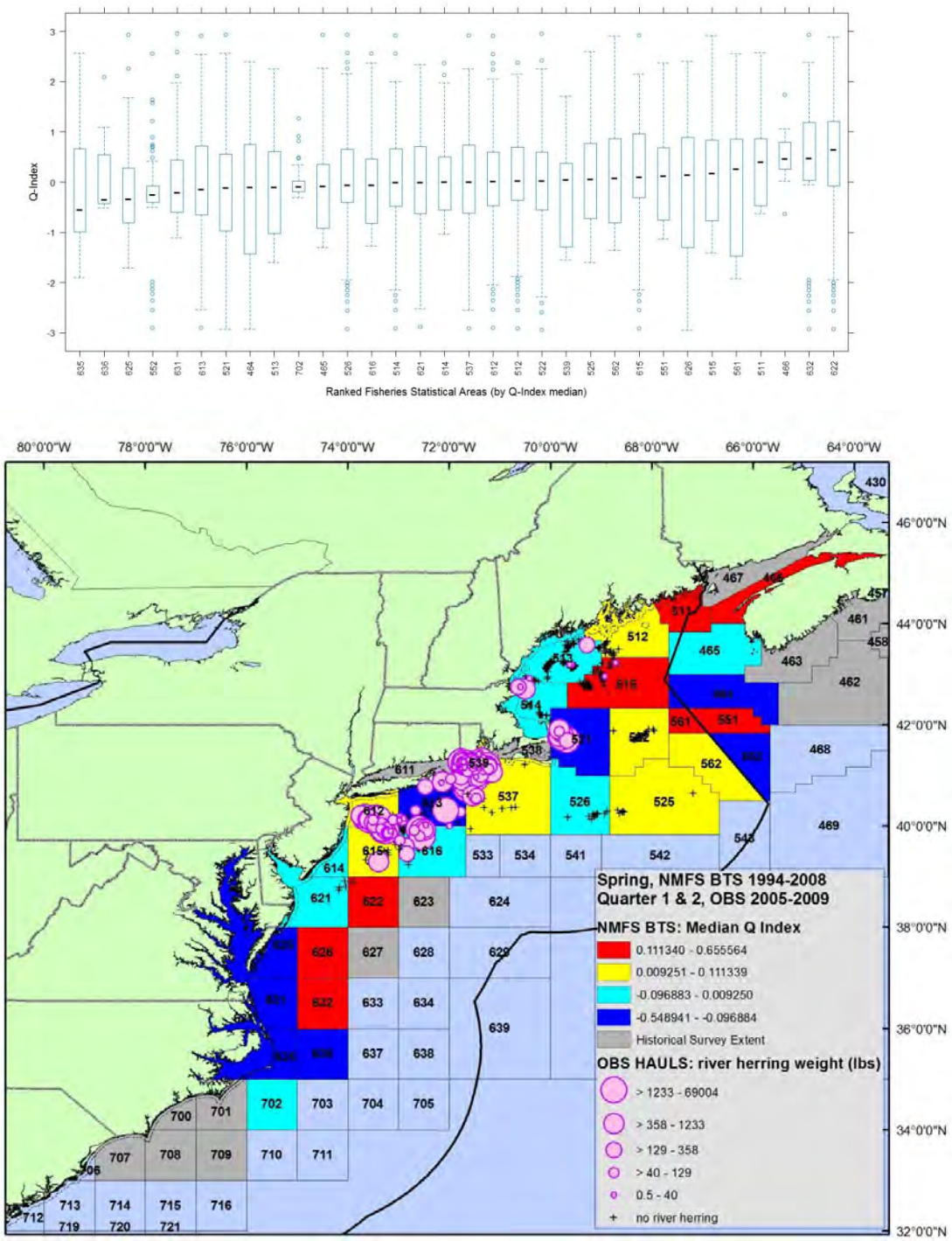

Figure A.10: Median Q index of river herring in spring research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring median Q index by statistical area grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 and 2 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

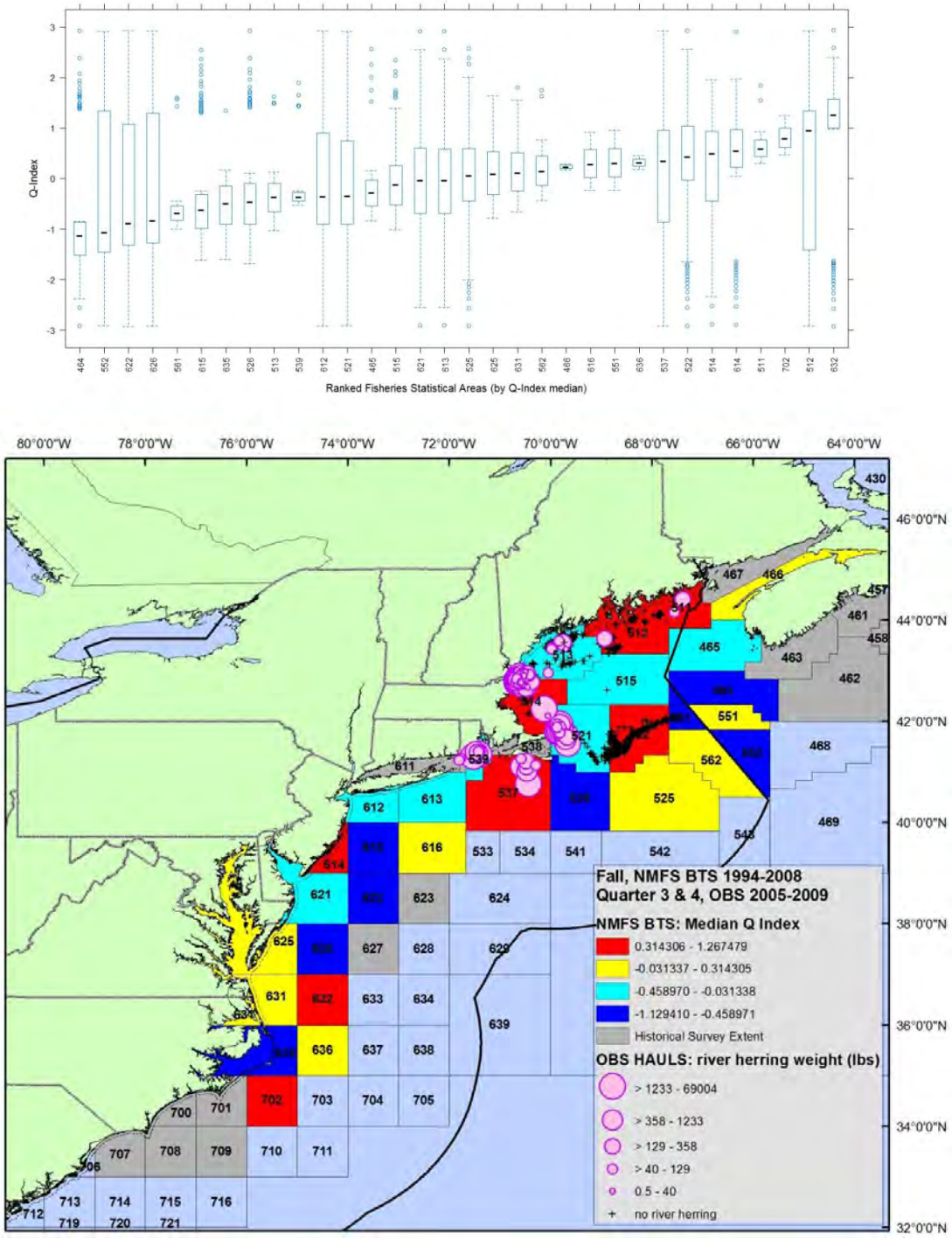

Figure A.11: Median Q index of river herring in fall research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring median Q index by statistical area grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 3 and 4 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

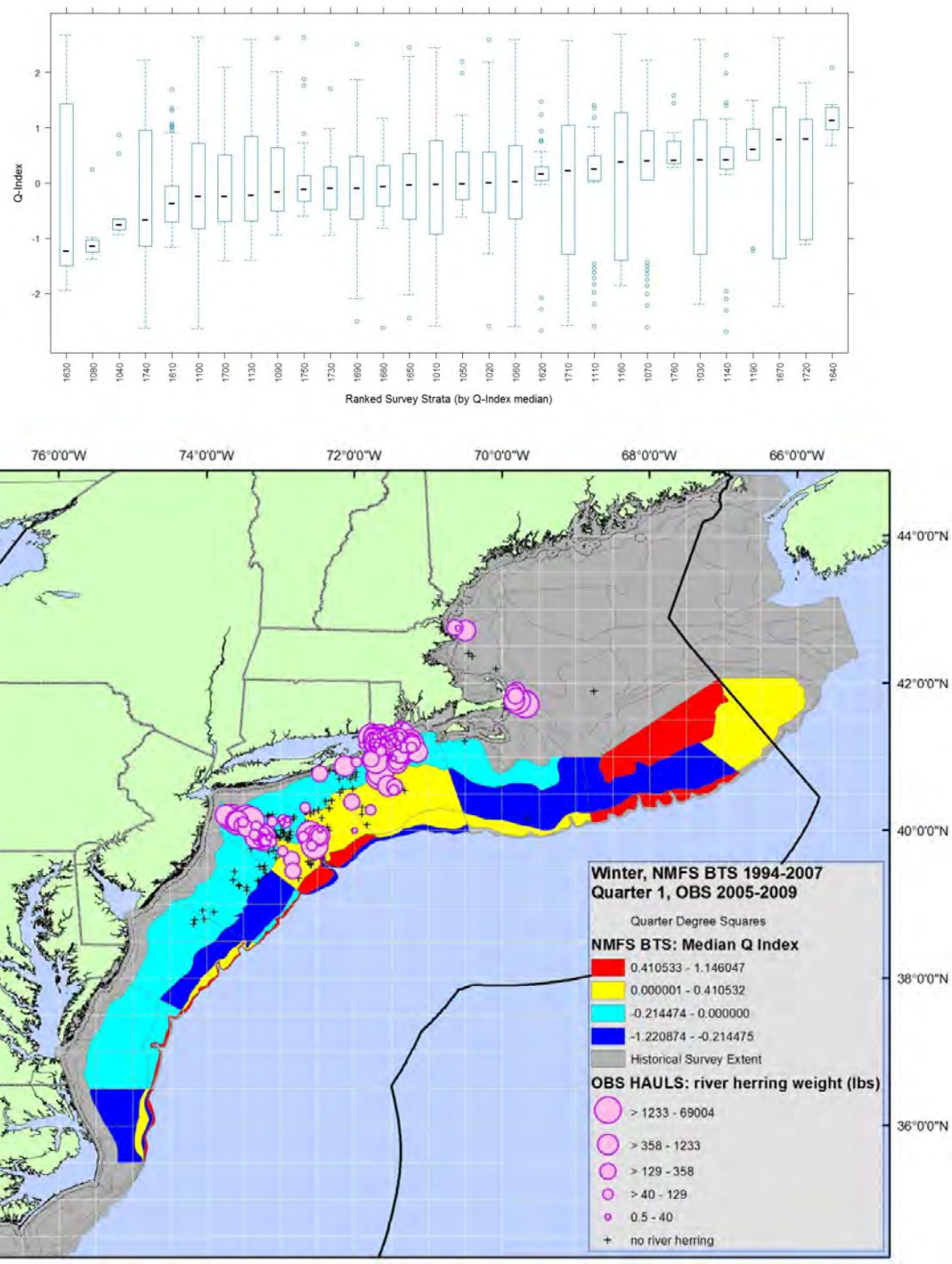

Figure A.12: Median Q index of river herring in winter research surveys by survey strata ranked from lowest to highest (top). Map of corresponding river herring median Q index by survey strata grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2007 and NEFOP Database 2005-2009.

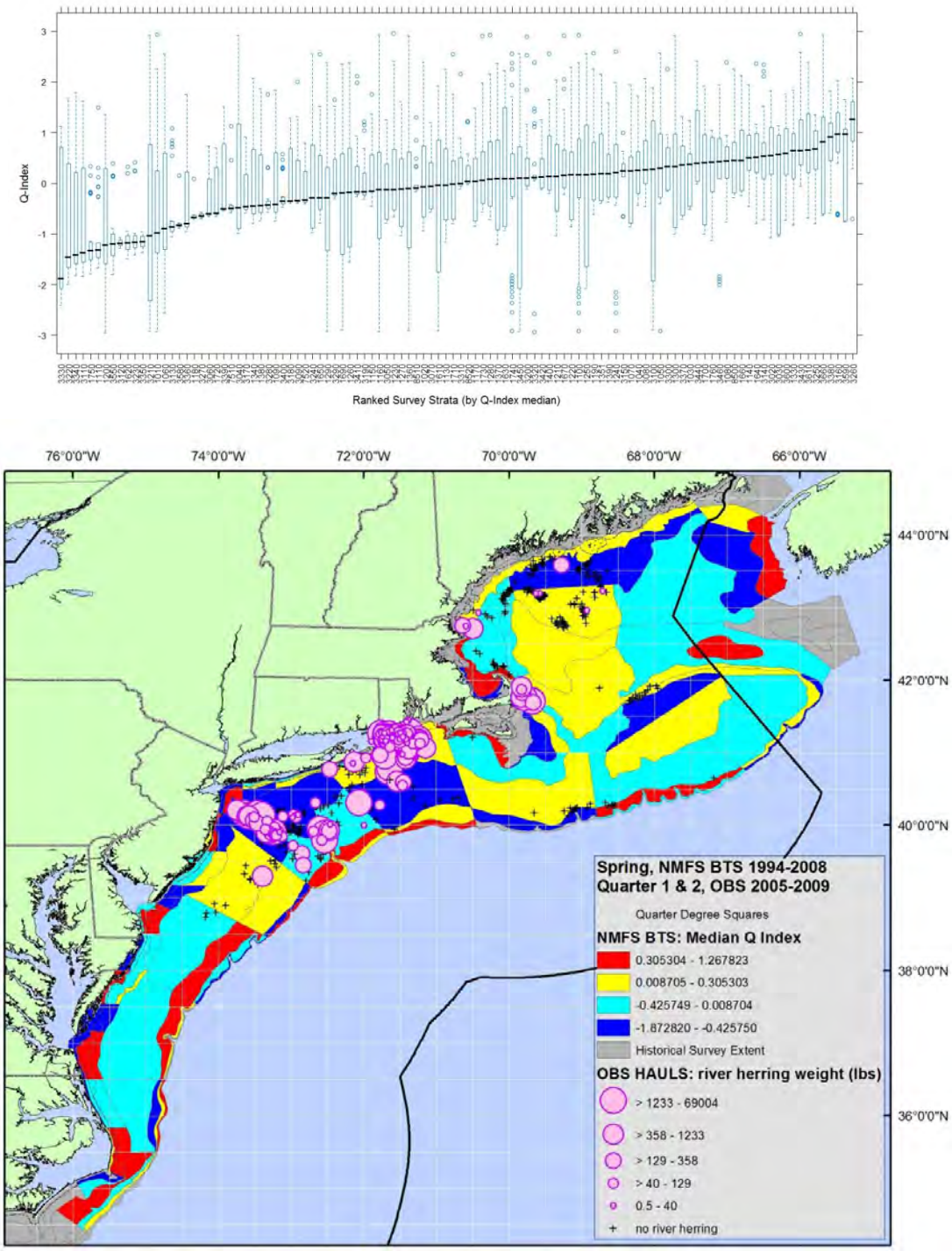

Figure A.13: Median Q index of river herring in spring research surveys by survey strata ranked from lowest to highest (top). Map of corresponding river herring median Q index by survey strata grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 1 and 2 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

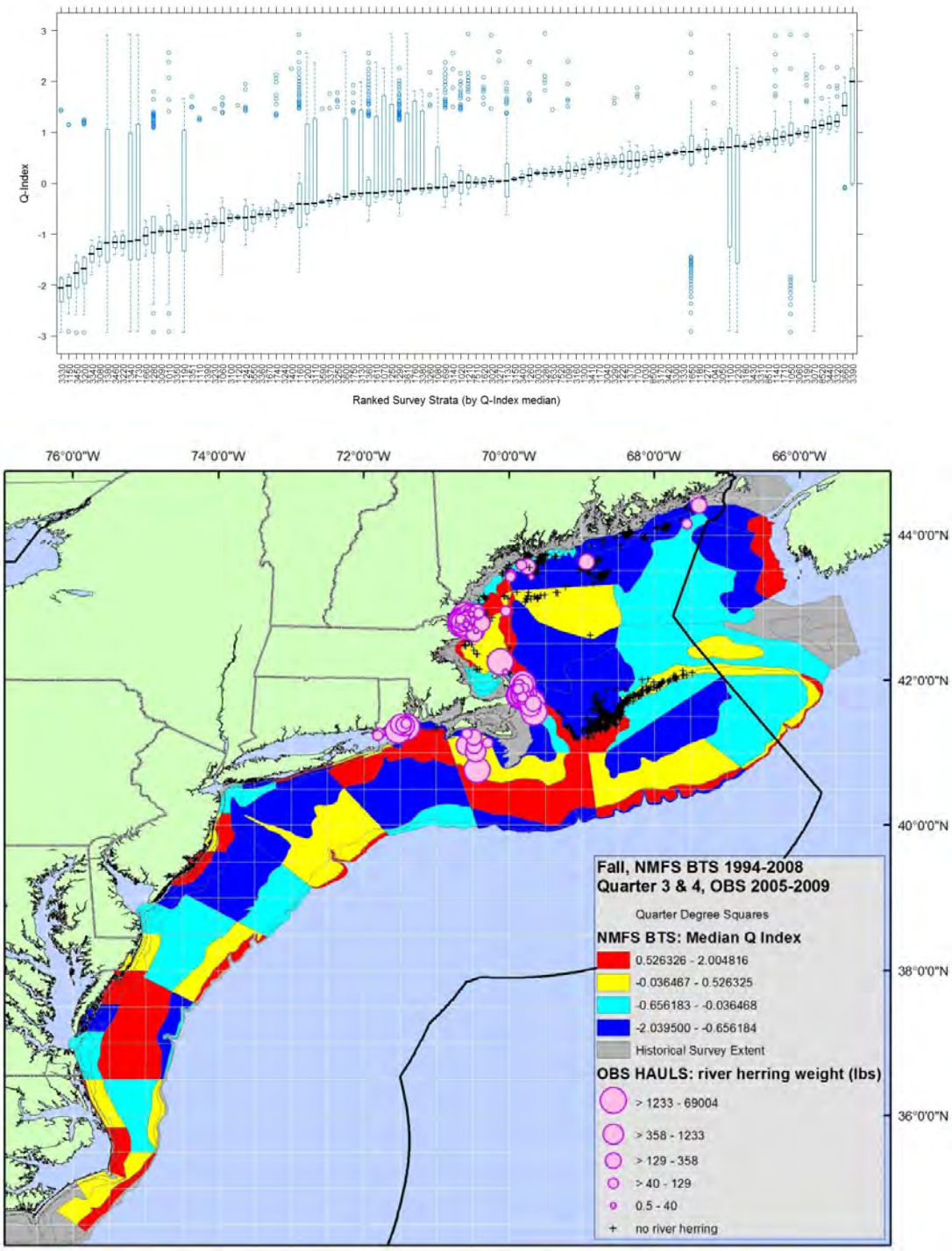

Figure A.14: Median Q index of river herring in fall research surveys by survey strata ranked from lowest to highest (top). Map of corresponding river herring median Q index by survey strata grouped by quantiles (bottom). Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets from quarter 3 and 4 directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: NMFS bottom-trawl surveys 1994-2008 and NEFOP Database 2005-2009.

DRAFT

UPDATE: Identification of river herring hotspots at sea using fisheries dependent and independent datasets

Prepared for the Atlantic Herring PDT

by

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Background

At its May 2010 meeting, the New England Fisheries Management Council Herring Oversight Committee (Committee) tasked the Plan Development Team (PDT) with identifying river herring hotspots as part of the analysis for Amendment 5 to the Atlantic Herring fishery management plan (FMP). Specifically, one of the objectives for Amendment 5 of the FMP is to address river herring bycatch in the Atlantic herring, *Clupea harengus*, fishery.

Here, the term "river herring" refers to alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*. This analysis combines available data on both species to identify river herring hotspots. As recommended by the Committee at its July 2010 meeting, the following is an update to the methods and analysis developed by the PDT to identify river herring hotspots.

Study Area

The study area includes the Atlantic herring fishery management plan areas that overlap the Eastern US Continental shelf (Fig. 1).

Datasets and Data Selection

Multiple data sources are used in this analysis to identify river herring hotspots at sea. These sources include fishery dependent (Vessel Trip Reports, VTR and Northeast Fishery Observer Program, NEFOP) and fishery independent (National Marine Fisheries Service, NMFS bottom-trawl surveys) datasets (Tables 1-3). The most recent 5 years (2005-2009) of fishery dependent data and all years (1948-2008) of fishery independent are pooled separately by dataset in the analysis.

Data from directed herring trips were selected from VTR and NEFOP databases and grouped into bimonthly blocks (Tables 1 and 2). Here, directed herring trips were defined as 2,000 lbs of kept Atlantic herring on a trip. Data from other non-directed trips is not included in the analysis, but may become the scope of future examination. In addition, fishery dependent data included three broad gear categories: bottom otter-trawl, purse seine, and mid-water trawl (combining single and pair mid-water trawls).

River herring data from observed directed herring trips (NEFOP) were presence/absence and weight (lbs) from each haul or set. Data from the Massachusetts Division of Marine Fisheries and the Maine Department of Marine Resources portside surveys were excluded because spatial information was not available for all years and all trips.

Selected river herring data from NMFS bottom-trawl surveys included presence/absence and the number of individuals found at each sampling location. Surveys were separated by season: winter, spring, summer and fall (Tables 3 and 4).

Methods

Fishing Effort and River Herring Bycatch

To understand where and when the directed herring fishery operated throughout the fishing year, bimonthly maps and tables of the number of trips per statistical area were constructed using VTRs (Appendix Tables A1-A6 and Figs. A1-A6). Fishing effort was approximated by the number of trips within a statistical area. Bimonthly maps of fishing effort by statistical areas were color-coded from hot (red) to cool (blue) to identify fishing effort concentration areas.

These maps were overlaid with bimonthly NEFOP data on river herring bycatch events from observed hauls and sets. Circles of increasing size represent the magnitude of the bycatch event. These bycatch events were binned into circles of increasing size using all years and months combined and then mapped separately in bimonthly blocks.

Survey Hotspots

Seasonal NMFS bottom-trawl surveys were used to identify river herring "hotspot" areas. Analyses for the winter, spring, summer and fall surveys were conducted separately using a quarter degree squares spatial stratification scheme. Greater than 10 tows per square were required for inclusion in the analysis. Squares with less than 10 tows were omitted from the analysis.

For each seasonal survey, two metrics were used to determine hotspots:

- percent occurrence and
- percent occurrence and catch in number (number of individuals).

Percent occurrence. Within each square, percent occurrence was defined as the count of tows with river herring present divided by the total tows. For example if for a given area, the number of tows was 100, and out of those 100 tows 66 tows detected river herring. The percent occurrence for that area was 66%. The percent occurrence for each square was used for ranking. Maps of ranked squares were color-coded from hot (red) to cool (blue or purple) to identify river herring hotspot areas.

Percent occurrence and catch in number. An algorithm defined hot spots based on the intersection of the set of squares above a selected quantile for percent occurrence and set of squares above a selected quantile of a summary statistic for river herring catch (number of individuals). Tows with no river herring catch were omitted from the analysis. For example, candidate hotspots can be defined using the 75th quantile of percent occurrence and 75th quantile of median catch in number. Candidate “hot spot” squares were identified as squares meeting the following criteria:

- percent occurrence and mean catch in number ≥ the 75th quantiles of both variables

- percent occurrence and median catch in number ≥ the 75th quantiles of both variables
- percent occurrence and catch in number ≥ the 75th quantiles of both variables.

Candidate squares were ranked using each metric and recorded in respective tables, plots and maps (Appendix Tables A7-A18, Figs. A7- A38). These candidate hotspots were overlaid with bimonthly directed fishing trips per statistical area (VTRs) and river herring bycatch from observed hauls and sets (NEFOP) based on the timing of the NMFS bottom-trawl surveys (Figs. 2-5, Table 4).

Results

Fishing Effort and River Herring Bycatch

Visual differences in the spatial and temporal distribution of directed herring trips were evident from maps of fishing effort (Appendix Figs. A1-A6). In general during the first six months of the year, fishing effort shifted from the northern Mid-Atlantic Bight and southern New England waters (January-February) to primarily southern New England waters (March-April), and then to the Gulf of Maine (May-June). Then, fishing effort concentrated in the Gulf of Maine and Georges Bank (July-August and September-October), contracting to the Gulf of Maine and southern New England waters (November-December) at the end of the year.

Using NEFOP haul and set data, river herring bycatch events were inspected bimonthly (Appendix Figs. A1-A6). River herring bycatch events included areas in Ipswich Bay, off the back of Cape Cod, and in the northern Mid-Atlantic Bight (January-February and March-April). River herring bycatch events occurred in the northern Gulf of Maine and off the back of Cape Cod (May- June). Bycatch events also included areas in the northern Gulf of Maine (July-August and September-October), Ipswich Bay (September-October and November-December), and Massachusetts Bay, the back of Cape Cod, south of Martha's Vineyard, and near Block Island (November-December).

Survey Hotspots

Results include river herring hotspot areas ranked in tables, plots, and maps:

- percent occurrence (Appendix Figs. A31-A34)
- percent occurrence and mean catch in number ≥ the 75th quantiles of both variables (Appendix Tables A7, A10, A13, A16, and Figs. A7, A10, A13, A16, A19, A22, A25, A28, A35-A38)
- percent occurrence and median catch in number ≥ the 75th quantiles of both variables (Appendix Tables A8, A11, A14, A17, and Figs. A8, A11, A14, A17, A20, A23, A26, A29, A35-A38)
- percent occurrence and catch in number ≥ the 75th quantiles of both variables (Appendix Tables A9, A12, A15, A18, and Figs. A9, A12, A15, A18, A21, A24, A27, A30, A35-A38)

Each of these above combinations produced different hotspot maps, but there was substantial overlap among maps of candidate river herring hotspot areas (Appendix Figs. A35-A38 and Table 5). The number of identified candidate river herring hotspot areas also varied by identification method and season (Table 5).

Fishing Effort, River Herring Bycatch, and Survey Hotspots

Fishery Observer data, Vessel Trip Reports and seasonal candidate hotspots provide can be integrated at the bimonthly-quarter degree square resolution. Fishery observer data can provide information on the distribution of observed river herring bycatch on a bimonthly-block basis for areas where the fishery is prosecuted. VTR data can provide spatial distribution of fishing effort. Note that the historic distribution of effort reflects locations where Atlantic herring and Atlantic mackerel can be caught. These target species may be available in other areas not currently fished because of regulations or economic considerations. Candidate hotspots are defined as bimonthly blocks combinations with high (≥75th quantile) of both percent occurrence and counts. The candidate spots provide information on the relative likelihood of encountering river herring for areas that have either little to no fishing effort or observer coverage. The candidate hotspots can be useful for evaluating the likely impact of changing the spatial-temporal distribution of fishing effort on reducing river herring bycatch.

We provide an example of the integrative approach by overlaying candidate hotspots identified using blocks at or above the 75th quantiles of the median catch in number and percent occurrence with fishing effort and observed river herring bycatch (Figures 2-5). We note that resolution finer than bimonthly and quarter degree square is not feasible.

Additional Information

State by state migration patterns of alewife, blueback herring, and American shad, *Alosa sapidissima*, in state fresh waters are included for reference (Table A19).

Tables

Jan-Dec	Gear Category			
Year	OT	PR	PS	ALL
2005	77	774	200	1051
2006	150	739	175	1064
2007	414	389	365	1168
2008	109	304	246	659
2009	203	406	225	834
ALL	953	2612	1211	**4776**

Jan-Feb	Gear Category			
Year	OT	PR	PS	ALL
2005	10	89	0	99
2006	52	108	0	160
2007	140	141	0	281
2008	56	101	0	157
2009	79	128	0	207
ALL	337	567	0	**904**

Mar-Apr	Gear Category			
Year	OT	PR	PS	ALL
2005	5	48	0	53
2006	19	71	0	90
2007	15	65	0	80
2008	7	44	0	51
2009	26	55	0	81
ALL	72	283	0	**355**

May-Jun	Gear Category			
Year	OT	PR	PS	ALL
2005	7	151	25	183
2006	0	158	27	185
2007	0	75	52	127
2008	0	25	53	78
2009	1	18	53	72
ALL	8	427	210	**645**

Jun-Aug	Gear Category			
Year	OT	PR	PS	ALL
2005	7	182	88	277
2006	12	202	94	308
2007	163	0	187	350
2008	17	12	177	206
2009	27	9	121	157
ALL	226	405	667	**1298**

Sep-Oct	Gear Category			
Year	OT	PR	PS	ALL
2005	20	195	82	297
2006	25	143	54	222
2007	64	52	126	242
2008	10	68	16	94
2009	25	128	45	198
ALL	144	586	323	**1053**

Nov-Dec	Gear Category			
Year	OT	PR	PS	ALL
2005	28	109	5	142
2006	42	57	0	99
2007	32	56	0	88
2008	19	54	0	73
2009	45	68	6	119
ALL	166	344	11	**521**

Table 1: Number of directed herring trips separated by gear, year and bimonthly groupings. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Jan-Dec	Gear Category			
Year	OT	PR	PS	ALL
2005	15	465	95	575
2006	64	120	0	184
2007	59	75	27	161
2008	8	209	69	286
2009	35	437	97	569
ALL	181	1306	288	**1775**

Jan-Feb	Gear Category			
Year	OT	PR	PS	ALL
2005	0	39	0	39
2006	36	72	0	108
2007	37	19	0	56
2008	4	44	0	48
2009	23	76	0	99
ALL	100	250	0	**350**

Mar-Apr	Gear Category			
Year	OT	PR	PS	ALL
2005	0	21	0	21
2006	0	3	0	3
2007	0	22	0	22
2008	0	41	0	41
2009	4	34	0	38
ALL	4	121	0	**125**

May-Jun	Gear Category			
Year	OT	PR	PS	ALL
2005	0	64	5	69
2006	0	6	0	6
2007	0	3	0	3
2008	0	28	25	53
2009	0	37	39	76
ALL	0	138	69	**207**

Jul-Aug	Gear Category			
Year	OT	PR	PS	ALL
2005	3	112	47	162
2006	16	17	0	33
2007	11	0	18	29
2008	4	15	36	55
2009	0	11	51	62
ALL	34	155	152	**341**

Sep-Oct	Gear Category			
Year	OT	PR	PS	ALL
2005	12	111	43	166
2006	8	20	0	28
2007	3	15	9	27
2008	0	42	8	50
2009	4	194	3	201
ALL	27	382	63	**472**

Nov-Dec	Gear Category			
Year	OT	PR	PS	ALL
2005	0	118	0	118
2006	4	2	0	6
2007	8	16	0	24
2008	0	39	0	39
2009	4	85	4	93
ALL	16	260	4	**280**

Table 2: Observed hauls from directed herring trips separated by gear, year and bimonthly groupings. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Source: NEFOP Database 2005-2009.

	Season				
Year	Winter	Spring	Summer	Fall	ALL
1948			52		52
1949			167		167
↓					
1963			154	88	242
1964	105		148	126	379
1965	99		151	142	392
1966	105			147	252
1967				195	195
1968		199		192	391
1969		203	204	175	582
1970		215		180	395
1971		203		216	419
1972	52	199		449	700
1973		481		436	917
1974		385		366	751
1975		267		391	658
1976		373		339	712
1977		353	262	407	1022
1978	77	385	264	529	1255
1979		469	245	556	1270
1980		435	264	388	1087
1981	81	366	160	356	963
1982		330		282	612
1983		327		343	670
1984		339		302	641
1985		317		289	606
1986		321		287	608
1987		285		290	575
1988		289		285	574
1989		252		277	529
1990		289		292	581
1991		291	6	305	602
1992	112	281		284	677
1993	105	285	56	299	745
1994	75	299	22	288	684
1995	117	288	26	297	728
1996	110	287		263	660
1997	108	290		287	685
1998	116	321		294	731
1999	118	291		295	704
2000	106	290		294	690
2001	140	279		283	702
2002	134	272		288	694
2003	65	270		280	615
2004	114	284		277	675
2005	80	260		278	618
2006	101	292		305	698
2007	114	312		294	720
2008		297		305	602
ALL	2234	12471	2181	13541	**30427**

Table 3: Number of tows from seasonal research surveys separated by year and season. Source: NMFS bottom-trawl surveys 1948-2008.

		NMFS BTS Seasons			
Month	Fishing Quarter	Winter	Spring	Summer	Fall
January	1	210			
February	1	1878	32		
March	1	85	6013		
April	2	61	5567		
May	2		821		
June	2		38	39	
July	3			764	
August	3			1350	
September	3			28	4545
October	4				6688
November	4				2152
December	4				156

Table 4: Number of tows from seasonal research surveys separated month, fishing quarter, and survey season. Note that spring and fall surveys overlap multiple fishing quarters. Source: NMFS bottom-trawl surveys 1948-2008.

	Number of Candidate Areas		
Season	mean	median	75th
Winter	12	16	14
Spring	25	37	27
Summer	13	18	18
Fall	20	29	29

Table 5: Resulting number of candidate river herring hotspot areas by season. Candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables (mean), percent occurrence and median catch in number ≥ the 75th quantiles of both variables (median), and percent occurrence and catch in number ≥ the 75th quantiles of both variables (75th). Source: NMFS bottom-trawl surveys 1948-2008.

Figures

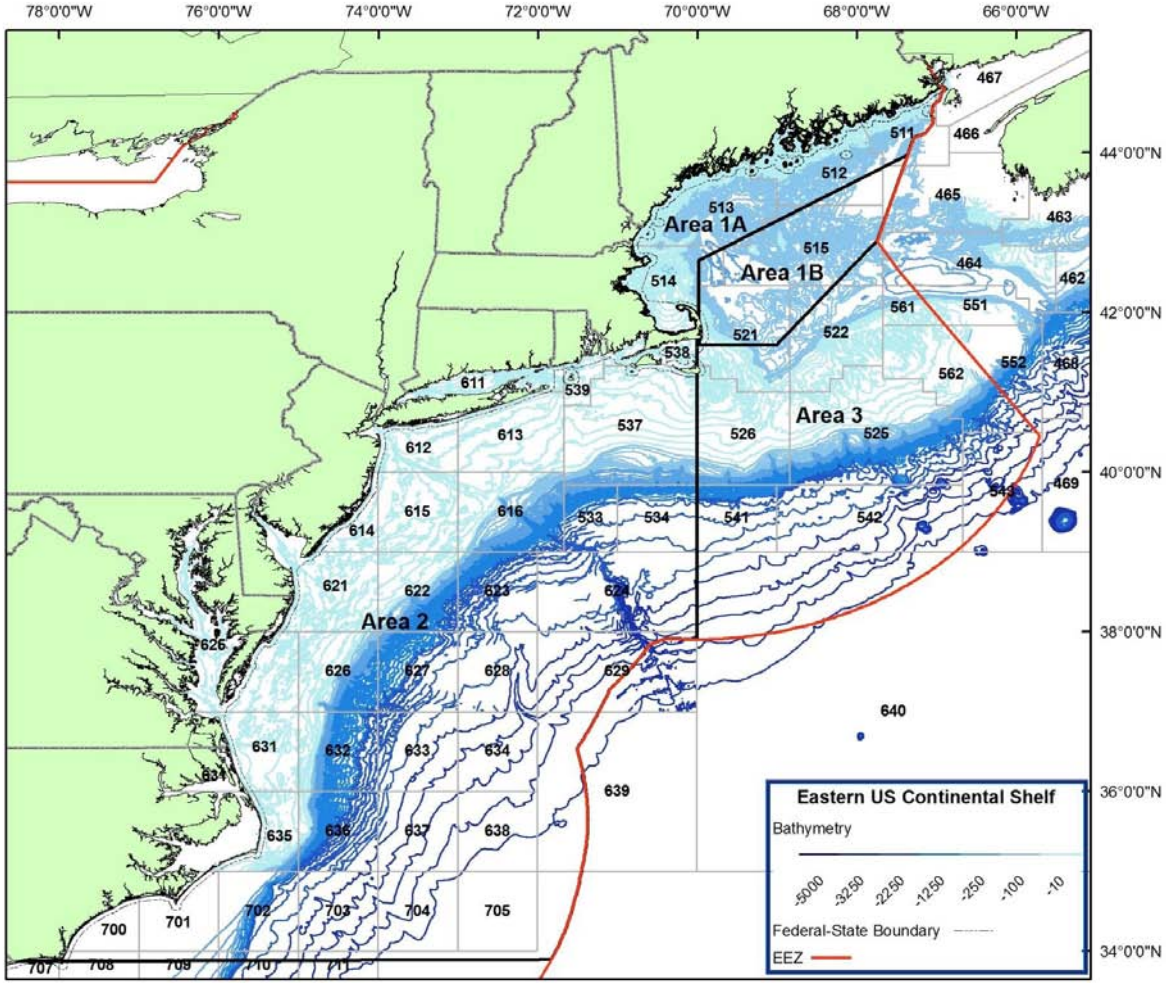


Figure 1: Study area of the Eastern US Continental Shelf. Overlapping Atlantic herring fishery management plan areas (Area 1A, 1B, 2, and 3) and fisheries management statistical areas (400-700s) indicated.

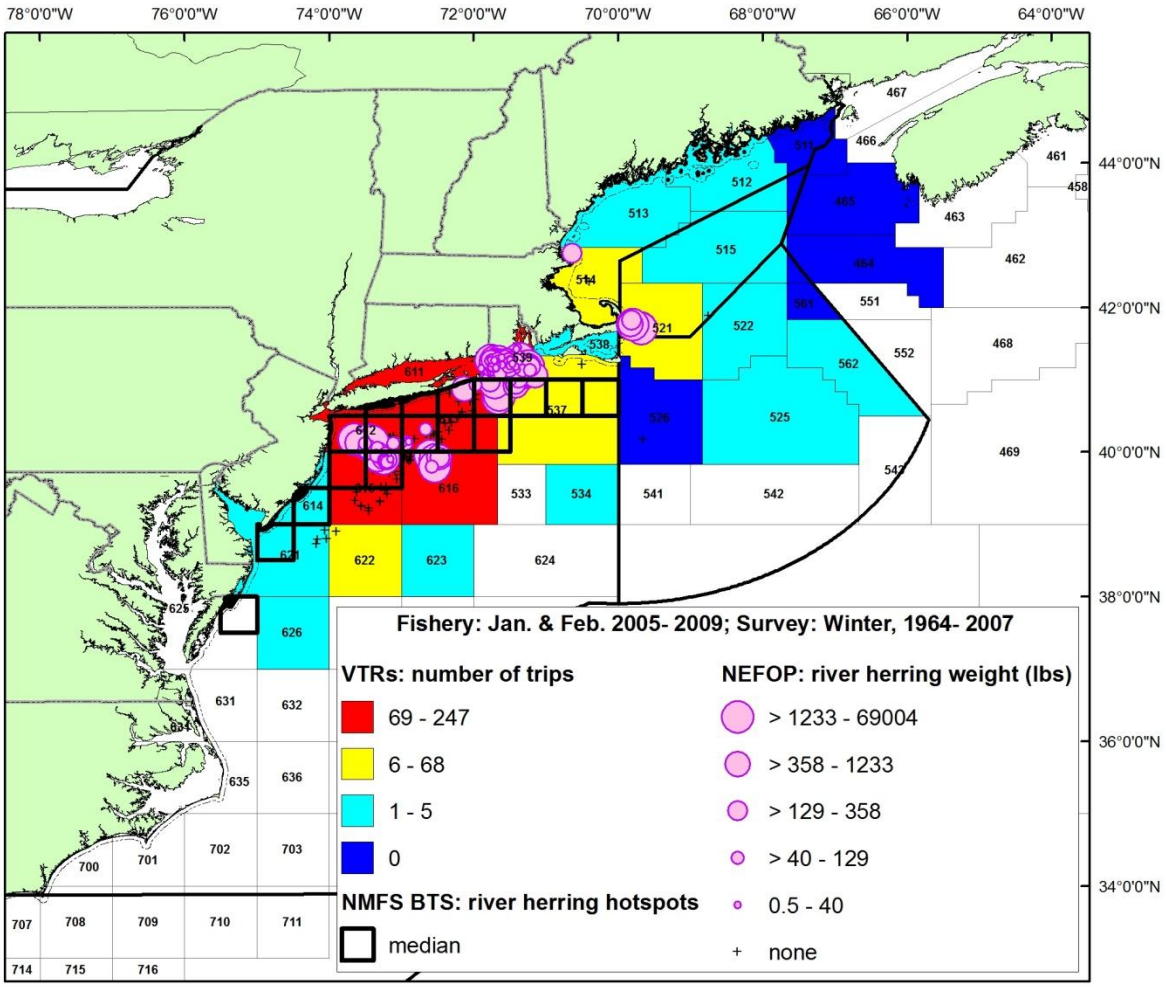


Figure 2: Reported trips (VTR) and observed hauls and sets (NEFOP) during January and February, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-247 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Winter candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Winter 1963-2007 NMFS bottom-trawl surveys.

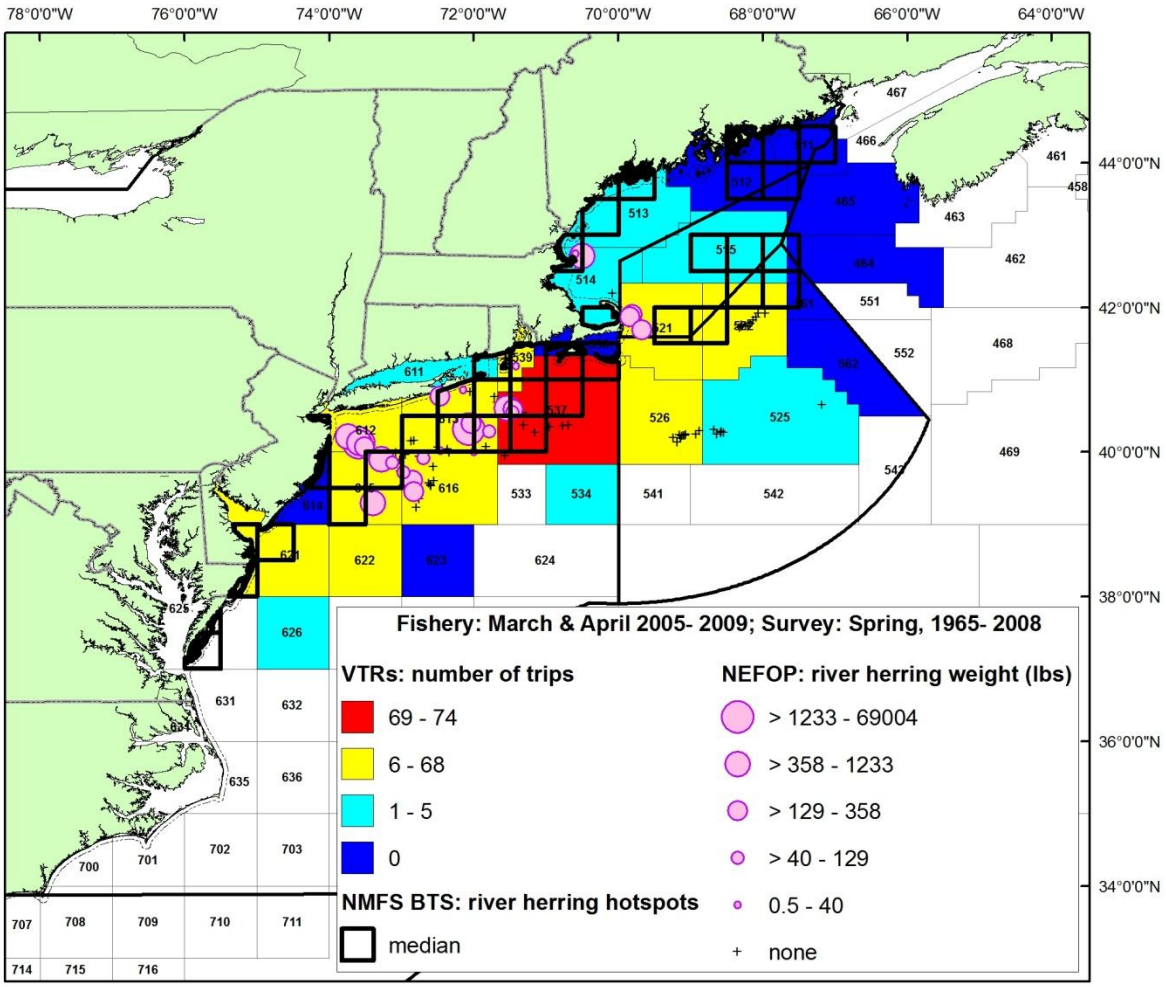


Figure 3: Reported trips (VTR) and observed hauls and sets (NEFOP) during March and April, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-74 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Spring candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Spring 1965-2008 NMFS bottom-trawl surveys.

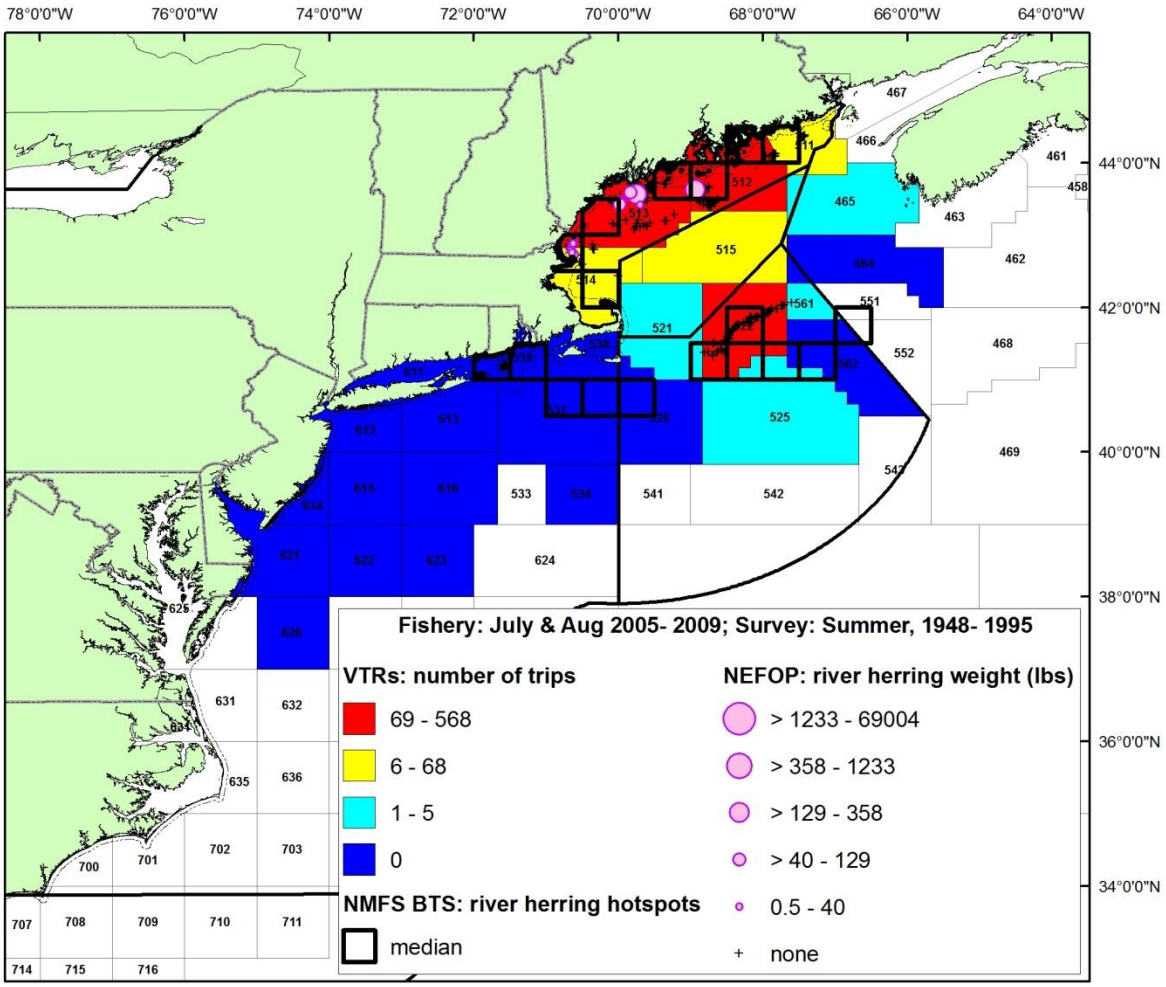


Figure 4: Reported trips (VTR) and observed hauls and sets (NEFOP) during July and August, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-568 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Summer candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Summer 1948-1995 NMFS bottom-trawl surveys.

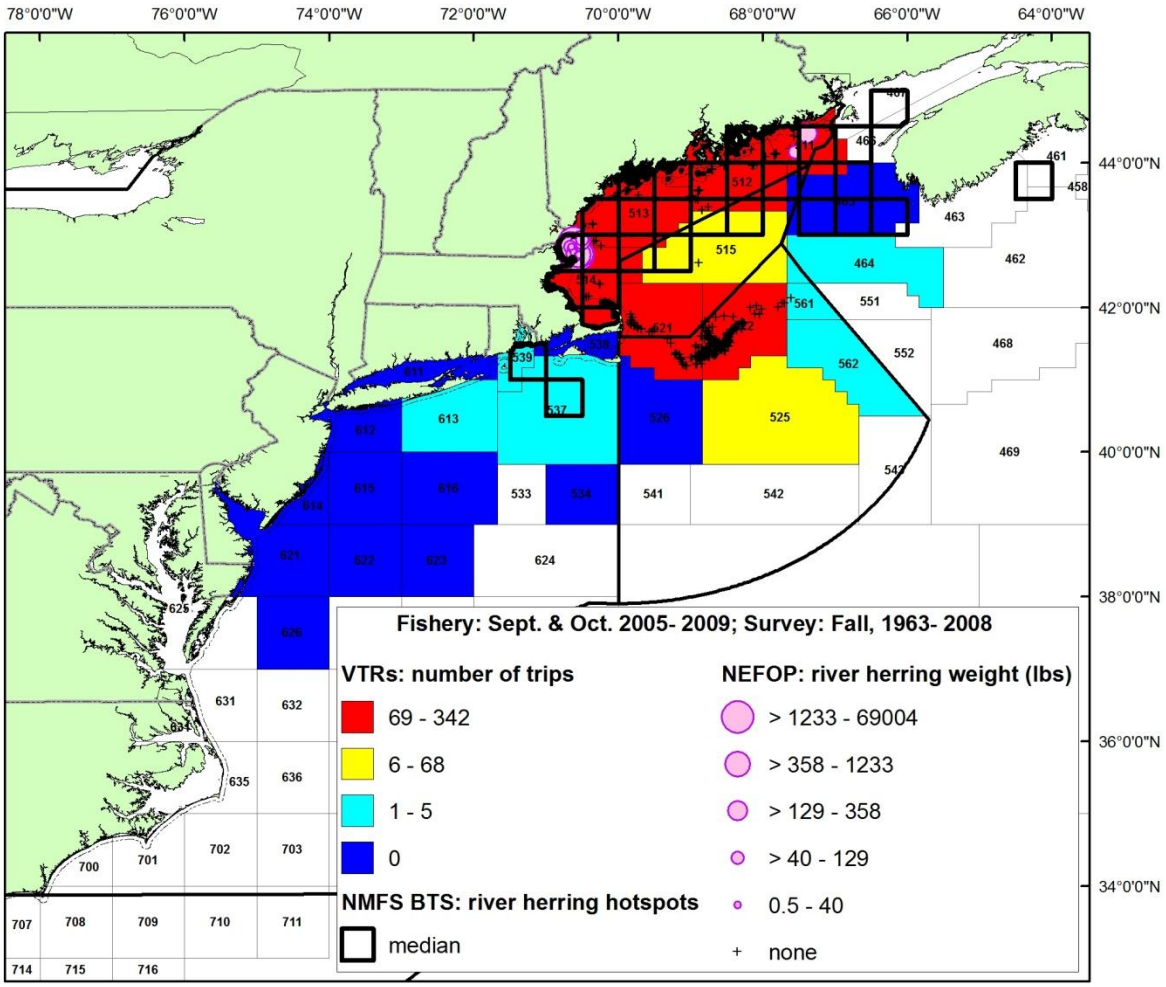


Figure 5: Reported trips (VTR) and observed hauls and sets (NEFOP) during September and October, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-342(red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Fall candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Fall 1963-2008 NMFS bottom-trawl surveys.

Appendix

Tables

Jan-Feb	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	0	0	0
511	0	0	0	0
512	0	1	0	1
513	0	2	0	2
514	0	14	0	14
515	0	1	0	1
521	1	22	0	23
522	0	2	0	2
525	0	1	0	1
526	0	0	0	0
534	1	1	0	2
537	40	24	0	64
538	2	2	0	4
539	144	103	0	247
561	0	0	0	0
562	0	2	0	2
611	77	31	0	108
612	6	100	0	106
613	20	95	0	115
614	0	1	0	1
615	23	99	0	122
616	19	51	0	70
621	1	3	0	4
622	3	9	0	12
623	0	1	0	1
626	0	2	0	2

Table A1: Number of directed herring trips separated by gear and statistical area for January-February. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Mar-Apr	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	0	0	0
511	0	0	0	0
512	0	0	0	0
513	0	5	0	5
514	0	5	0	5
515	0	1	0	1
521	0	6	0	6
522	0	20	0	20
525	0	2	0	2
526	1	11	0	12
534	0	1	0	1
537	19	55	0	74
538	0	0	0	0
539	24	16	0	40
561	0	0	0	0
562	0	0	0	0
611	3	2	0	5
612	2	32	0	34
613	12	36	0	48
614	0	0	0	0
615	2	29	0	31
616	6	36	0	42
621	1	7	0	8
622	2	15	0	17
623	0	0	0	0
626	0	4	0	4

Table A2: Number of directed herring trips separated by gear and statistical area for March-April. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

May-Jun	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	0	0	0
511	0	8	2	10
512	0	10	76	86
513	1	276	121	398
514	0	35	1	36
515	0	34	8	42
521	0	35	2	37
522	0	7	0	7
525	0	0	0	0
526	0	1	0	1
534	0	0	0	0
537	1	20	0	21
538	0	0	0	0
539	2	0	0	2
561	0	0	0	0
562	0	0	0	0
611	1	0	0	1
612	1	0	0	1
613	1	1	0	2
614	0	0	0	0
615	0	0	0	0
616	1	0	0	1
621	0	0	0	0
622	0	0	0	0
623	0	0	0	0
626	0	0	0	0

Table A3: Number of directed herring trips separated by gear and statistical area for May-June. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Jul-Aug	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	0	2	2
511	0	8	60	68
512	3	134	360	497
513	184	160	224	568
514	37	17	5	59
515	0	8	15	23
521	0	1	0	1
522	2	71	1	74
525	0	1	0	1
526	0	0	0	0
534	0	0	0	0
537	0	0	0	0
538	0	0	0	0
539	0	0	0	0
561	0	5	0	5
562	0	0	0	0
611	0	0	0	0
612	0	0	0	0
613	0	0	0	0
614	0	0	0	0
615	0	0	0	0
616	0	0	0	0
621	0	0	0	0
622	0	0	0	0
623	0	0	0	0
626	0	0	0	0

Table A4: Number of directed herring trips separated by gear and statistical area for July-August. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Sep-Oct	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	1	1
465	0	0	0	0
511	0	24	112	136
512	0	31	77	108
513	69	153	120	342
514	72	115	5	192
515	0	5	6	11
521	1	92	0	93
522	1	153	2	156
525	1	6	0	7
526	0	0	0	0
534	0	0	0	0
537	0	1	0	1
538	0	0	0	0
539	0	1	0	1
561	0	1	0	1
562	0	1	0	1
611	0	0	0	0
612	0	0	0	0
613	0	3	0	3
614	0	0	0	0
615	0	0	0	0
616	0	0	0	0
621	0	0	0	0
622	0	0	0	0
623	0	0	0	0
626	0	0	0	0

Table A5: Number of directed herring trips separated by gear and statistical area for September-October. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Nov-Dec	Gear Category			
Statistical Area	OT	PR	PS	ALL
464	0	0	0	0
465	0	1	0	1
511	0	1	0	1
512	0	1	0	1
513	2	35	5	42
514	9	118	6	133
515	0	0	0	0
521	6	120	0	126
522	0	12	0	12
525	0	0	0	0
526	0	1	0	1
534	0	0	0	0
537	2	19	0	21
538	0	0	0	0
539	93	21	0	114
561	0	1	0	1
562	0	0	0	0
611	43	10	0	53
612	2	1	0	3
613	8	3	0	11
614	1	0	0	1
615	0	0	0	0
616	0	0	0	0
621	0	0	0	0
622	0	0	0	0
623	0	0	0	0
626	0	0	0	0

Table A6: Number of directed herring trips separated by gear and statistical area for November-December. Directed herring trips defined as 2,000 lbs of kept Atlantic herring on a trip. Gear categories include bottom otter-trawl (OT), purse seine (PS) and mid-water trawl (PR). Mid-water trawl (PR) refers to pair and single mid-water trawls. Source: Vessel Trip Report Database 2005-2009.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
38753	91.1%	45	22.5	1013	2.0	11.0	23.0	50.4	266
37754	87.5%	24	77.6	1862	1.0	7.0	33.0	129.9	1213
40714	86.8%	114	36.2	4123	2.0	8.0	24.8	58.0	1002
40712	85.6%	90	46.1	4145	3.0	12.0	43.5	112.1	671
40741	84.6%	13	24.4	317	1.0	4.0	32.0	66.8	92
41684	83.6%	61	22.0	1343	3.0	7.0	18.0	60.0	200
41703	83.1%	83	44.1	3662	1.0	11.0	41.5	105.6	685
41712	81.2%	69	36.0	2481	2.0	7.0	15.0	92.6	843
40723	80.9%	251	26.5	6652	1.0	5.0	18.0	64.0	646
40713	80.0%	90	24.3	2185	1.0	7.5	19.5	38.0	408
40721	79.2%	96	51.1	4907	1.0	7.5	37.3	112.5	886
38751	79.1%	86	31.4	2701	1.0	4.0	19.3	52.5	483
42704	79.0%	62	67.0	4157	1.3	14.5	38.8	146.8	1202
44672	78.5%	79	16.5	1306	1.0	3.0	12.0	33.4	261
39743	74.6%	122	19.1	2336	0.3	3.0	7.8	39.9	584
39733	74.0%	73	27.6	2018	0.0	3.0	12.0	77.2	326
40722	73.7%	76	15.0	1139	0.0	3.0	7.3	44.0	185
41711	73.5%	83	26.5	2199	0.0	3.0	11.5	54.8	426
37752	73.1%	171	15.0	2561	0.0	2.0	8.0	26.0	713
38744	72.1%	233	14.5	3367	0.0	2.0	8.0	23.0	852
40711	71.2%	118	28.5	3365	0.0	2.0	14.8	64.3	892
43701	70.2%	94	18.2	1711	0.0	2.0	9.0	50.1	227
39732	70.0%	60	17.6	1057	0.0	2.0	13.3	29.3	366
43683	69.2%	78	16.0	1245	0.0	3.0	10.0	43.3	215
43694	68.8%	16	15.9	254	0.0	4.0	14.0	46.0	105

Table A7: Spring candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
38753	91.1%	45	22.5	1013	2.0	11.0	23.0	50.4	266
37754	87.5%	24	77.6	1862	1.0	7.0	33.0	129.9	1213
40714	86.8%	114	36.2	4123	2.0	8.0	24.8	58.0	1002
40712	85.6%	90	46.1	4145	3.0	12.0	43.5	112.1	671
40741	84.6%	13	24.4	317	1.0	4.0	32.0	66.8	92
44671	84.4%	64	5.5	352	1.0	3.0	8.3	15.7	29
41684	83.6%	61	22.0	1343	3.0	7.0	18.0	60.0	200
41703	83.1%	83	44.1	3662	1.0	11.0	41.5	105.6	685
40704	81.5%	65	13.1	851	1.0	4.0	12.0	20.0	264
41712	81.2%	69	36.0	2481	2.0	7.0	15.0	92.6	843
40723	80.9%	251	26.5	6652	1.0	5.0	18.0	64.0	646
40713	80.0%	90	24.3	2185	1.0	7.5	19.5	38.0	408
41702	79.2%	53	11.4	603	1.0	2.0	10.0	29.8	139
42674	79.2%	53	3.0	157	1.0	2.0	4.0	7.8	12
42683	79.2%	53	5.2	277	1.0	3.0	8.0	11.8	37
40721	79.2%	96	51.1	4907	1.0	7.5	37.3	112.5	886
38751	79.1%	86	31.4	2701	1.0	4.0	19.3	52.5	483
42704	79.0%	62	67.0	4157	1.3	14.5	38.8	146.8	1202
44672	78.5%	79	16.5	1306	1.0	3.0	12.0	33.4	261
39743	74.6%	122	19.1	2336	0.3	3.0	7.8	39.9	584
42672	74.5%	94	7.6	718	0.3	3.0	9.0	21.4	73
42681	74.1%	58	12.6	733	0.3	4.0	11.8	25.9	150
39733	74.0%	73	27.6	2018	0.0	3.0	12.0	77.2	326
40722	73.7%	76	15.0	1139	0.0	3.0	7.3	44.0	185
41711	73.5%	83	26.5	2199	0.0	3.0	11.5	54.8	426
44681	73.3%	15	11.4	171	1.0	5.0	8.0	24.6	84
37752	73.1%	171	15.0	2561	0.0	2.0	8.0	26.0	713
38744	72.1%	233	14.5	3367	0.0	2.0	8.0	23.0	852
43674	72.1%	43	12.0	516	0.0	2.0	8.5	27.8	157
40711	71.2%	118	28.5	3365	0.0	2.0	14.8	64.3	892
41693	70.7%	82	11.0	906	0.0	4.0	12.0	29.8	131
43701	70.2%	94	18.2	1711	0.0	2.0	9.0	50.1	227
42684	70.1%	77	8.9	683	0.0	3.0	11.0	24.8	66
39732	70.0%	60	17.6	1057	0.0	2.0	13.3	29.3	366
43683	69.2%	78	16.0	1245	0.0	3.0	10.0	43.3	215
41701	69.0%	42	6.0	252	0.0	2.0	4.0	20.5	44
43694	68.8%	16	15.9	254	0.0	4.0	14.0	46.0	105

Table A8: Spring candidate “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
38753	91.1%	45	22.5	1013	2.0	11.0	23.0	50.4	266
37754	87.5%	24	77.6	1862	1.0	7.0	33.0	129.9	1213
40714	86.8%	114	36.2	4123	2.0	8.0	24.8	58.0	1002
40712	85.6%	90	46.1	4145	3.0	12.0	43.5	112.1	671
40741	84.6%	13	24.4	317	1.0	4.0	32.0	66.8	92
41684	83.6%	61	22.0	1343	3.0	7.0	18.0	60.0	200
41703	83.1%	83	44.1	3662	1.0	11.0	41.5	105.6	685
40704	81.5%	65	13.1	851	1.0	4.0	12.0	20.0	264
41712	81.2%	69	36.0	2481	2.0	7.0	15.0	92.6	843
40723	80.9%	251	26.5	6652	1.0	5.0	18.0	64.0	646
40713	80.0%	90	24.3	2185	1.0	7.5	19.5	38.0	408
41702	79.2%	53	11.4	603	1.0	2.0	10.0	29.8	139
40721	79.2%	96	51.1	4907	1.0	7.5	37.3	112.5	886
38751	79.1%	86	31.4	2701	1.0	4.0	19.3	52.5	483
42704	79.0%	62	67.0	4157	1.3	14.5	38.8	146.8	1202
44672	78.5%	79	16.5	1306	1.0	3.0	12.0	33.4	261
42672	74.5%	94	7.6	718	0.3	3.0	9.0	21.4	73
42681	74.1%	58	12.6	733	0.3	4.0	11.8	25.9	150
39733	74.0%	73	27.6	2018	0.0	3.0	12.0	77.2	326
41711	73.5%	83	26.5	2199	0.0	3.0	11.5	54.8	426
40711	71.2%	118	28.5	3365	0.0	2.0	14.8	64.3	892
41693	70.7%	82	11.0	906	0.0	4.0	12.0	29.8	131
43701	70.2%	94	18.2	1711	0.0	2.0	9.0	50.1	227
42684	70.1%	77	8.9	683	0.0	3.0	11.0	24.8	66
39732	70.0%	60	17.6	1057	0.0	2.0	13.3	29.3	366
43683	69.2%	78	16.0	1245	0.0	3.0	10.0	43.3	215
43694	68.8%	16	15.9	254	0.0	4.0	14.0	46.0	105

Table A9: Spring candidate “hot spot” quarter degree squares identified as squares with percent occurrence and catch in number ≥ the 75th quantiles of both variables. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
44672	65.0%	20	15.0	299	0.0	3.0	14.5	45.7	81
44681	60.0%	15	8.3	124	0.0	3.0	7.0	23.2	58
40703	53.8%	26	26.0	676	0.0	1.0	3.0	29.5	520
43693	50.0%	14	72.2	1011	0.0	1.0	46.5	199.1	610
41682	38.2%	34	5.2	178	0.0	0.0	3.0	15.4	65
41672	34.4%	32	36.7	1175	0.0	0.0	25.3	123.2	298
40704	33.3%	15	5.2	78	0.0	0.0	4.0	18.4	37
41711	33.3%	12	21.4	257	0.0	0.0	4.3	17.6	224
40694	28.6%	28	111.6	3124	0.0	0.0	1.8	77.7	2431
41683	25.8%	31	6.1	190	0.0	0.0	0.5	6.0	62
41664	25.0%	20	7.9	157	0.0	0.0	2.0	19.8	86
41671	25.0%	24	9.3	223	0.0	0.0	0.5	8.7	181
41681	24.1%	29	22.4	650	0.0	0.0	0.0	86.6	178

Table A10: Summer candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
44672	65.0%	20	15.0	299	0.0	3.0	14.5	45.7	81
44681	60.0%	15	8.3	124	0.0	3.0	7.0	23.2	58
40703	53.8%	26	26.0	676	0.0	1.0	3.0	29.5	520
43693	50.0%	14	72.2	1011	0.0	1.0	46.5	199.1	610
42704	46.2%	26	3.7	97	0.0	0.0	4.0	10.0	37
43684	38.5%	26	3.5	90	0.0	0.0	2.8	6.0	54
41682	38.2%	34	5.2	178	0.0	0.0	3.0	15.4	65
41672	34.4%	32	36.7	1175	0.0	0.0	25.3	123.2	298
43701	34.1%	41	2.0	84	0.0	0.0	2.0	5.0	30
40704	33.3%	15	5.2	78	0.0	0.0	4.0	18.4	37
41711	33.3%	12	21.4	257	0.0	0.0	4.3	17.6	224
41712	29.4%	17	1.1	18	0.0	0.0	1.0	3.4	8
40694	28.6%	28	111.6	3124	0.0	0.0	1.8	77.7	2431
41683	25.8%	31	6.1	190	0.0	0.0	0.5	6.0	62
41664	25.0%	20	7.9	157	0.0	0.0	2.0	19.8	86
41671	25.0%	24	9.3	223	0.0	0.0	0.5	8.7	181
41681	24.1%	29	22.4	650	0.0	0.0	0.0	86.6	178
42701	24.1%	58	3.0	176	0.0	0.0	0.0	6.0	99

Table A11: Summer candidate “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
44672	65.0%	20	15.0	299	0.0	3.0	14.5	45.7	81
44681	60.0%	15	8.3	124	0.0	3.0	7.0	23.2	58
40703	53.8%	26	26.0	676	0.0	1.0	3.0	29.5	520
43693	50.0%	14	72.2	1011	0.0	1.0	46.5	199.1	610
42704	46.2%	26	3.7	97	0.0	0.0	4.0	10.0	37
43684	38.5%	26	3.5	90	0.0	0.0	2.8	6.0	54
41682	38.2%	34	5.2	178	0.0	0.0	3.0	15.4	65
41672	34.4%	32	36.7	1175	0.0	0.0	25.3	123.2	298
43701	34.1%	41	2.0	84	0.0	0.0	2.0	5.0	30
40704	33.3%	15	5.2	78	0.0	0.0	4.0	18.4	37
41711	33.3%	12	21.4	257	0.0	0.0	4.3	17.6	224
41712	29.4%	17	1.1	18	0.0	0.0	1.0	3.4	8
40694	28.6%	28	111.6	3124	0.0	0.0	1.8	77.7	2431
41683	25.8%	31	6.1	190	0.0	0.0	0.5	6.0	62
41664	25.0%	20	7.9	157	0.0	0.0	2.0	19.8	86
41671	25.0%	24	9.3	223	0.0	0.0	0.5	8.7	181
41681	24.1%	29	22.4	650	0.0	0.0	0.0	86.6	178
42701	24.1%	58	3.0	176	0.0	0.0	0.0	6.0	99

Table A12: Summer candidate “hot spot” quarter degree squares identified as squares with percent occurrence and catch in number ≥ the 75th quantiles of both variables. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
44681	90.9%	22	21.0	462	2.0	5.0	30.3	74.7	110
41703	68.4%	76	49.0	3727	0.0	2.0	25.0	158.0	787
42704	67.7%	62	82.9	5139	0.0	3.0	35.3	84.6	1865
44672	64.9%	74	27.0	1999	0.0	2.0	14.3	59.3	533
43694	59.1%	22	5.8	128	0.0	2.0	5.8	13.4	38
42702	58.8%	51	45.7	2330	0.0	1.0	20.0	145.0	449
43684	55.0%	60	12.5	752	0.0	1.0	7.5	31.1	167
43693	50.0%	38	5.7	218	0.0	0.5	6.3	19.0	73
43683	48.4%	95	7.0	669	0.0	0.0	4.0	12.6	320
43643	47.4%	19	1.9	37	0.0	0.0	3.5	5.6	8
42701	43.3%	180	13.3	2401	0.0	0.0	3.0	11.3	452
43701	40.2%	107	4.0	427	0.0	0.0	3.0	11.4	80
44662	39.2%	79	2.8	223	0.0	0.0	3.0	6.2	58
43664	39.1%	110	4.4	483	0.0	0.0	4.0	14.1	62
43673	33.8%	80	4.4	348	0.0	0.0	1.0	3.1	227
44671	33.3%	81	2.7	216	0.0	0.0	1.0	6.0	53
43681	32.7%	55	2.2	120	0.0	0.0	1.0	4.8	36
43674	28.3%	60	1.8	107	0.0	0.0	1.0	3.0	57
42703	26.5%	132	2.3	306	0.0	0.0	1.0	3.0	93
41711	23.9%	71	14.4	1020	0.0	0.0	0.0	14.0	646

Table A13: Fall candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
44681	90.9%	22	21.0	462	2.0	5.0	30.3	74.7	110
41703	68.4%	76	49.0	3727	0.0	2.0	25.0	158.0	787
42704	67.7%	62	82.9	5139	0.0	3.0	35.3	84.6	1865
44672	64.9%	74	27.0	1999	0.0	2.0	14.3	59.3	533
43694	59.1%	22	5.8	128	0.0	2.0	5.8	13.4	38
42702	58.8%	51	45.7	2330	0.0	1.0	20.0	145.0	449
43684	55.0%	60	12.5	752	0.0	1.0	7.5	31.1	167
43693	50.0%	38	5.7	218	0.0	0.5	6.3	19.0	73
43683	48.4%	95	7.0	669	0.0	0.0	4.0	12.6	320
43643	47.4%	19	1.9	37	0.0	0.0	3.5	5.6	8
42701	43.3%	180	13.3	2401	0.0	0.0	3.0	11.3	452
43701	40.2%	107	4.0	427	0.0	0.0	3.0	11.4	80
44662	39.2%	79	2.8	223	0.0	0.0	3.0	6.2	58
43664	39.1%	110	4.4	483	0.0	0.0	4.0	14.1	62
43673	33.8%	80	4.4	348	0.0	0.0	1.0	3.1	227
44671	33.3%	81	2.7	216	0.0	0.0	1.0	6.0	53
43681	32.7%	55	2.2	120	0.0	0.0	1.0	4.8	36
43674	28.3%	60	1.8	107	0.0	0.0	1.0	3.0	57
43662	28.2%	71	1.2	87	0.0	0.0	1.0	2.0	25
43671	28.1%	57	0.8	46	0.0	0.0	1.0	3.4	9
44663	27.3%	11	0.5	6	0.0	0.0	0.5	2.0	3
42703	26.5%	132	2.3	306	0.0	0.0	1.0	3.0	93
41711	23.9%	71	14.4	1020	0.0	0.0	0.0	14.0	646
43691	23.5%	81	1.3	108	0.0	0.0	0.0	2.0	37
42693	23.3%	90	1.0	88	0.0	0.0	0.0	3.1	17
43682	22.1%	95	1.3	124	0.0	0.0	0.0	4.0	18
42694	21.7%	92	1.0	88	0.0	0.0	0.0	2.0	23
43661	21.1%	19	0.7	14	0.0	0.0	0.0	2.0	9
40704	19.8%	81	1.1	93	0.0	0.0	0.0	2.0	31

Table A14: Fall candidate “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
44681	90.9%	22	21.0	462	2.0	5.0	30.3	74.7	110
41703	68.4%	76	49.0	3727	0.0	2.0	25.0	158.0	787
42704	67.7%	62	82.9	5139	0.0	3.0	35.3	84.6	1865
44672	64.9%	74	27.0	1999	0.0	2.0	14.3	59.3	533
43694	59.1%	22	5.8	128	0.0	2.0	5.8	13.4	38
42702	58.8%	51	45.7	2330	0.0	1.0	20.0	145.0	449
43684	55.0%	60	12.5	752	0.0	1.0	7.5	31.1	167
43693	50.0%	38	5.7	218	0.0	0.5	6.3	19.0	73
43683	48.4%	95	7.0	669	0.0	0.0	4.0	12.6	320
43643	47.4%	19	1.9	37	0.0	0.0	3.5	5.6	8
42701	43.3%	180	13.3	2401	0.0	0.0	3.0	11.3	452
43701	40.2%	107	4.0	427	0.0	0.0	3.0	11.4	80
44662	39.2%	79	2.8	223	0.0	0.0	3.0	6.2	58
43664	39.1%	110	4.4	483	0.0	0.0	4.0	14.1	62
43673	33.8%	80	4.4	348	0.0	0.0	1.0	3.1	227
44671	33.3%	81	2.7	216	0.0	0.0	1.0	6.0	53
43681	32.7%	55	2.2	120	0.0	0.0	1.0	4.8	36
43674	28.3%	60	1.8	107	0.0	0.0	1.0	3.0	57
43662	28.2%	71	1.2	87	0.0	0.0	1.0	2.0	25
43671	28.1%	57	0.8	46	0.0	0.0	1.0	3.4	9
44663	27.3%	11	0.5	6	0.0	0.0	0.5	2.0	3
42703	26.5%	132	2.3	306	0.0	0.0	1.0	3.0	93
41711	23.9%	71	14.4	1020	0.0	0.0	0.0	14.0	646
43691	23.5%	81	1.3	108	0.0	0.0	0.0	2.0	37
42693	23.3%	90	1.0	88	0.0	0.0	0.0	3.1	17
43682	22.1%	95	1.3	124	0.0	0.0	0.0	4.0	18
42694	21.7%	92	1.0	88	0.0	0.0	0.0	2.0	23
43661	21.1%	19	0.7	14	0.0	0.0	0.0	2.0	9
40704	19.8%	81	1.1	93	0.0	0.0	0.0	2.0	31

Table A15: Fall candidate “hot spot” quarter degree squares identified as squares with percent occurrence and catch in number ≥ the 75th quantiles of both variables. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
40713	91.3%	46	29.9	1376	2.3	6.0	28.0	49.5	326
39741	90.9%	22	23.4	515	2.5	7.0	22.3	45.6	197
40721	87.9%	33	13.1	431	3.0	7.0	15.0	32.8	58
38744	82.6%	23	30.0	690	2.0	5.0	23.5	74.8	261
40714	80.9%	47	29.0	1362	1.0	8.0	29.0	93.0	274
40732	79.2%	24	10.7	257	1.0	2.0	6.3	17.5	115
40722	77.8%	27	15.3	413	1.0	3.0	9.5	54.2	99
39734	77.4%	31	13.6	422	1.0	4.0	18.5	46.0	71
40704	71.4%	35	11.0	385	0.0	2.0	9.5	18.6	187
40724	69.6%	23	9.9	227	0.0	3.0	7.5	25.0	67
39733	69.2%	39	14.1	550	0.0	3.0	23.0	32.8	139
40712	69.0%	42	20.6	864	0.0	3.0	19.8	42.0	239

Table A16: Winter candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
40713	91.3%	46	29.9	1376	2.3	6.0	28.0	49.5	326
39741	90.9%	22	23.4	515	2.5	7.0	22.3	45.6	197
40721	87.9%	33	13.1	431	3.0	7.0	15.0	32.8	58
38744	82.6%	23	30.0	690	2.0	5.0	23.5	74.8	261
40714	80.9%	47	29.0	1362	1.0	8.0	29.0	93.0	274
37753	80.0%	20	7.6	152	1.0	3.5	12.5	15.3	39
40732	79.2%	24	10.7	257	1.0	2.0	6.3	17.5	115
40722	77.8%	27	15.3	413	1.0	3.0	9.5	54.2	99
39734	77.4%	31	13.6	422	1.0	4.0	18.5	46.0	71
40723	75.0%	52	7.9	410	0.8	3.0	9.5	19.9	95
40704	71.4%	35	11.0	385	0.0	2.0	9.5	18.6	187
40724	69.6%	23	9.9	227	0.0	3.0	7.5	25.0	67
39733	69.2%	39	14.1	550	0.0	3.0	23.0	32.8	139
40712	69.0%	42	20.6	864	0.0	3.0	19.8	42.0	239
40703	66.7%	39	9.3	362	0.0	2.0	4.0	25.6	79
40733	66.7%	12	3.8	45	0.0	2.5	5.0	5.9	20

Table A17: Winter candidate “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

Quarter degree square	Percent occurrence	Count of tows	Mean	Total catch numbers	25th quantile	median	75th quantile	90th quantile	Maximum catch
40713	91.3%	46	29.9	1376	2.3	6.0	28.0	49.5	326
39741	90.9%	22	23.4	515	2.5	7.0	22.3	45.6	197
40721	87.9%	33	13.1	431	3.0	7.0	15.0	32.8	58
38744	82.6%	23	30.0	690	2.0	5.0	23.5	74.8	261
40714	80.9%	47	29.0	1362	1.0	8.0	29.0	93.0	274
37753	80.0%	20	7.6	152	1.0	3.5	12.5	15.3	39
40722	77.8%	27	15.3	413	1.0	3.0	9.5	54.2	99
39734	77.4%	31	13.6	422	1.0	4.0	18.5	46.0	71
40723	75.0%	52	7.9	410	0.8	3.0	9.5	19.9	95
40704	71.4%	35	11.0	385	0.0	2.0	9.5	18.6	187
40724	69.6%	23	9.9	227	0.0	3.0	7.5	25.0	67
40711	69.4%	49	9.1	444	0.0	1.0	7.0	20.4	180
39733	69.2%	39	14.1	550	0.0	3.0	23.0	32.8	139
40712	69.0%	42	20.6	864	0.0	3.0	19.8	42.0	239

Table A18: Winter candidate “hot spot” quarter degree squares identified as squares with percent occurrence and catch in number ≥ the 75th quantiles of both variables. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

Table A19: Migration patterns of alewife, blueback, and American shad in state fresh waters (following three pages). Note that New Jersey is currently a place holder and will be updated. “SA” indicates some activity and “PA” indicates peak activity. ASMFC Shad and River herring Technical Committee 2010.

ALEWIFE

SA: Some Activity; PA: Peak Activity

		January		February		March		April		May		June		July		August		September		October		November		December	
		1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30
Maine	adult immigration						SA	PA	PA	PA	PA	PA	SA	SA											
	adult emmigration											PA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	spawning							SA	SA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	SA	SA		
	incubation							SA	SA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	SA	SA		
	juvenile freshwater residence							SA	SA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	SA	SA	SA	
	juvenile emigration													SA	SA	SA	SA	SA	SA	SA	SA			SA	
New Hampshire	adult immigration						SA	PA	PA	PA	PA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA				
	adult emmigration											PA	PA	PA	PA	SA	SA	SA	SA	SA	SA				
	spawning										SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA				
	incubation										SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA				
	juvenile freshwater residence										SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA				
	juvenile emigration													PA	SA	SA	SA	SA	SA	SA	SA				
Massachusetts	adult immigration						SA	PA	PA	PA	PA	PA	SA	PA	PA	SA	SA	SA	SA	SA	SA				
	adult emigration											PA	PA	PA	PA	SA	SA	SA	SA	SA	SA				
	spawning						SA	PA	PA	PA	PA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA				
	incubation						SA	PA	PA	PA	PA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA				
	juvenile freshwater residence						SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA				
	juvenile emigration											SA	SA	PA	PA	PA	PA	PA	PA	PA	PA	SA	SA	SA	
Rhode Island	adult immigration						SA	PA	PA	PA	PA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA				
	adult emmigration											PA	PA	PA	PA	SA	SA	SA	SA	SA	SA				
	spawning						SA	PA	PA	PA	PA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA				
	incubation						SA	PA	PA	PA	PA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA				
	juvenile freshwater residence							SA	SA	SA	SA	SA	SA	PA	PA	PA	PA	PA	PA	PA	PA				
	juvenile emigration													SA	SA	SA	SA	SA	SA	SA	SA	SA	SA		
Connecticut	adult immigration			SA	SA	PA	PA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	adult emmigration			SA	SA	PA	PA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	spawning			SA	SA	SA	SA	SA	SA																
	incubation			SA	SA	PA	PA																		
	juvenile freshwater residence						SA	SA	SA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	juvenile emigration													SA	SA	SA	SA	SA	SA	SA	SA	SA	SA		
New York	adult immigration					SA	PA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	adult emmigration						SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	spawning						SA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	incubation						SA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA	SA	SA				
	juvenile freshwater residence						SA	PA	PA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA	SA				
	juvenile emigration													SA	SA	SA	SA	SA	SA	SA	SA	SA	SA		
New Jersey	adult immigration																								
	adult emmigration																								
	spawning																								
	incubation																								
	juvenile freshwater residence																								
	juvenile emigration																								

BLUEBACK HERRING

SA: Some Activity; PA: Peak Activity

		January		February		March		April		May		June		July		August		September		October		November		December	
		1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30
Maine	adult immigration						SA	SA					PA	PA	SA										
	adult emmigration												SA	PA	PA	SA									
	spawning								SA	SA	PA	PA	PA	SA											
	incubation								SA	SA	PA	PA	PA	SA											
	juvenile freshwater residence									SA	PA	PA	PA	SA	PA	PA	PA	PA	PA	PA	SA	SA			
	juvenile emigration												SA	SA	PA	PA	PA	PA	PA	PA	SA	SA			
New Hampshire	adult immigration							SA	PA	PA	PA	PA	SA	SA	PA	PA	PA	PA	PA	PA	SA	SA			
	adult emmigration								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	spawning								PA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	incubation								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile freshwater residence									SA	PA	PA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile emigration												SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
Massachusetts	adult immigration							SA	PA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	adult emigration								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	spawning								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	incubation								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile freshwater residence									SA	PA	PA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile emigration												SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
Rhode Island	adult immigration							SA	PA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	adult emmigration								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	spawning								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	incubation								SA	PA	PA	PA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile freshwater residence									SA	PA	PA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile emigration												SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
Connecticut	adult immigration							SA	SA	SA	SA	SA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	adult emmigration								SA	SA	SA	SA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	spawning								SA	SA	SA	SA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	incubation								SA	SA	SA	SA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile freshwater residence									SA	SA	SA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile emigration												SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
New York	adult immigration						SA	PA	SA	SA	SA	SA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	adult emmigration						SA	PA	SA	SA	SA	SA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	spawning						SA	PA	PA	PA	PA	SA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	incubation						SA	PA	PA	PA	PA	SA	SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile freshwater residence									PA	PA	PA	PA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
	juvenile emigration												SA	SA	PA	SA	SA	SA	SA	SA	SA	SA			
New Jersey	adult immigration													SA	PA	SA	SA	SA	SA	SA	SA				
	adult emmigration													SA	PA	SA	SA	SA	SA	SA	SA				
	spawning													SA	PA	SA	SA	SA	SA	SA	SA				
	incubation													SA	PA	SA	SA	SA	SA	SA	SA				
	juvenile freshwater residence														PA	SA	SA	SA	SA	SA	SA				
	juvenile emigration														PA	SA	SA	SA	SA	SA	SA				

AMERICAN SHAD

SA: Some Activity; PA: Peak Activity

		January		February		March		April		May		June		July		August		September		October		November		December	
		1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30	1-15	16-30
Maine	adult immigration						SA	SA	PA	PA	PA	PA	PA	PA	SA	SA									
	adult emmigration							SA	SA				SA	SA	PA	PA	SA								
	spawning										SA	SA	PA	PA	PA	SA									
	incubation									SA	SA	PA	PA	PA	PA	SA									
	juvenile freshwater residence									SA	PA	PA	PA	PA	PA	PA	PA	PA	PA	SA	SA				
	juvenile emigration												SA	SA	PA	PA	PA	PA	PA	SA	SA	SA			
New Hampshire	adult immigration								SA	PA	PA	SA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	adult emmigration														SA	SA	SA	SA	SA	SA	SA				
	spawning											PA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	incubation											PA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	juvenile freshwater residence											PA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	juvenile emigration														SA	SA	SA	SA	SA	SA	SA				
Massachusetts	adult immigration							SA	SA	PA	PA	PA	PA	SA	SA	PA	SA	SA	SA						
	adult emmigration									PA	PA	PA	PA	SA	SA	PA	SA	SA	SA						
	spawning									PA	PA	PA	PA	SA	SA	PA	SA	SA	SA						
	incubation									SA	SA	PA	PA	SA	SA	PA	SA	SA	SA						
	juvenile freshwater residence									SA	PA	PA	PA	SA	SA	PA	SA	SA	SA						
	juvenile emigration											SA	SA	SA	SA	PA	SA	SA	SA						
Rhode Island	adult immigration							SA	SA	PA	PA	SA	SA												
	adult emmigration									SA	SA	PA	PA	SA											
	spawning									SA	SA	PA	PA	SA											
	incubation									SA	SA	PA	PA	SA											
	juvenile freshwater residence									SA	PA	PA	PA	SA											
	juvenile emigration											SA	SA	SA											
Connecticut	adult immigration							SA	SA	PA	PA	SA	SA												
	adult emmigration								SA	PA	PA	SA	SA												
	spawning									SA	PA	SA	SA												
	incubation									PA	PA	SA	SA												
	juvenile freshwater residence											SA	SA	SA											
	juvenile emigration													SA											
New York	adult immigration							SA	PA	PA	SA	SA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	adult emmigration								PA	PA	SA	SA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	spawning								SA	PA	SA	SA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	incubation								PA	PA	SA	SA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	juvenile freshwater residence								SA	PA	PA	PA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
	juvenile emigration											PA	PA	PA	SA	SA	SA	SA	SA	SA	SA				
New Jersey	adult immigration													SA	SA	SA	SA	SA	SA	SA	SA				
	adult emmigration															SA	SA	SA	SA	SA	SA				
	spawning																	SA	SA	SA	SA				
	incubation																			SA	SA				
	juvenile freshwater residence																								
	juvenile emigration																								

Figures

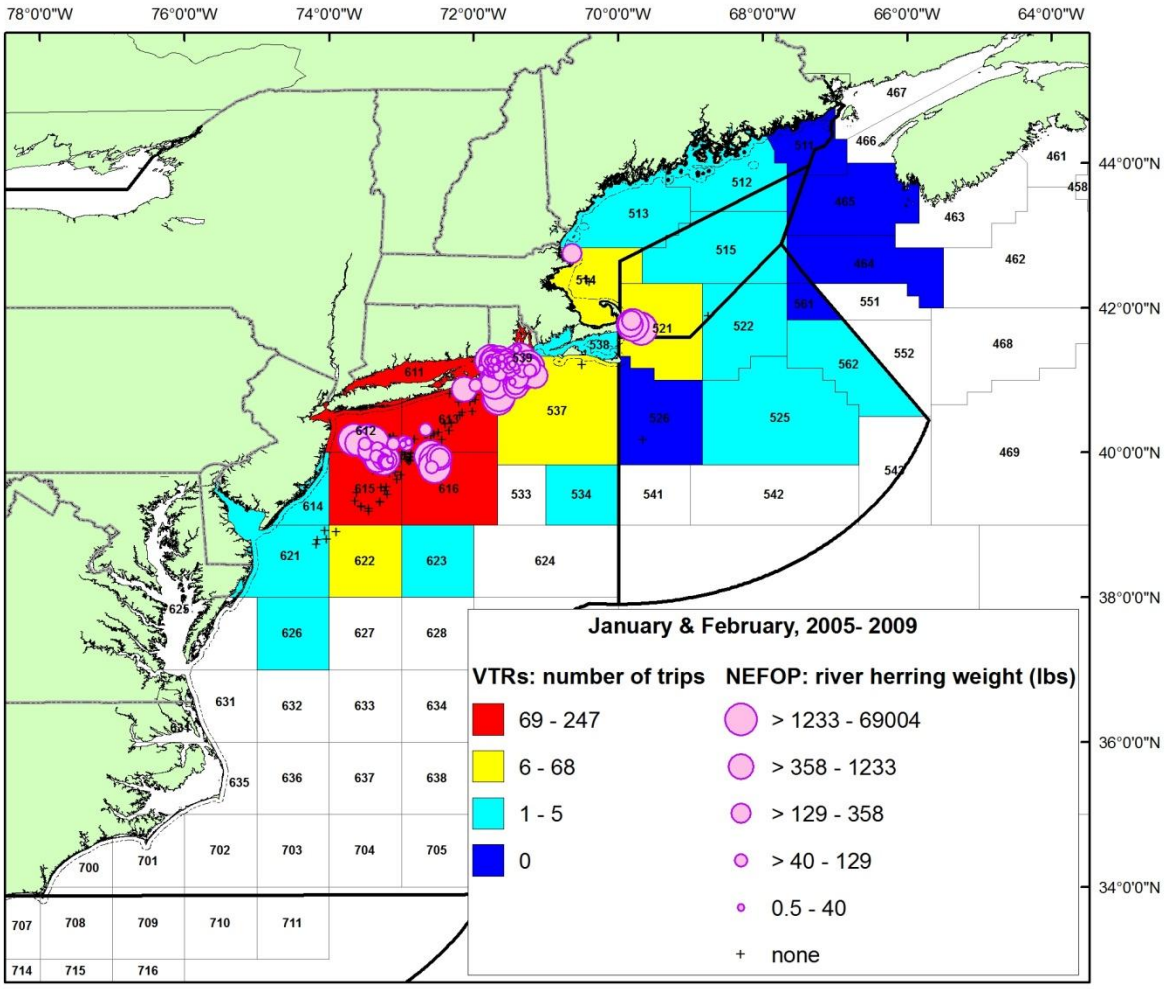


Figure A1: Reported trips (VTR) and observed hauls and sets (NEFOP) during January and February, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-247 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

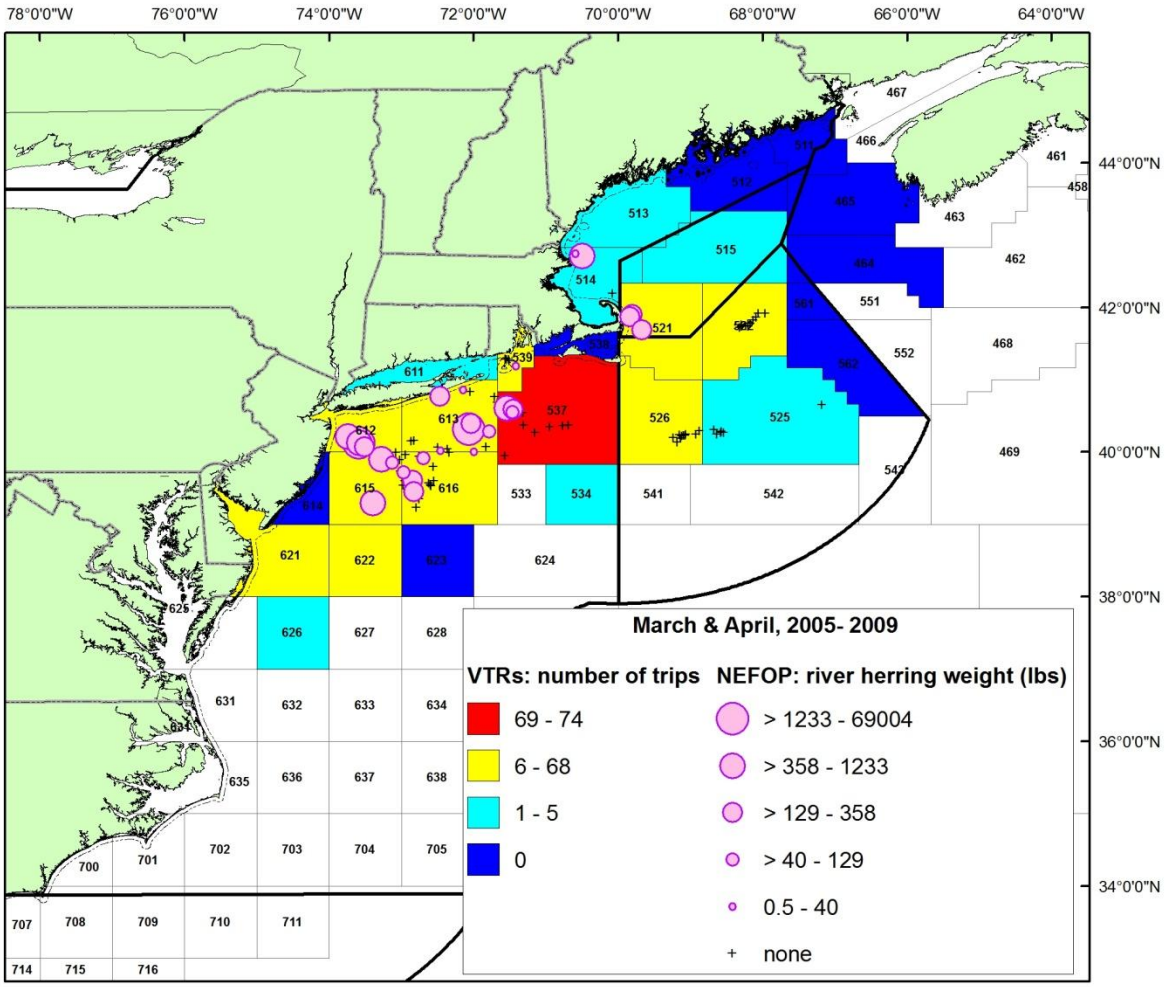


Figure A2: Reported trips (VTR) and observed hauls and sets (NEFOP) during March and April, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-74 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

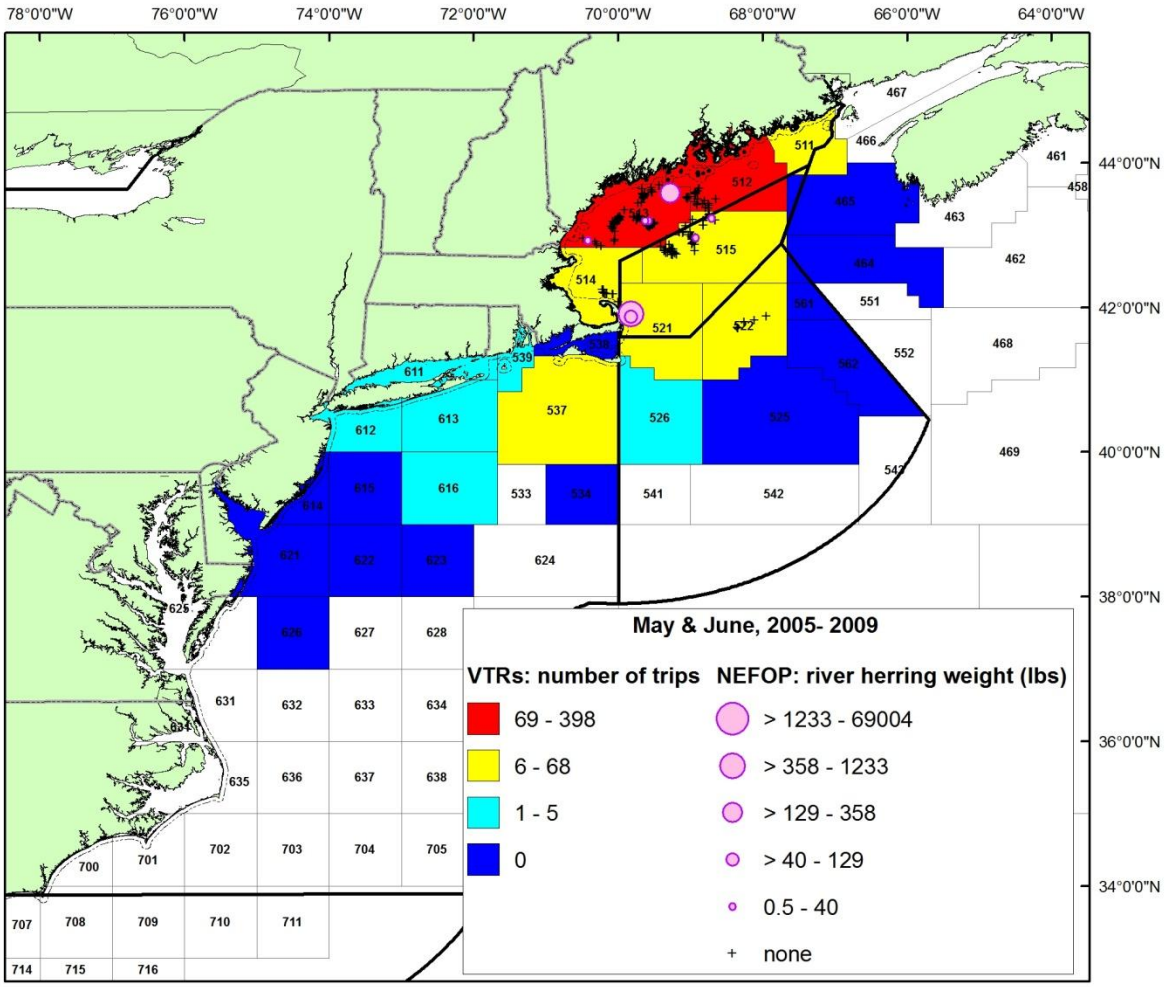


Figure A3: Reported trips (VTR) and observed hauls and sets (NEFOP) during May and June, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-398 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

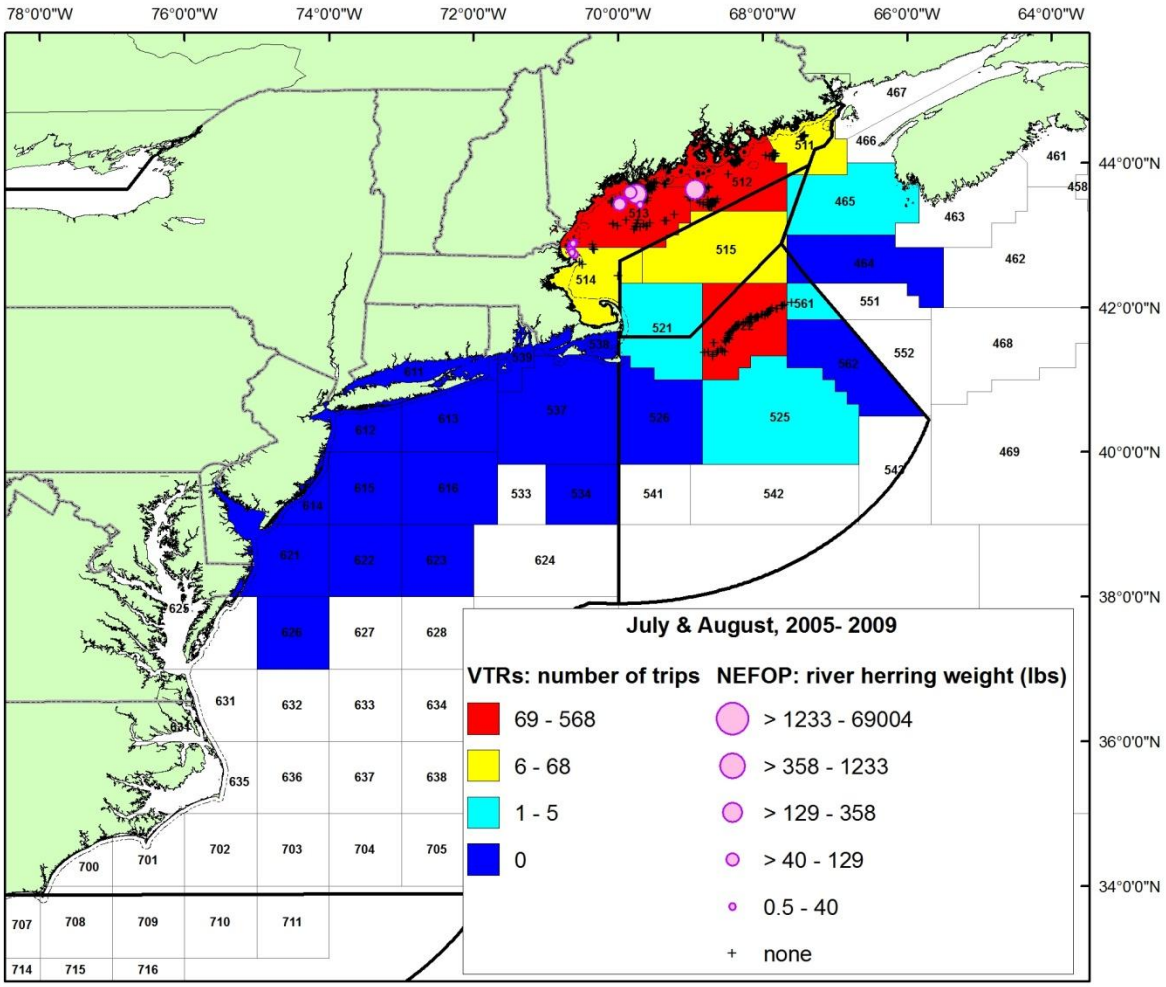


Figure A4: Reported trips (VTR) and observed hauls and sets (NEFOP) during July and August, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-568 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

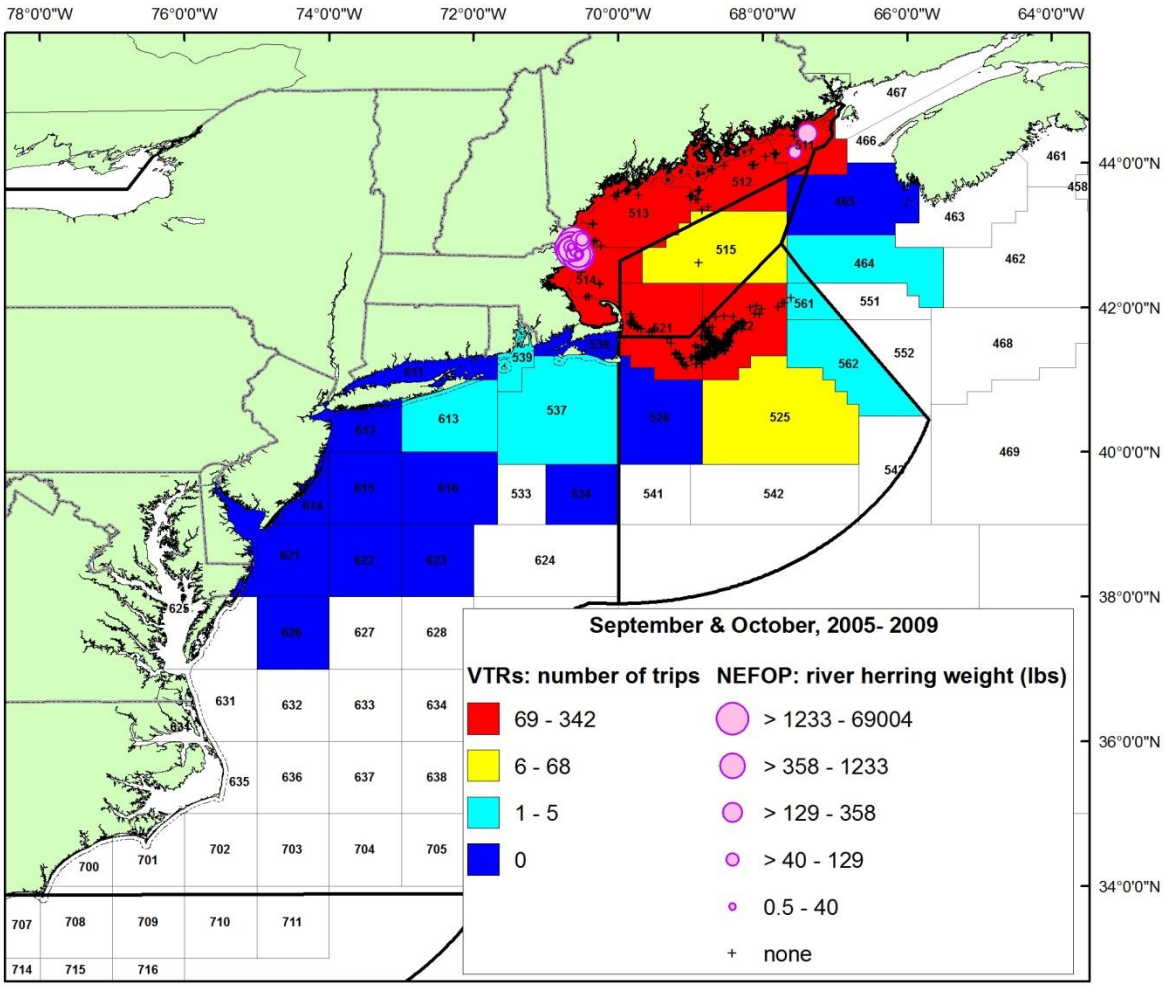


Figure A5: Reported trips (VTR) and observed hauls and sets (NEFOP) during September and October, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-342 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

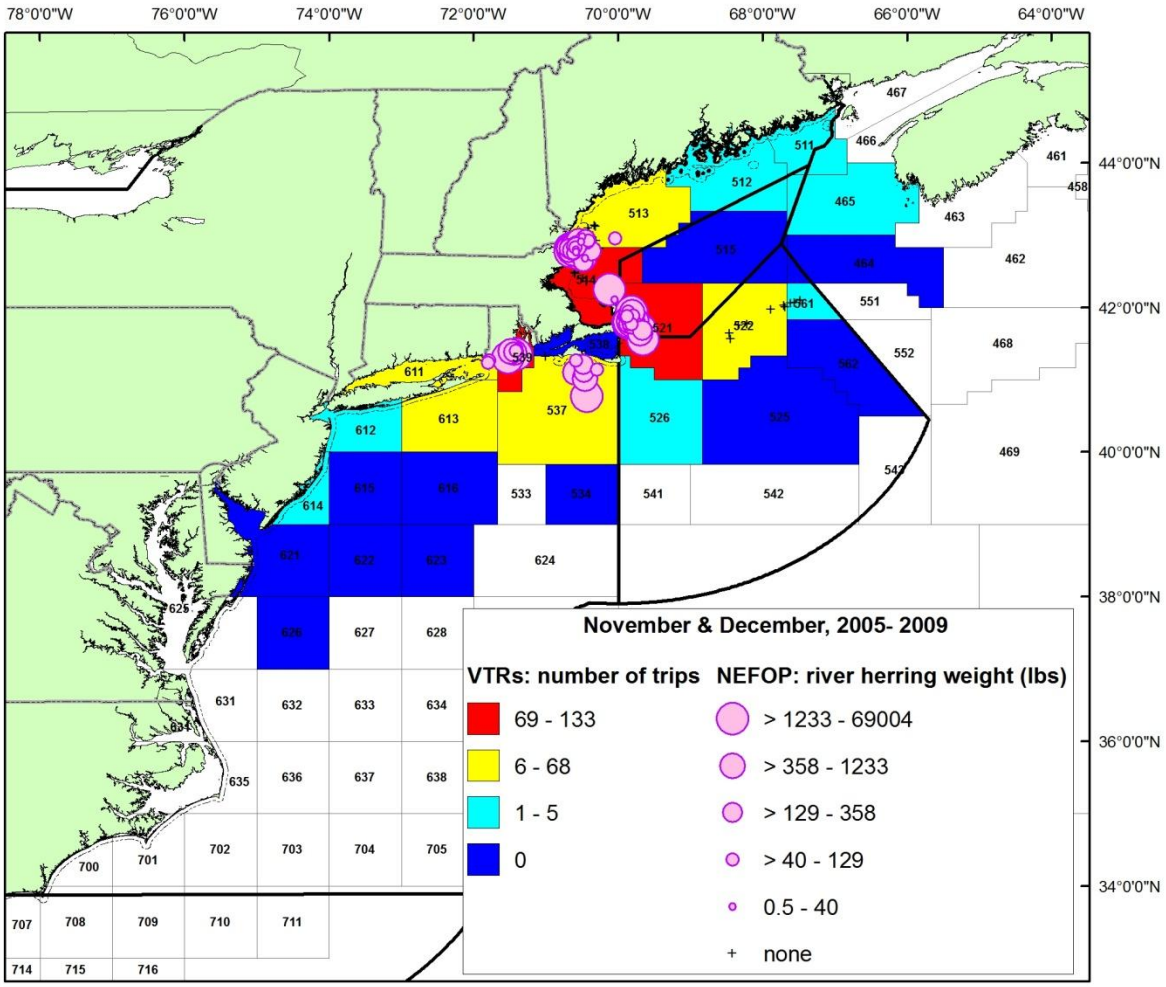


Figure A6: Reported trips (VTR) and observed hauls and sets (NEFOP) during November and December, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-133 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Sources: VTR Database 2005-2009 and NEFOP Database 2005-2009.

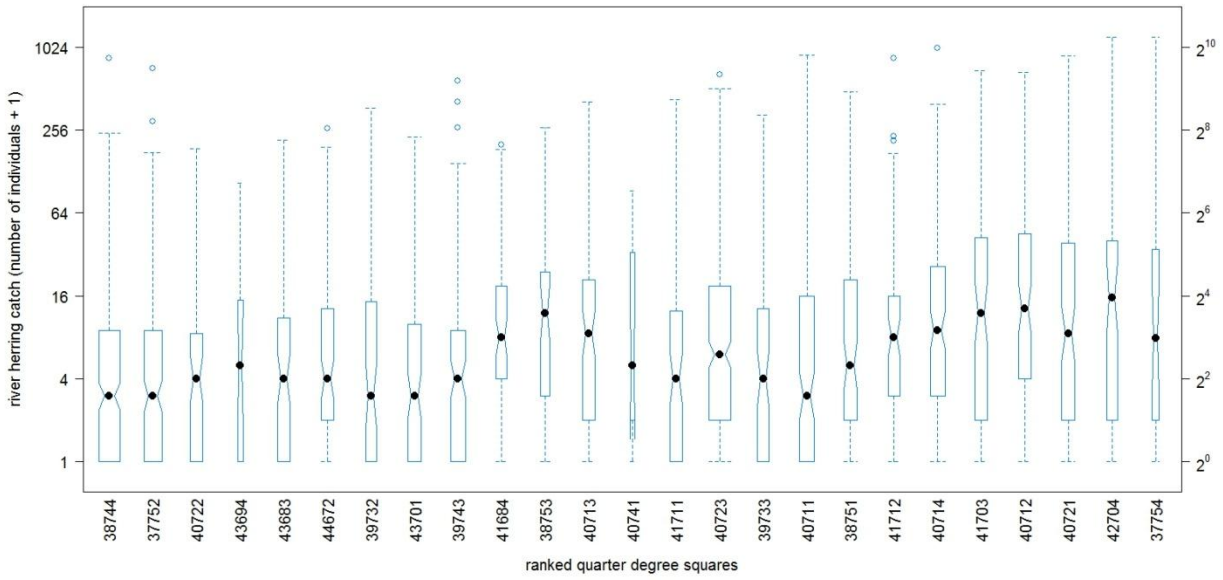


Figure A7: Spring quarter degree squares ranked by mean river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

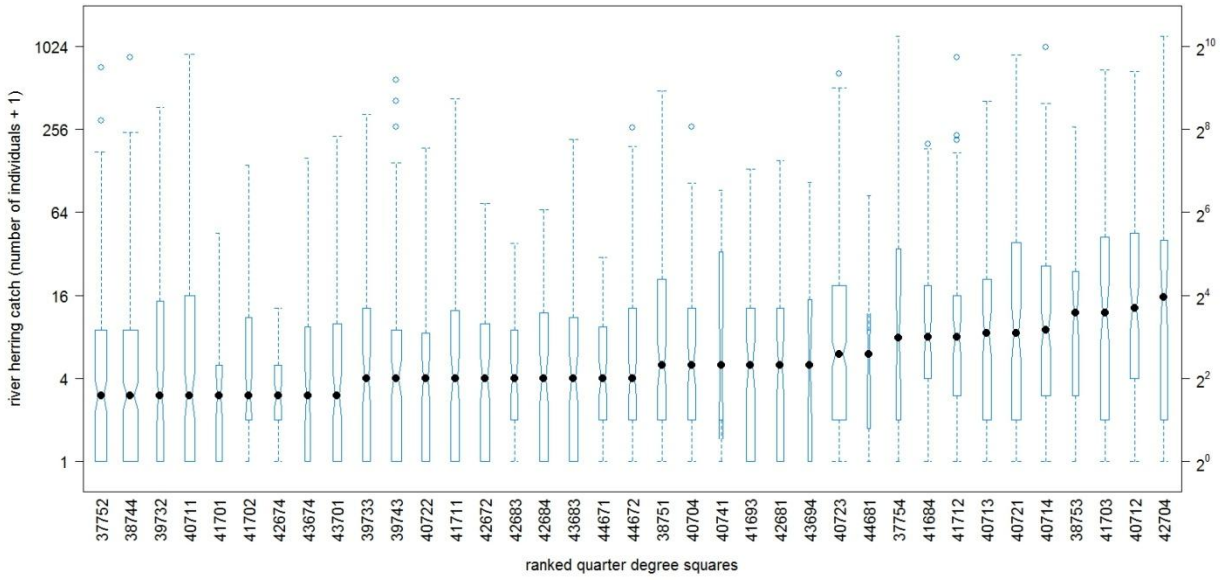


Figure A8: Spring quarter degree squares ranked by median river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

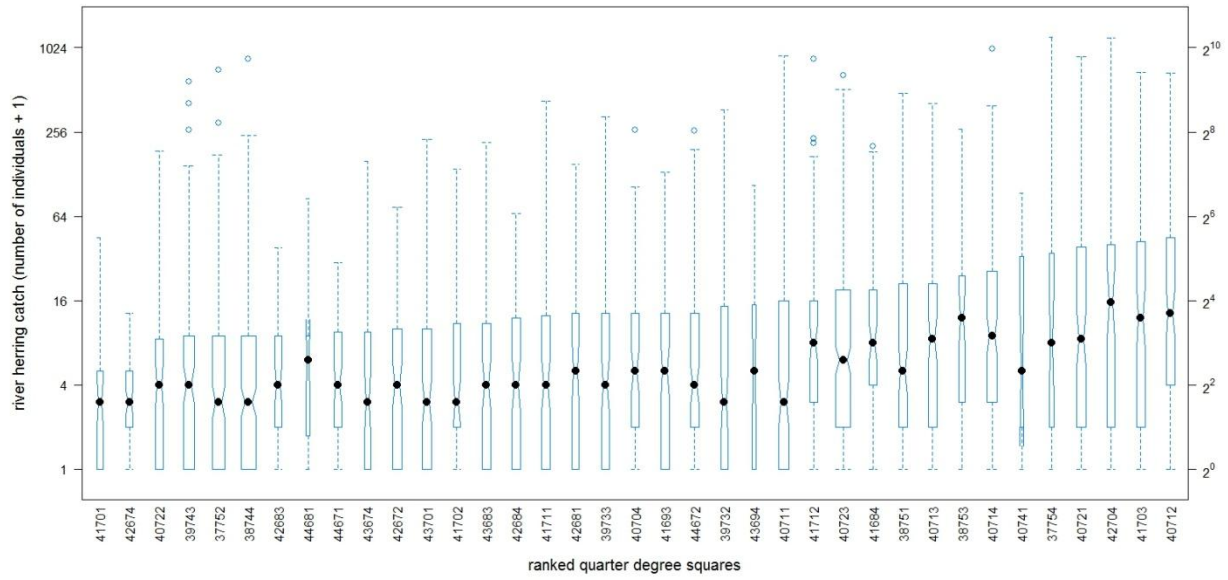


Figure A9: Spring quarter degree squares ranked by 75th quantile of river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

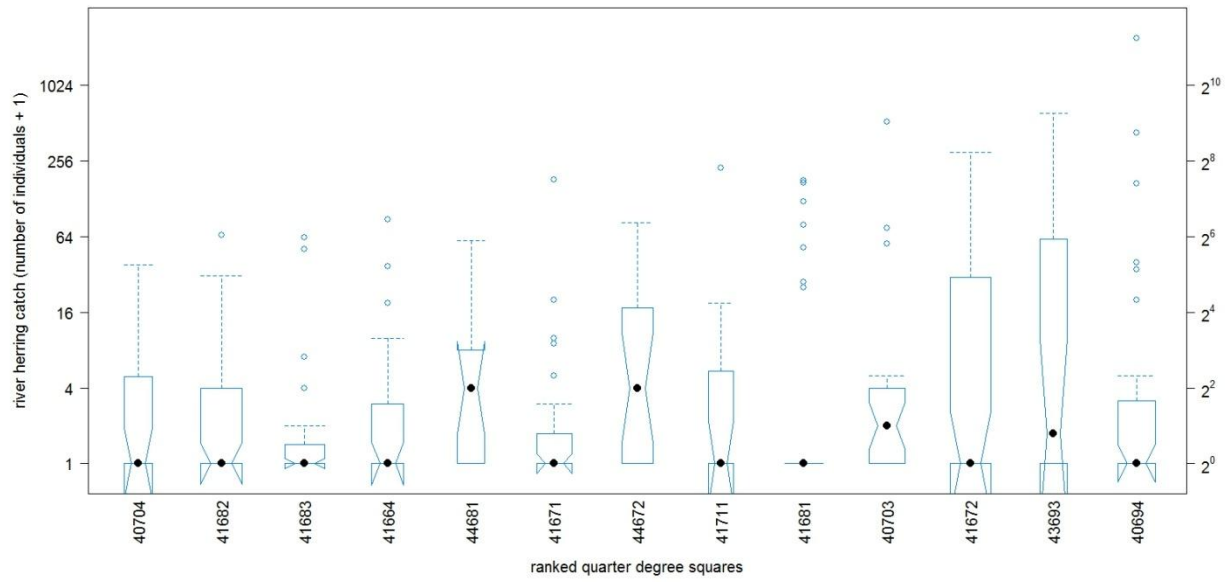


Figure A10: Summer quarter degree squares ranked by mean river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

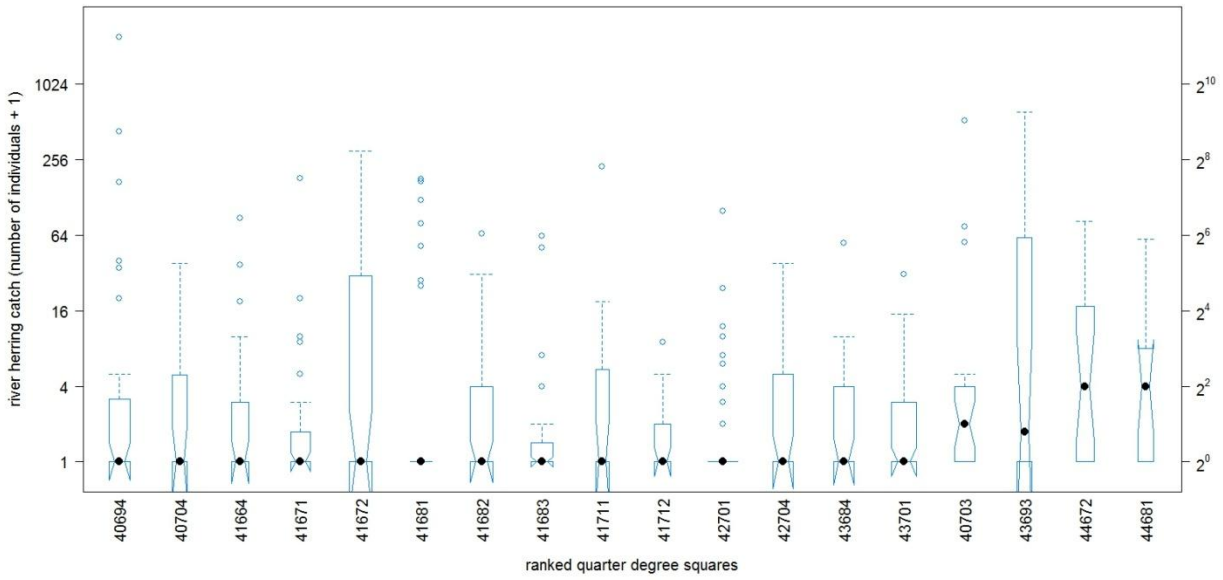


Figure A11: Summer quarter degree squares ranked by median river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

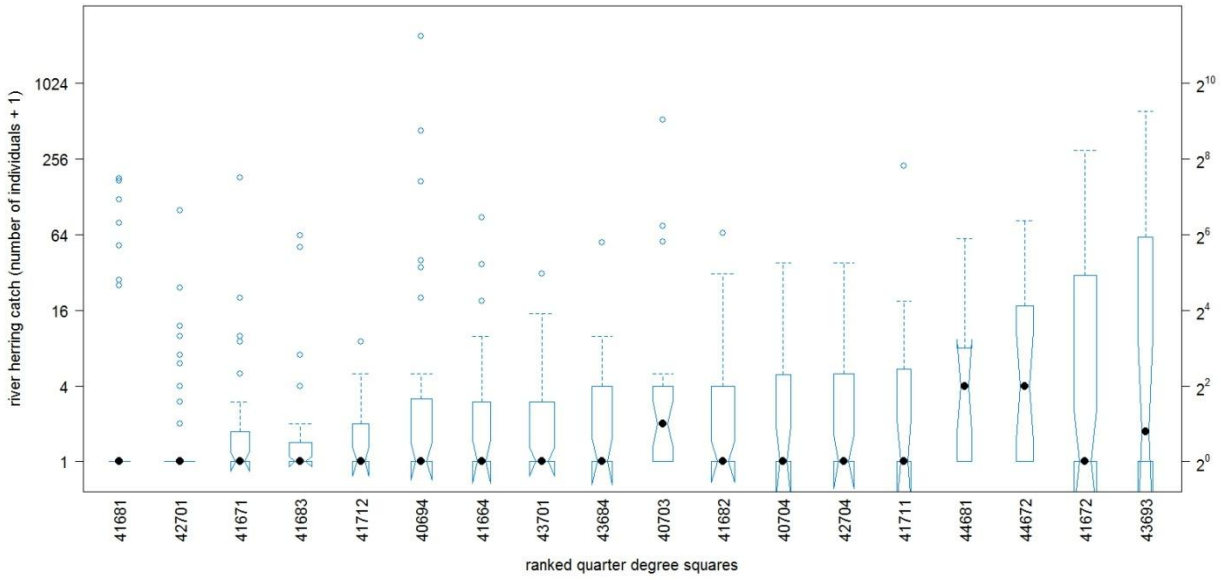


Figure A12: Summer quarter degree squares ranked by 75th quantile of river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

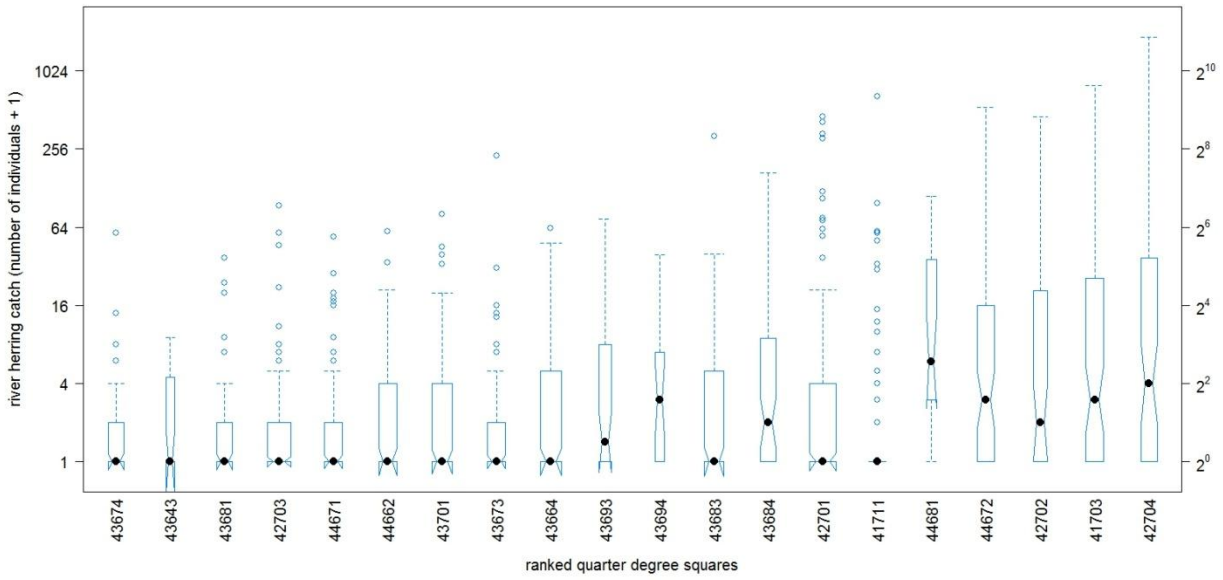


Figure A13: Fall quarter degree squares ranked by mean river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

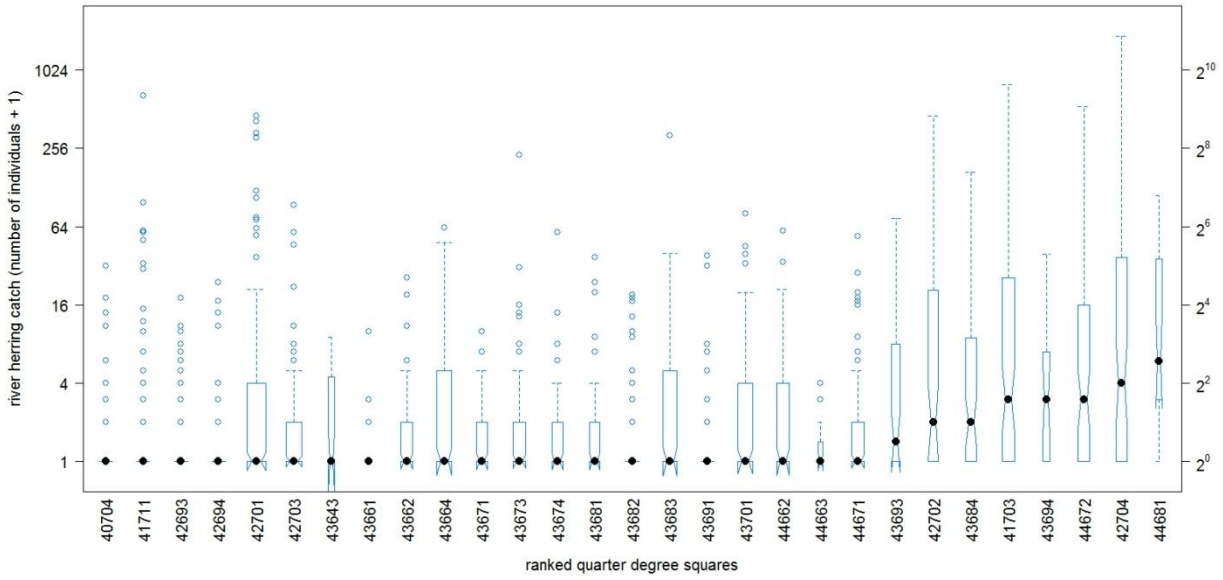


Figure A14: Fall quarter degree squares ranked by median river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

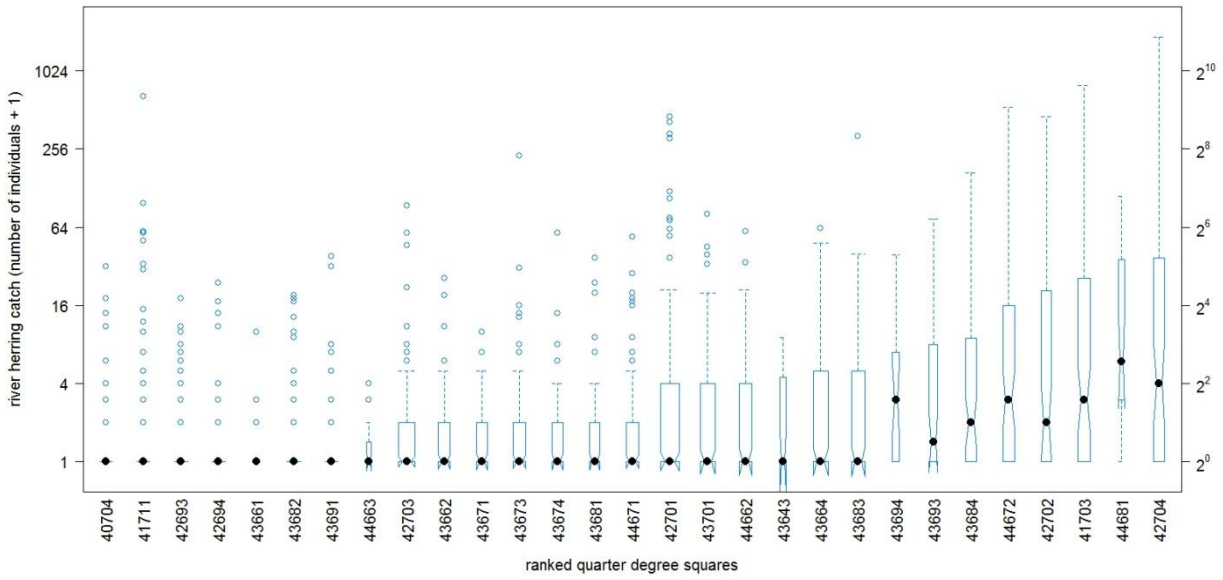


Figure A15: Fall quarter degree squares ranked by 75th quantile of river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

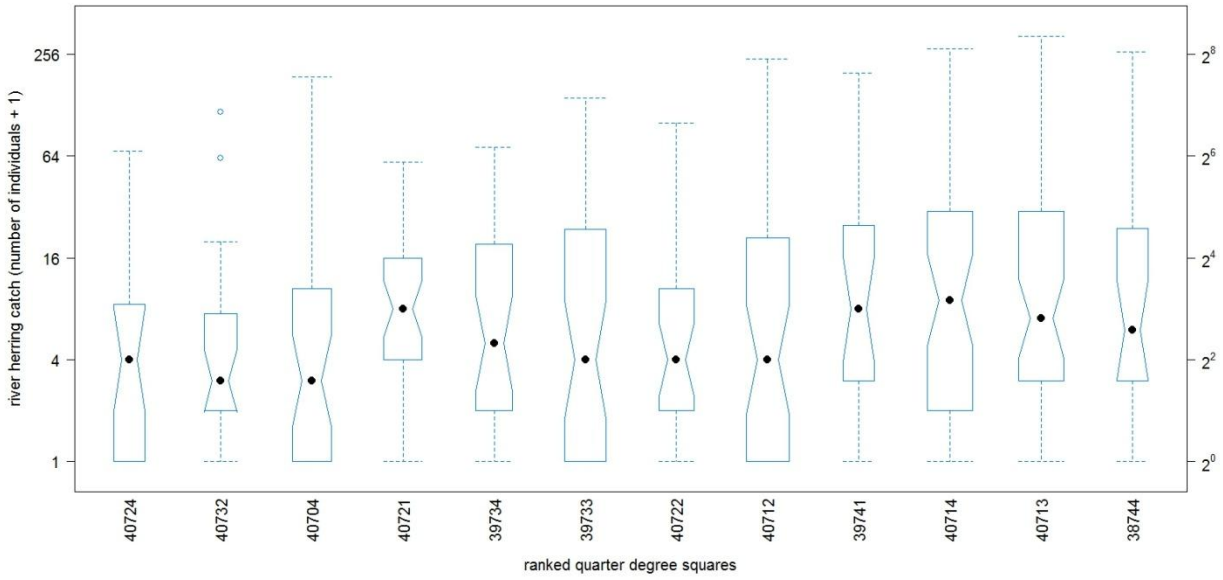


Figure A16: Winter quarter degree squares ranked by mean river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

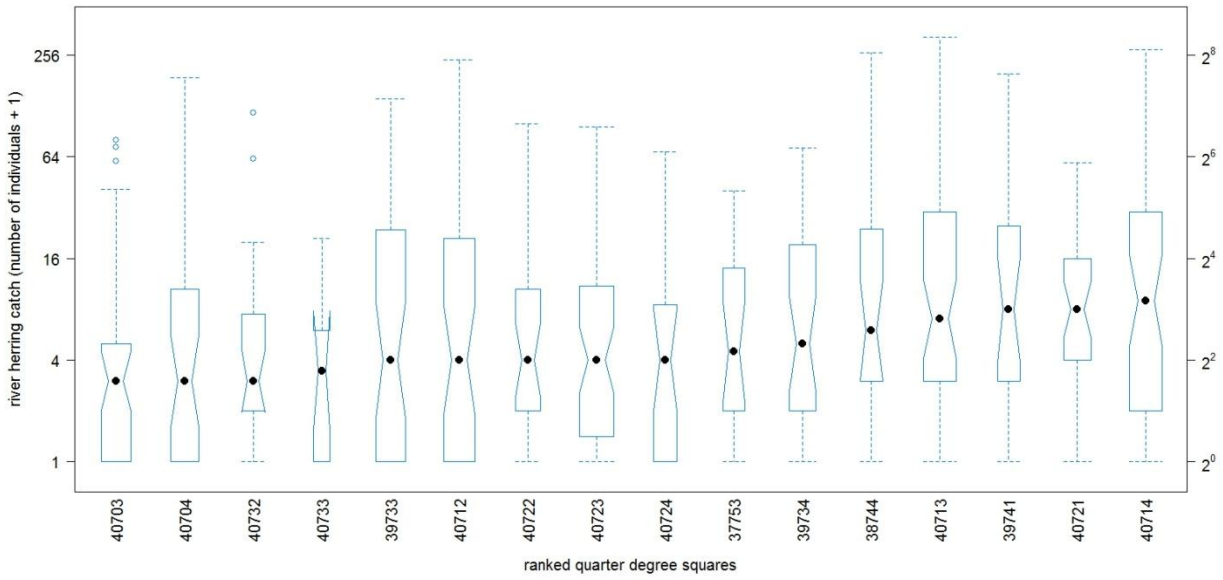


Figure A17: Winter quarter degree squares ranked by median river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

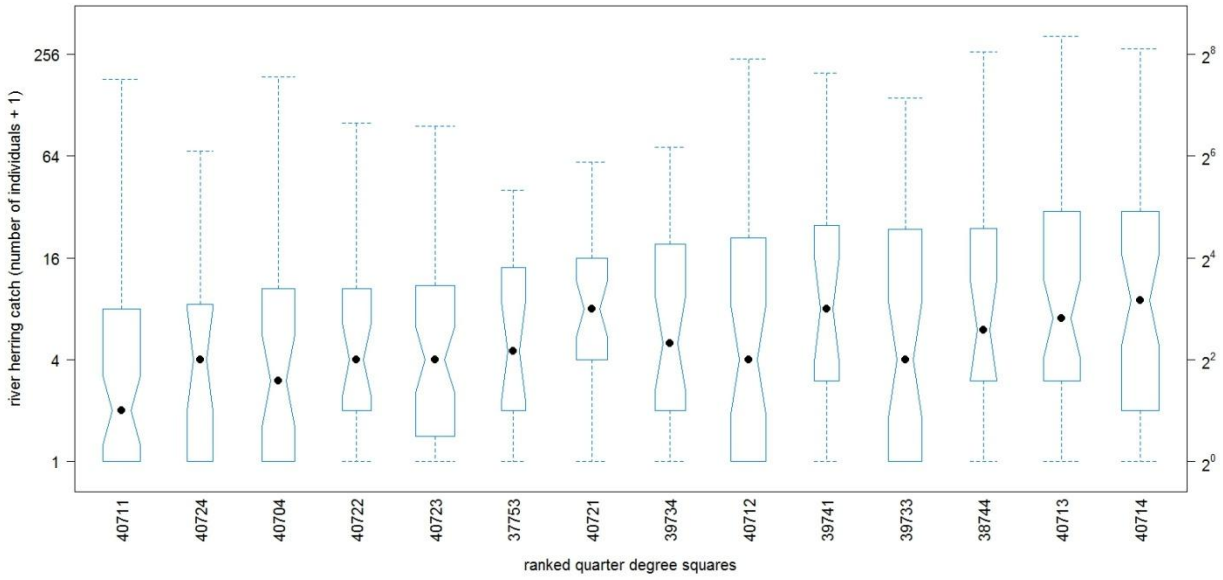


Figure A18: Winter quarter degree squares ranked by 75th quantile of river herring catch (number of individuals +1). Note the logarithmic scale on the y-axis. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

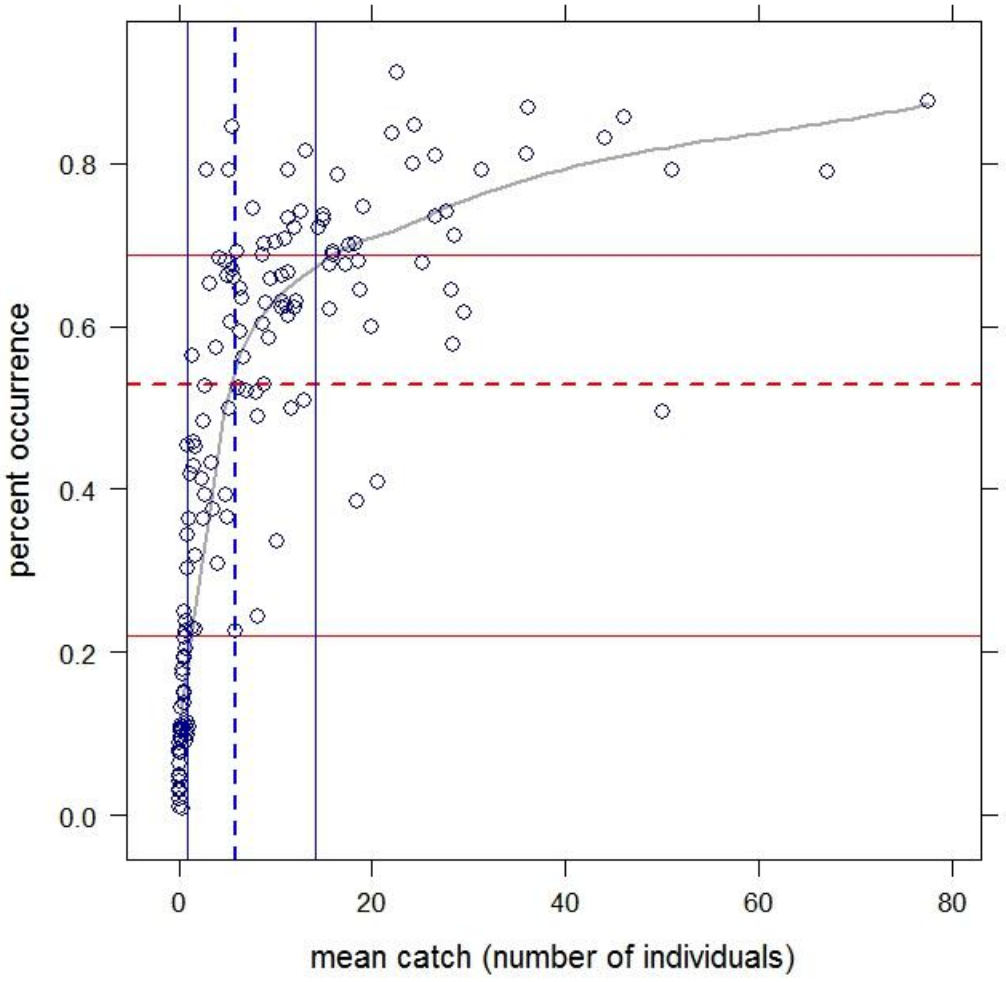


Figure A19: Spring percent occurrence against mean catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=mean catch in number. Dashed lines are medians (red=percent occurrence, blue=mean catch in number. Hot spots are defined as squares having percent occurrence and mean catch in number ≥ 75th quantiles for each variable. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

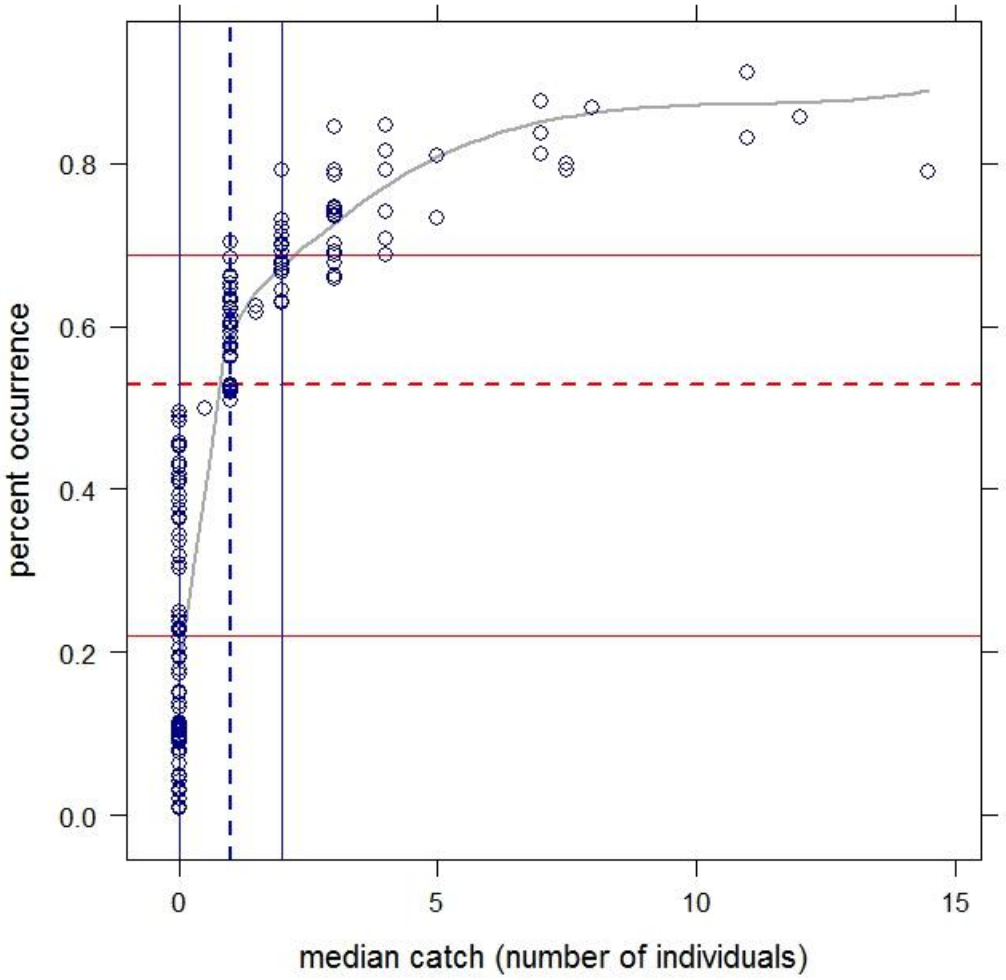


Figure A20: Spring percent occurrence against median catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=median catch in number. Dashed lines are medians (red=percent occurrence, blue=median catch in number. Hot spots are defined as squares having percent occurrence and median catch in number ≥ 75th quantiles for each variable. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

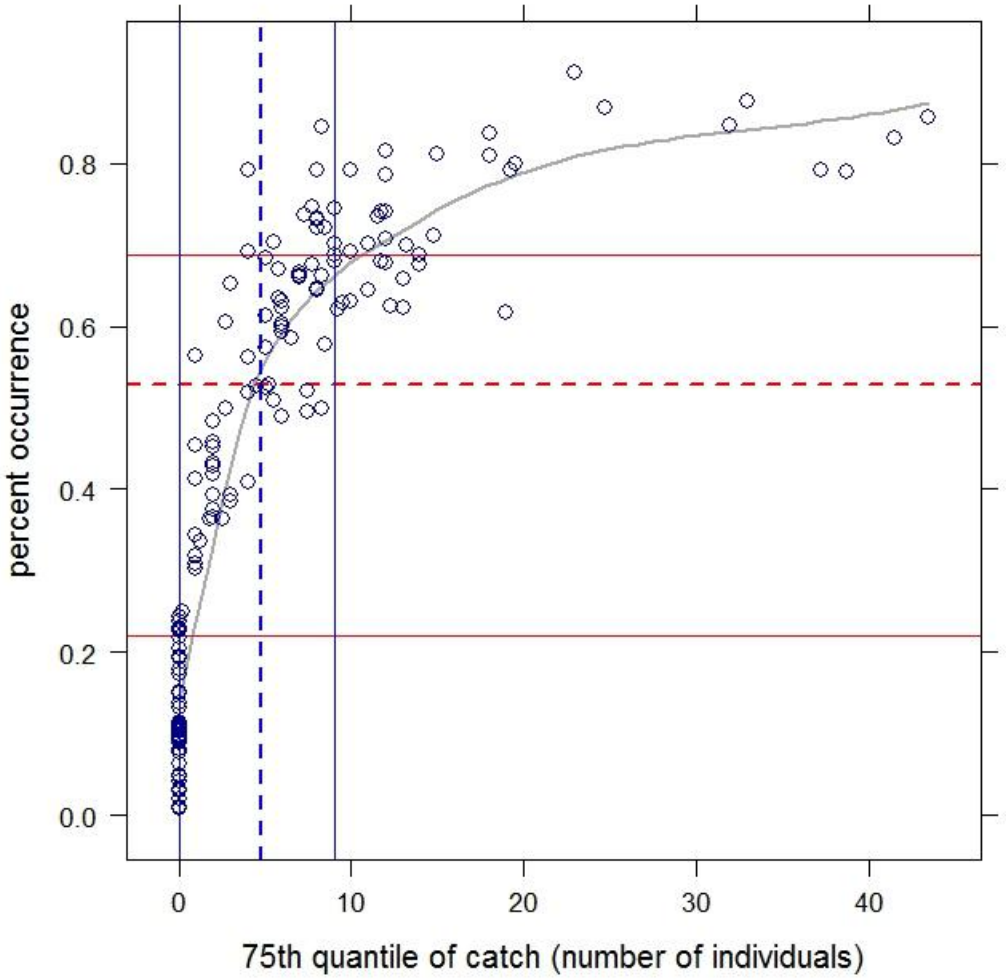


Figure A21: Spring percent occurrence against 75th quantile of catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=75th quantile of catch in number. Dashed lines are medians (red=percent occurrence, blue=75th quantile of catch in number. Hot spots are defined as squares having percent occurrence and 75th quantile of catch in number ≥ 75th quantiles for each variable. Source: Spring 1968-2008 NMFS bottom-trawl surveys.

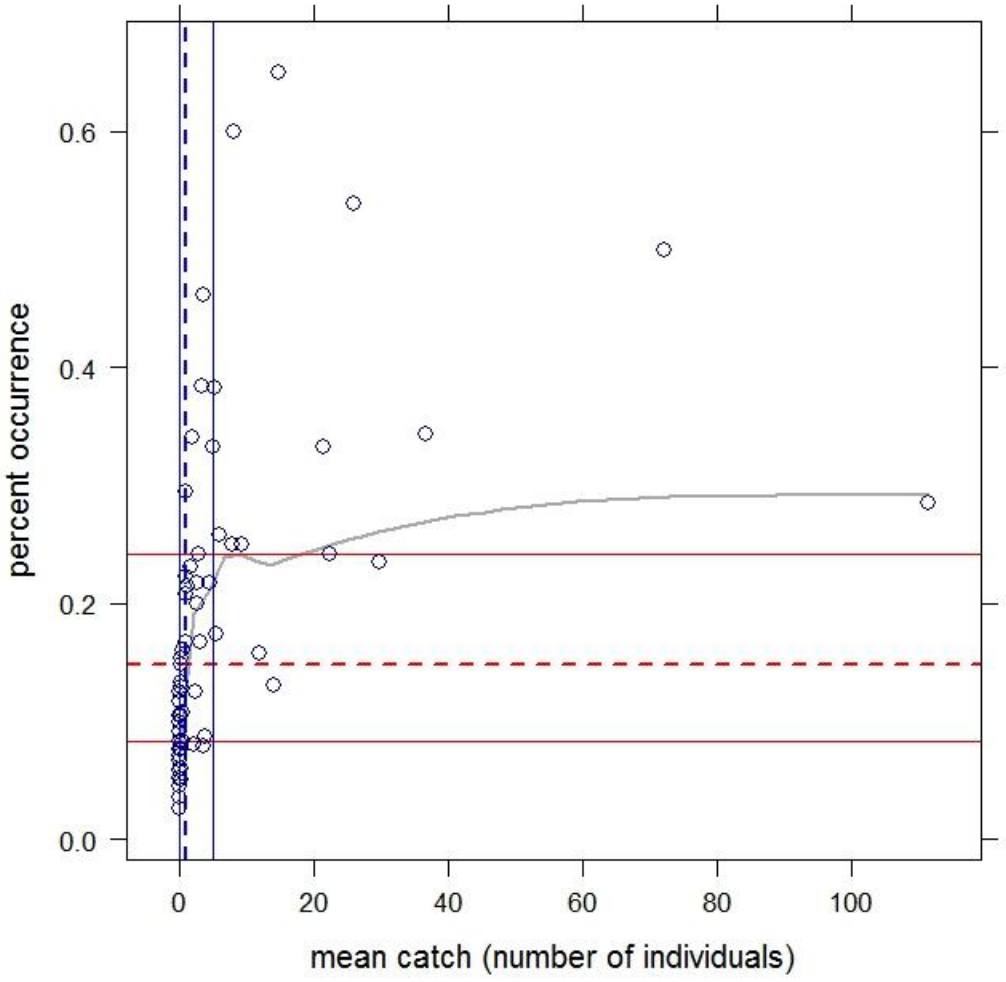


Figure A22: Summer percent occurrence against mean catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=mean catch in number. Dashed lines are medians (red=percent occurrence, blue=mean catch in number. Hot spots are defined as squares having percent occurrence and mean catch in number ≥ 75th quantiles for each variable. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

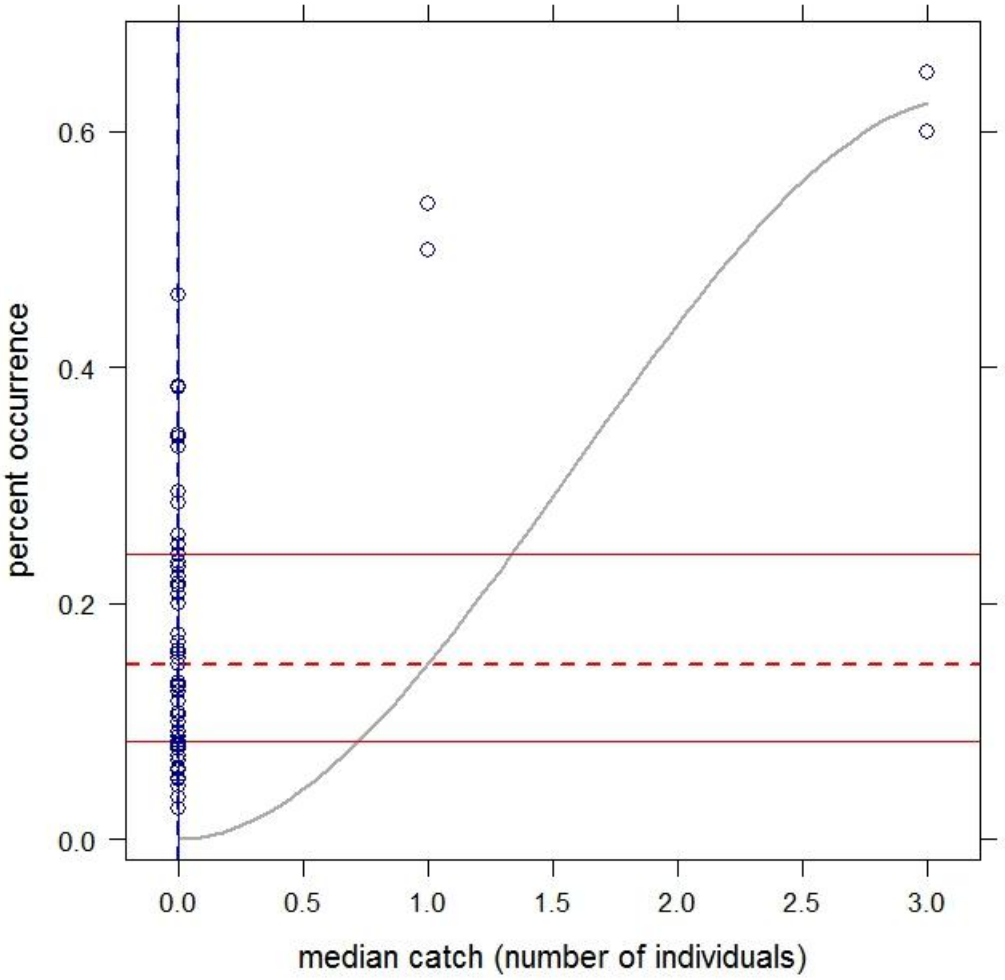


Figure A23: Summer percent occurrence against median catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=median catch in number. Dashed lines are medians (red=percent occurrence, blue=median catch in number. Hot spots are defined as squares having percent occurrence and median catch in number ≥ 75th quantiles for each variable. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

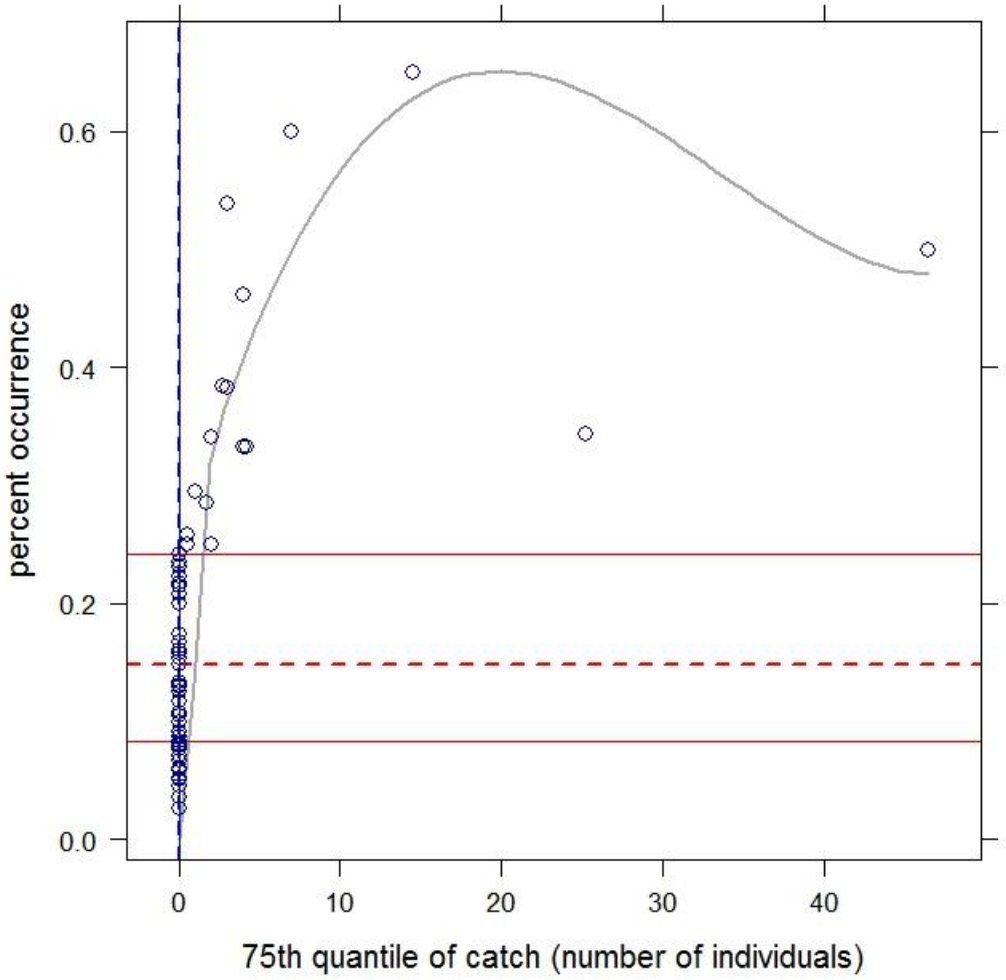


Figure A24: Summer percent occurrence against 75th quantile of catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=75th quantile of catch in number. Dashed lines are medians (red=percent occurrence, blue=75th quantile of catch in number. Hot spots are defined as squares having percent occurrence and 75th quantile of catch in number ≥ 75th quantiles for each variable. Source: Summer 1948-1995 NMFS bottom-trawl surveys.

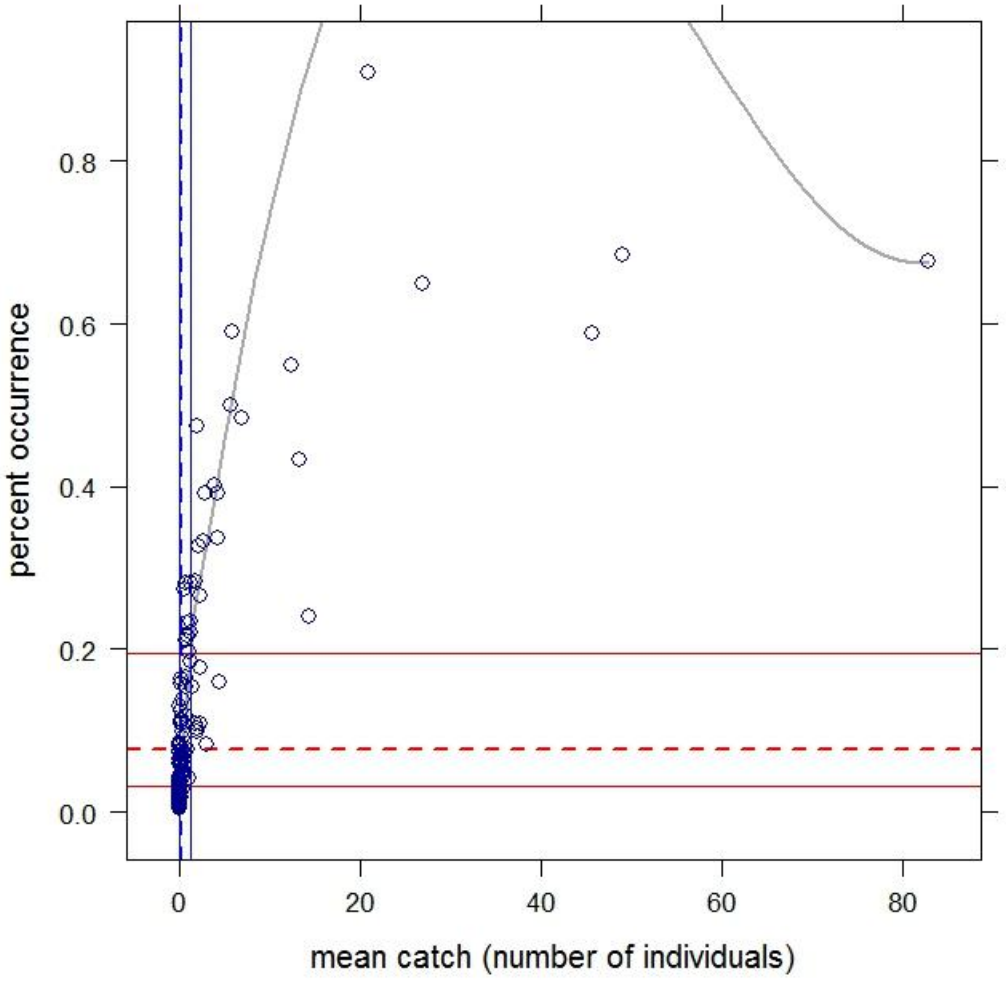


Figure A25: Fall percent occurrence against mean catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=mean catch in number. Dashed lines are medians (red=percent occurrence, blue=mean catch in number. Hot spots are defined as squares having percent occurrence and mean catch in number ≥ 75th quantiles for each variable. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

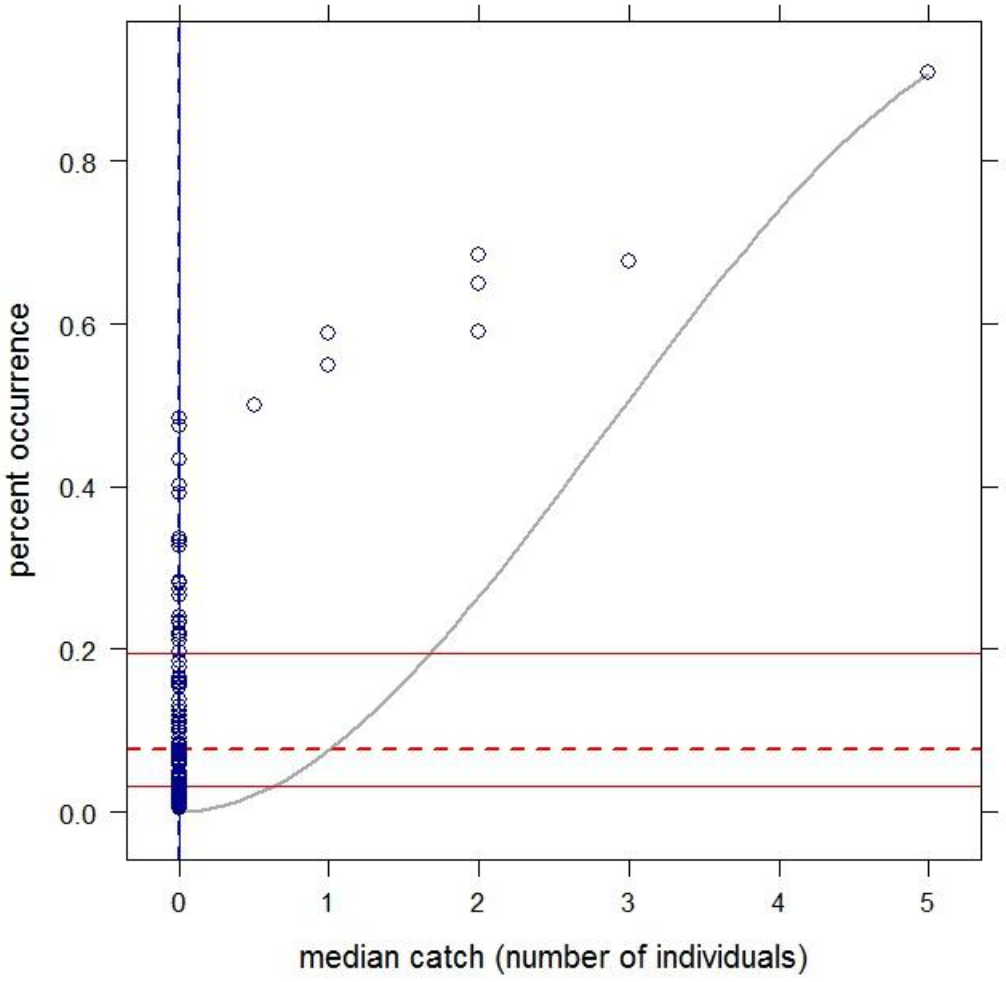


Figure A26: Fall percent occurrence against median catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=median catch in number. Dashed lines are medians (red=percent occurrence, blue=median catch in number. Hot spots are defined as squares having percent occurrence and median catch in number ≥ 75th quantiles for each variable. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

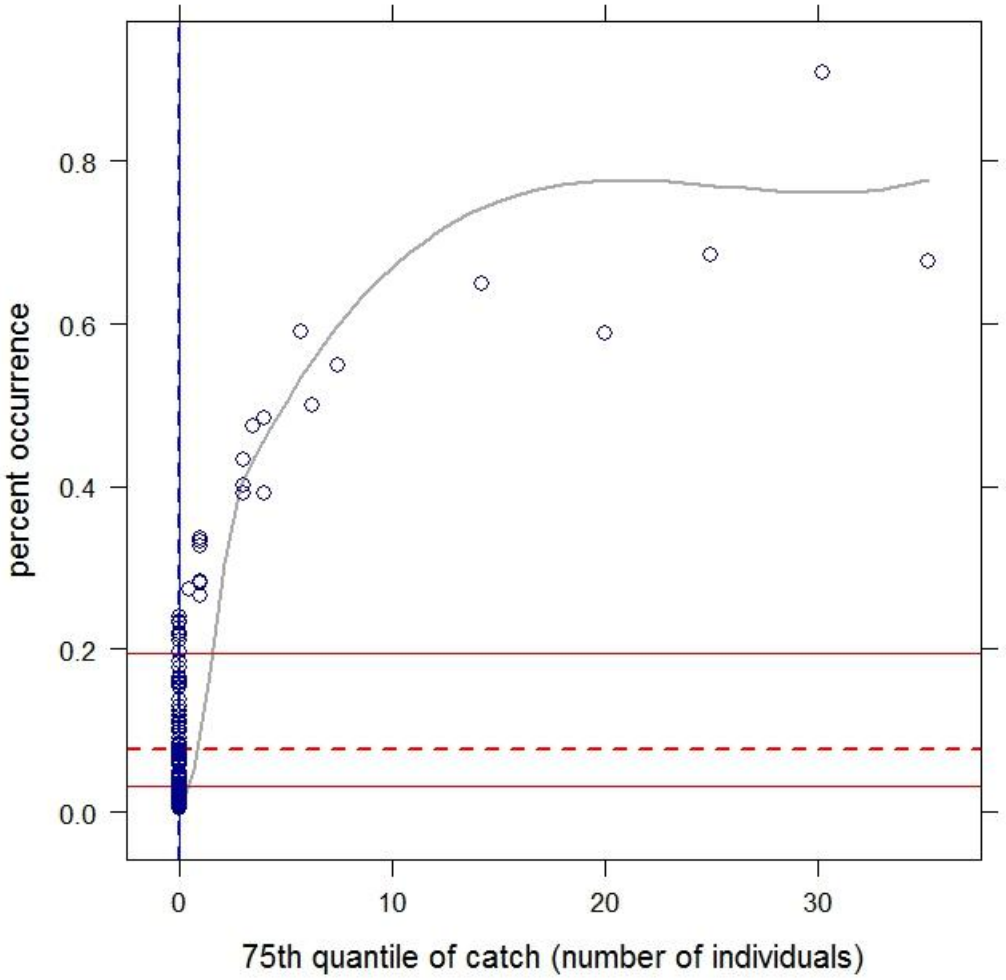


Figure A27: Fall percent occurrence against 75th quantile of catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=75th quantile of catch in number. Dashed lines are medians (red=percent occurrence, blue=75th quantile of catch in number. Hot spots are defined as squares having percent occurrence and 75th quantile of catch in number ≥ 75th quantiles for each variable. Source: Fall 1963-2008 NMFS bottom-trawl surveys.

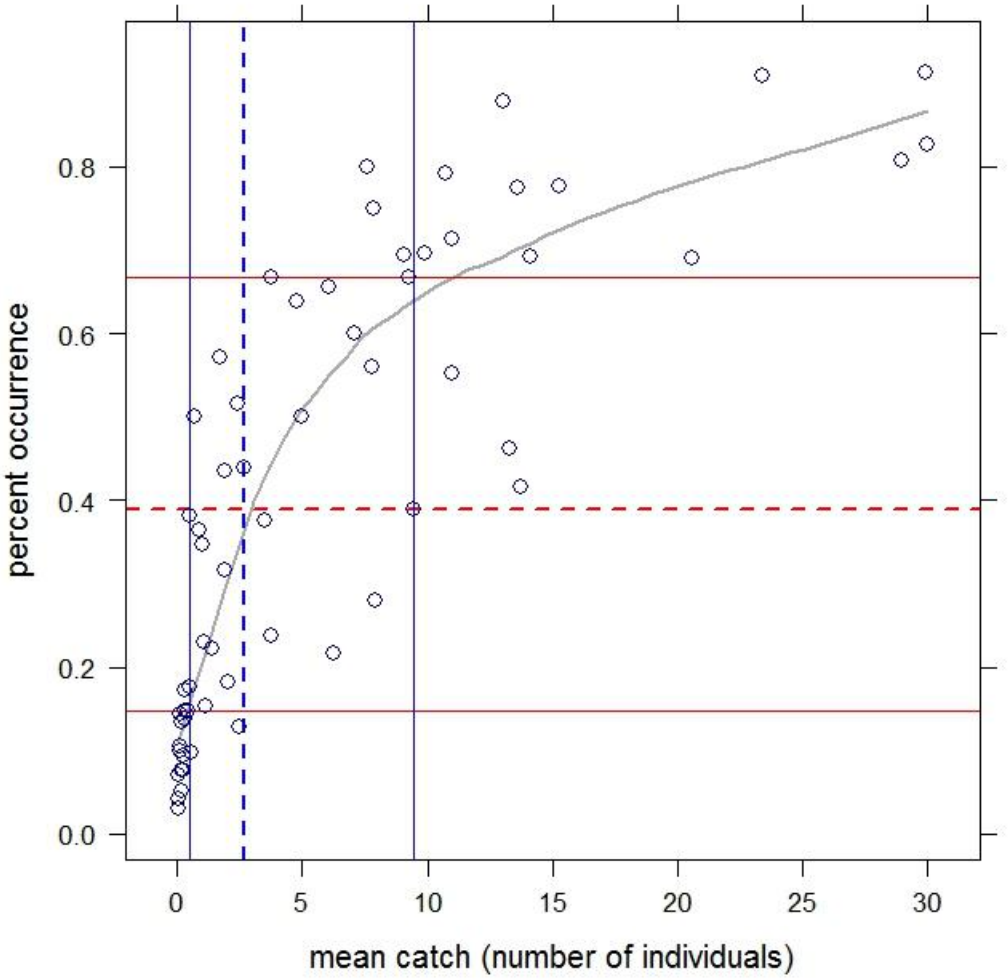


Figure A28: Winter percent occurrence against mean catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=mean catch in number. Dashed lines are medians (red=percent occurrence, blue=mean catch in number. Hot spots are defined as squares having percent occurrence and mean catch in number ≥ 75th quantiles for each variable. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

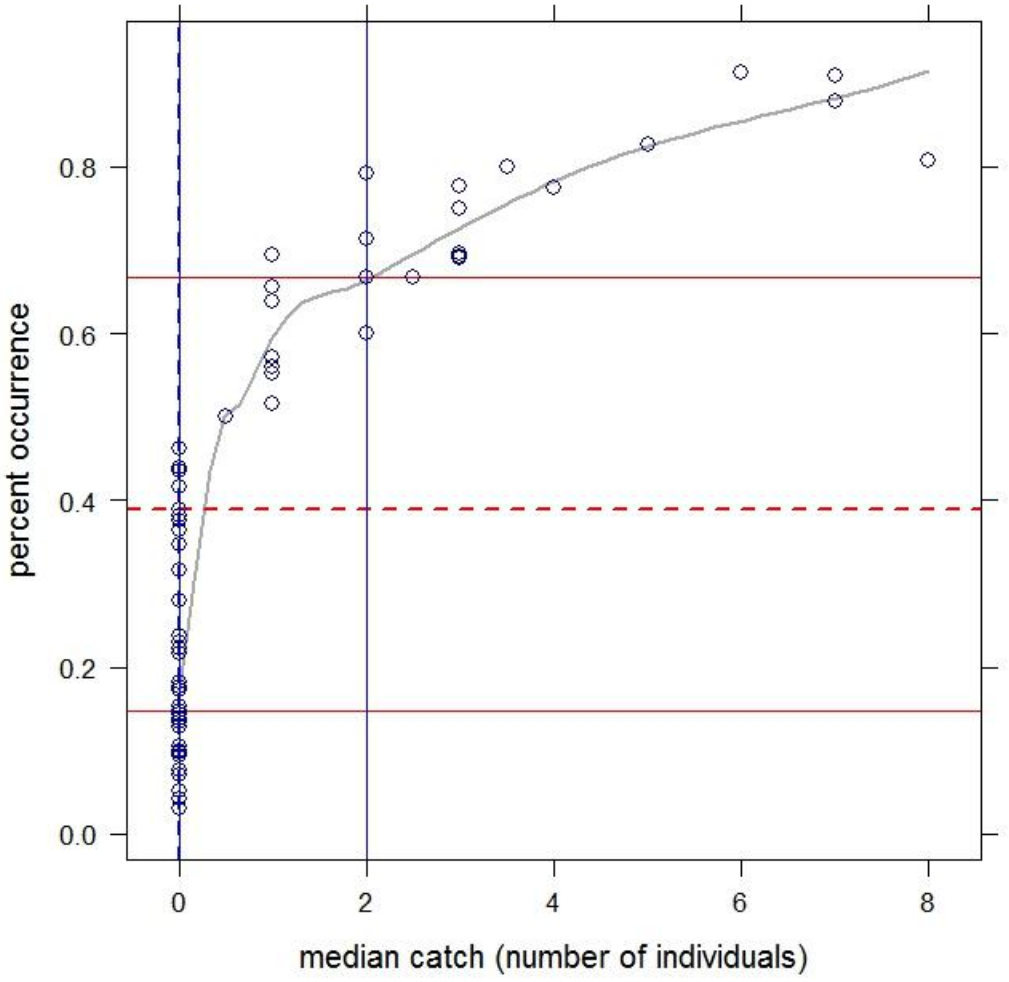


Figure A29: Winter percent occurrence against median catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=median catch in number. Dashed lines are medians (red=percent occurrence, blue=median catch in number. Hot spots are defined as squares having percent occurrence and median catch in number ≥ 75th quantiles for each variable. Source: Winter 1964-2007 NMFS bottom-trawl surveys.

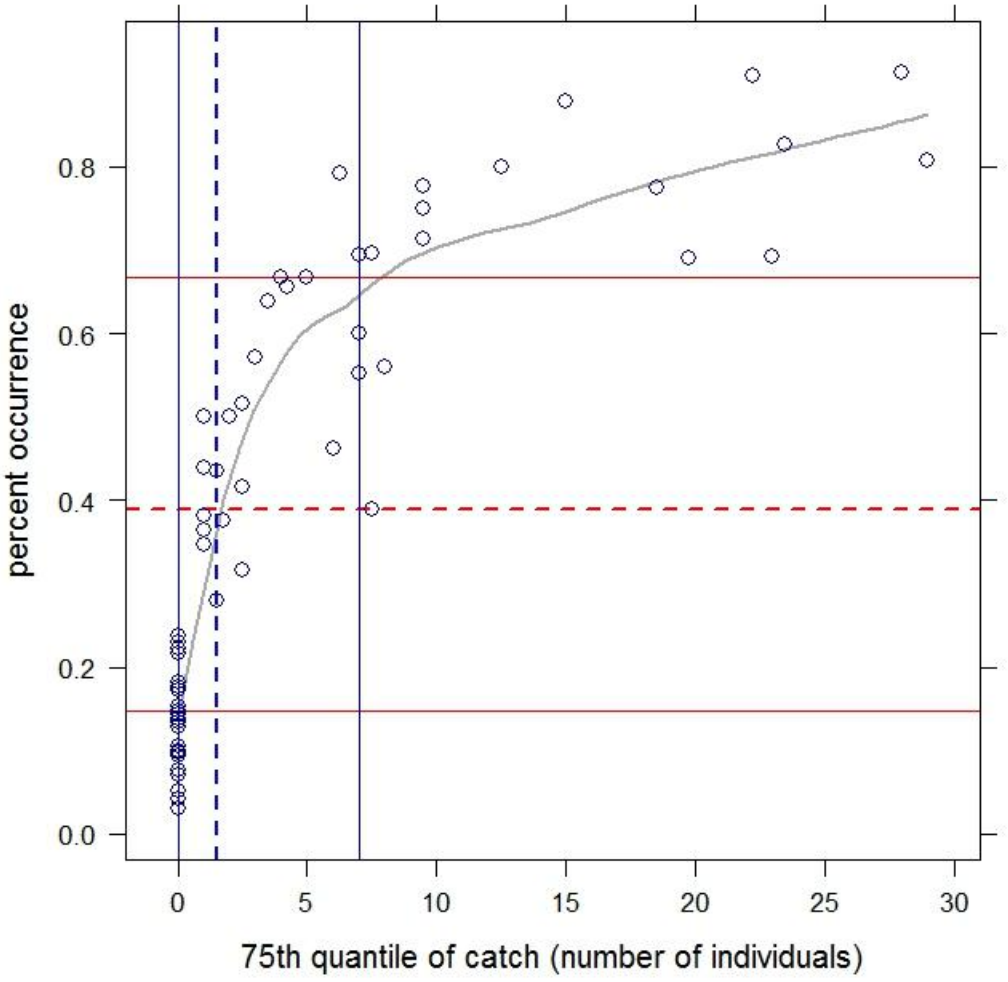
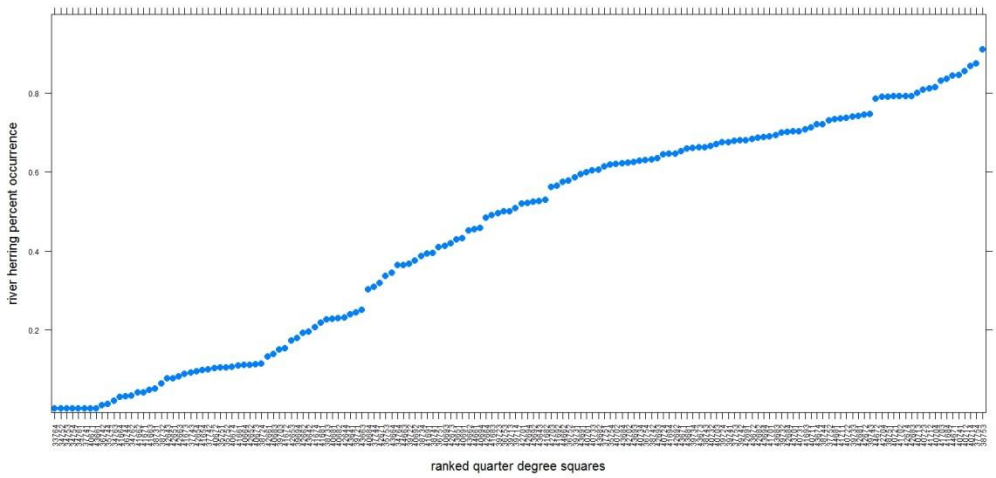


Figure A30: Winter percent occurrence against 75th quantile of catch in number for quarter degree square (dark blue circles). Solid lines are 25th and 75th quantiles (red=percent occurrence, blue=75th quantile of catch in number. Dashed lines are medians (red=percent occurrence, blue=75th quantile of catch in number. Hot spots are defined as squares having percent occurrence and 75th quantile of catch in number ≥ 75th quantiles for each variable. Source: Winter 1964-2007 NMFS bottom-trawl surveys.



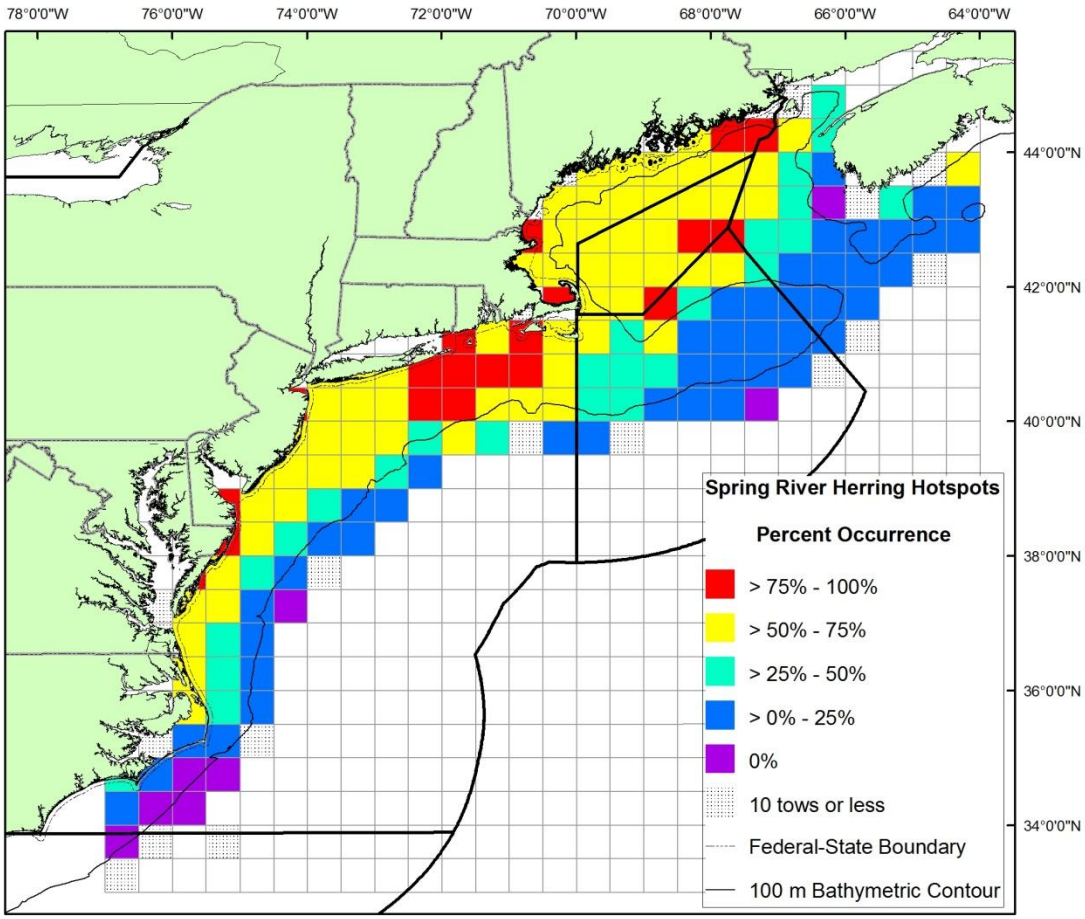


Figure A31: Percent occurrence of river herring in spring research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by quarter degree squares grouped from > 75% - 100% (red), > 50% - 75% (yellow), > 25% - 50% (aqua), > 0 - 25% (blue) and 0% (purple) (bottom). Source: Spring 1968-2008 NMFS bottom-trawl surveys.

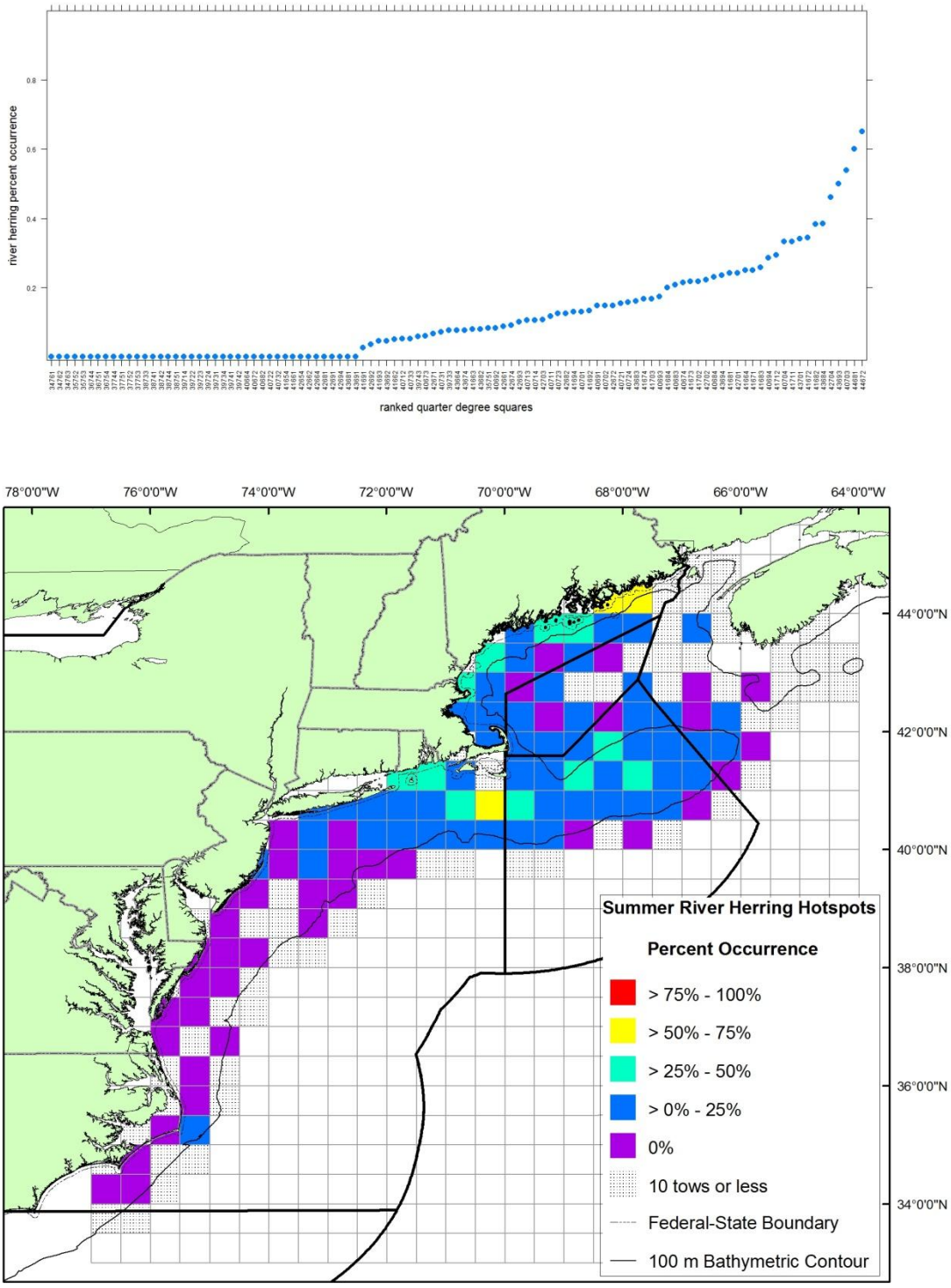


Figure A32: Percent occurrence of river herring in summer research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by quarter degree squares grouped from > 75% - 100% (red), > 50% - 75% (yellow), > 25% - 50% (aqua), > 0 - 25% (blue) and 0% (purple) (bottom). Source: Summer 1948-1995 NMFS bottom-trawl surveys.

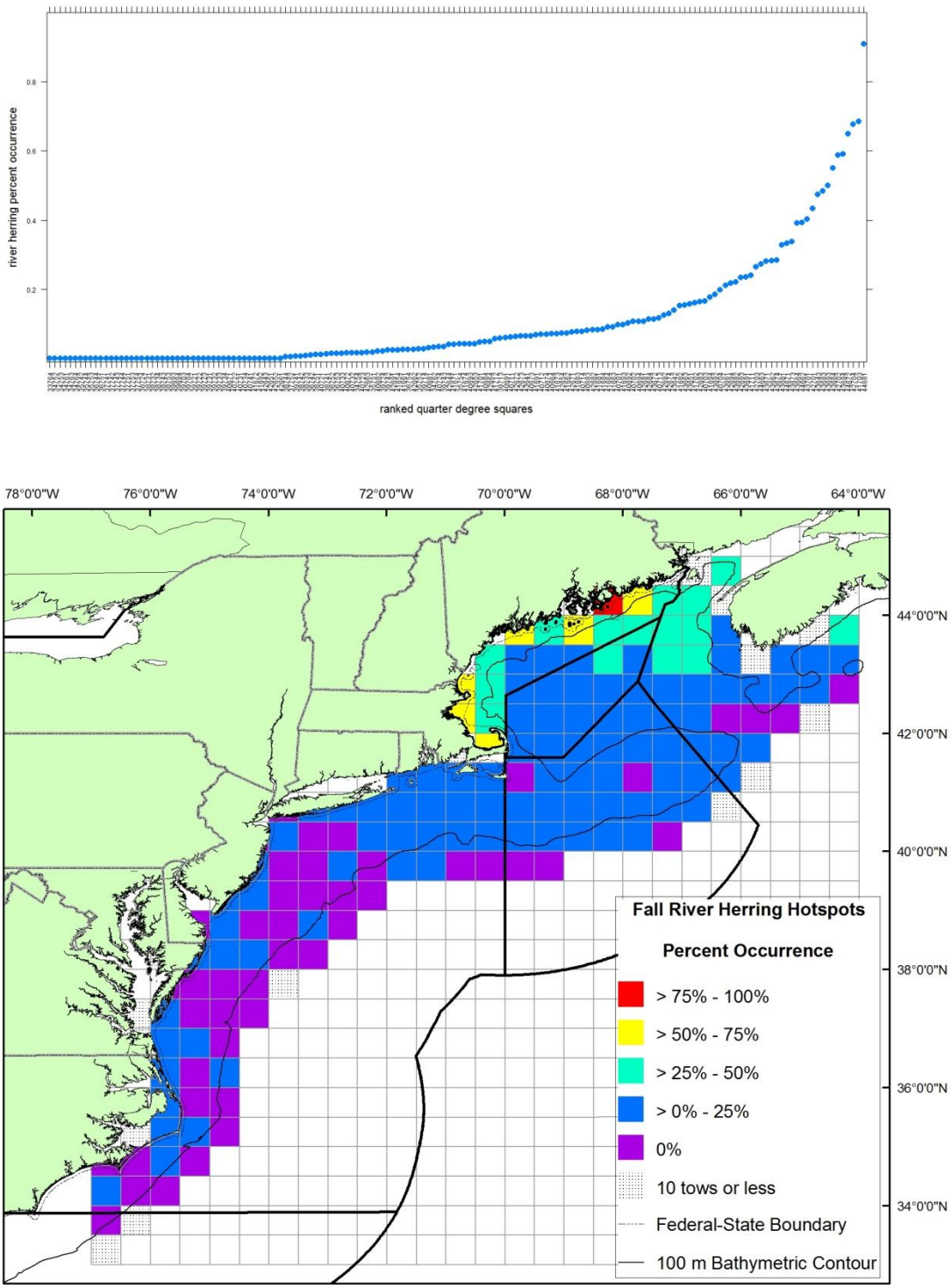


Figure A33: Percent occurrence of river herring in fall research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by quarter degree squares grouped from > 75% - 100% (red), > 50% - 75% (yellow), > 25% - 50% (aqua), > 0 - 25% (blue) and 0% (purple) (bottom). Source: Fall 1963-2008 NMFS bottom-trawl surveys.

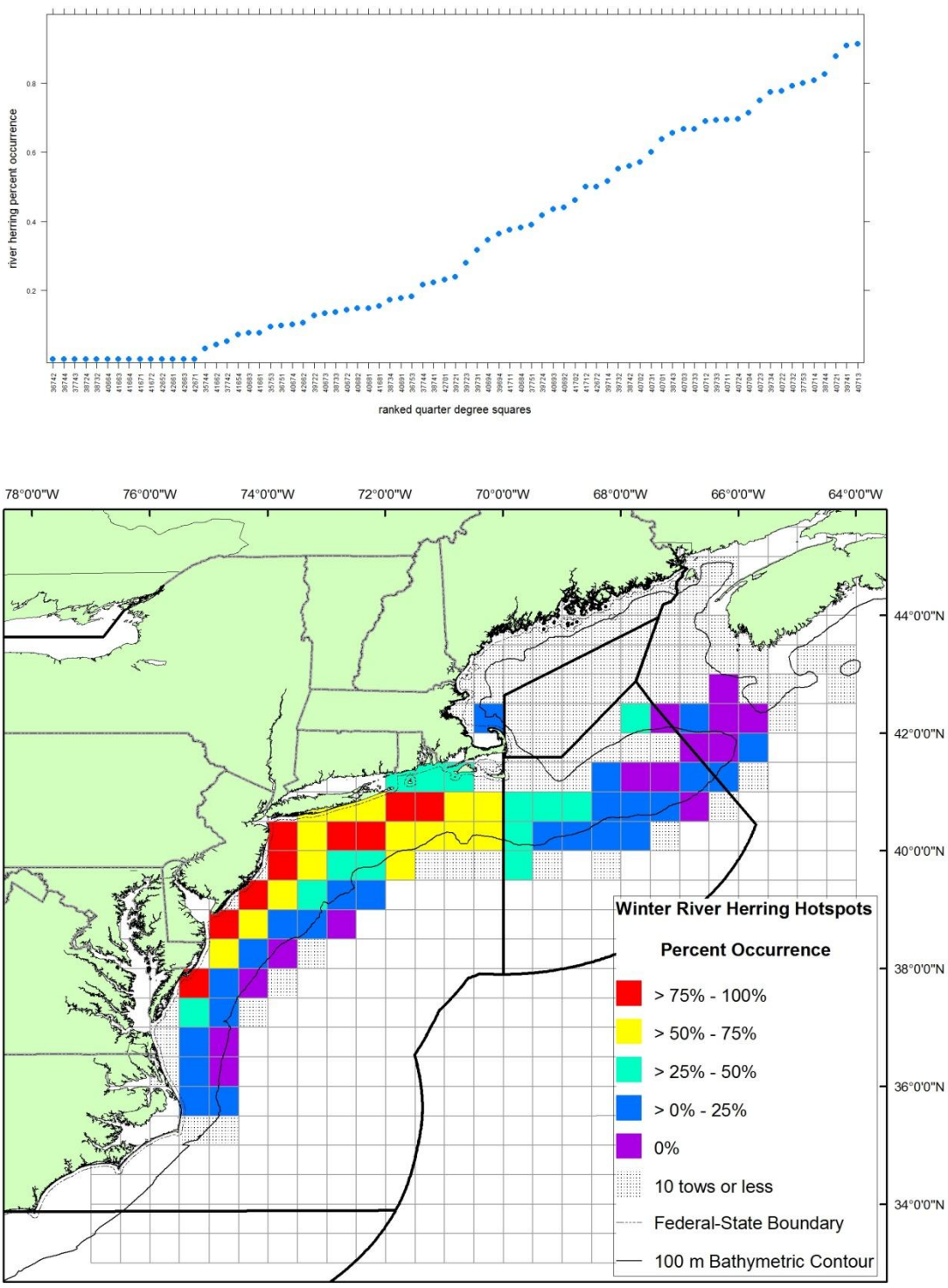


Figure A34: Percent occurrence of river herring in winter research surveys by statistical area ranked from lowest to highest (top). Map of corresponding river herring percent occurrence by quarter degree squares grouped from > 75% - 100% (red), > 50% - 75% (yellow), > 25% - 50% (aqua), > 0 - 25% (blue) and 0% (purple) (bottom). Source: Winter 1964-2007 NMFS bottom-trawl surveys.

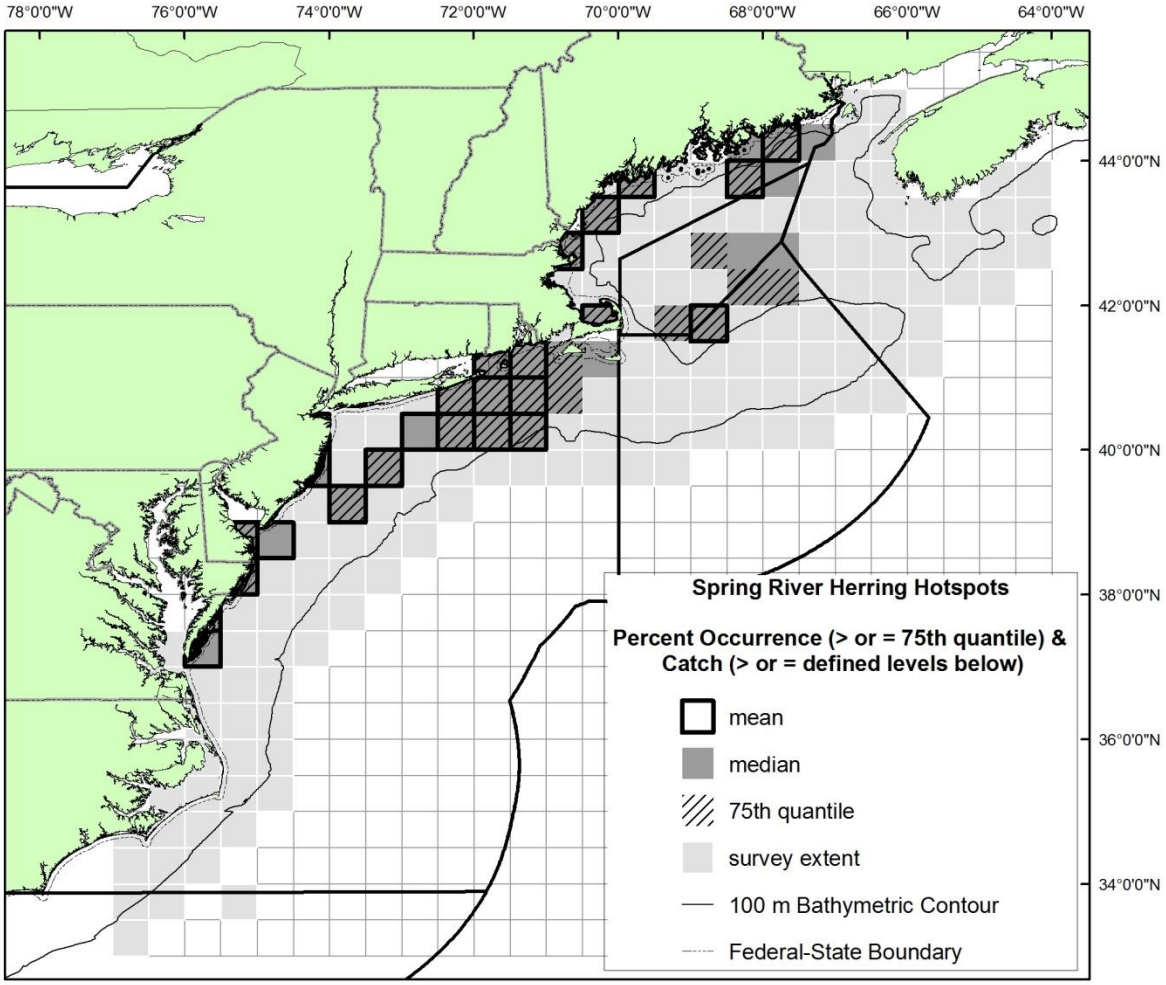


Figure A35: Spring candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables (yellow outlined squares), percent occurrence and median catch in number ≥ the 75th quantiles of both variables (red squares), and percent occurrence and catch in number ≥ the 75th quantiles of both variables (hatched squares). Source: Spring 1968-2008 NMFS bottom-trawl surveys.

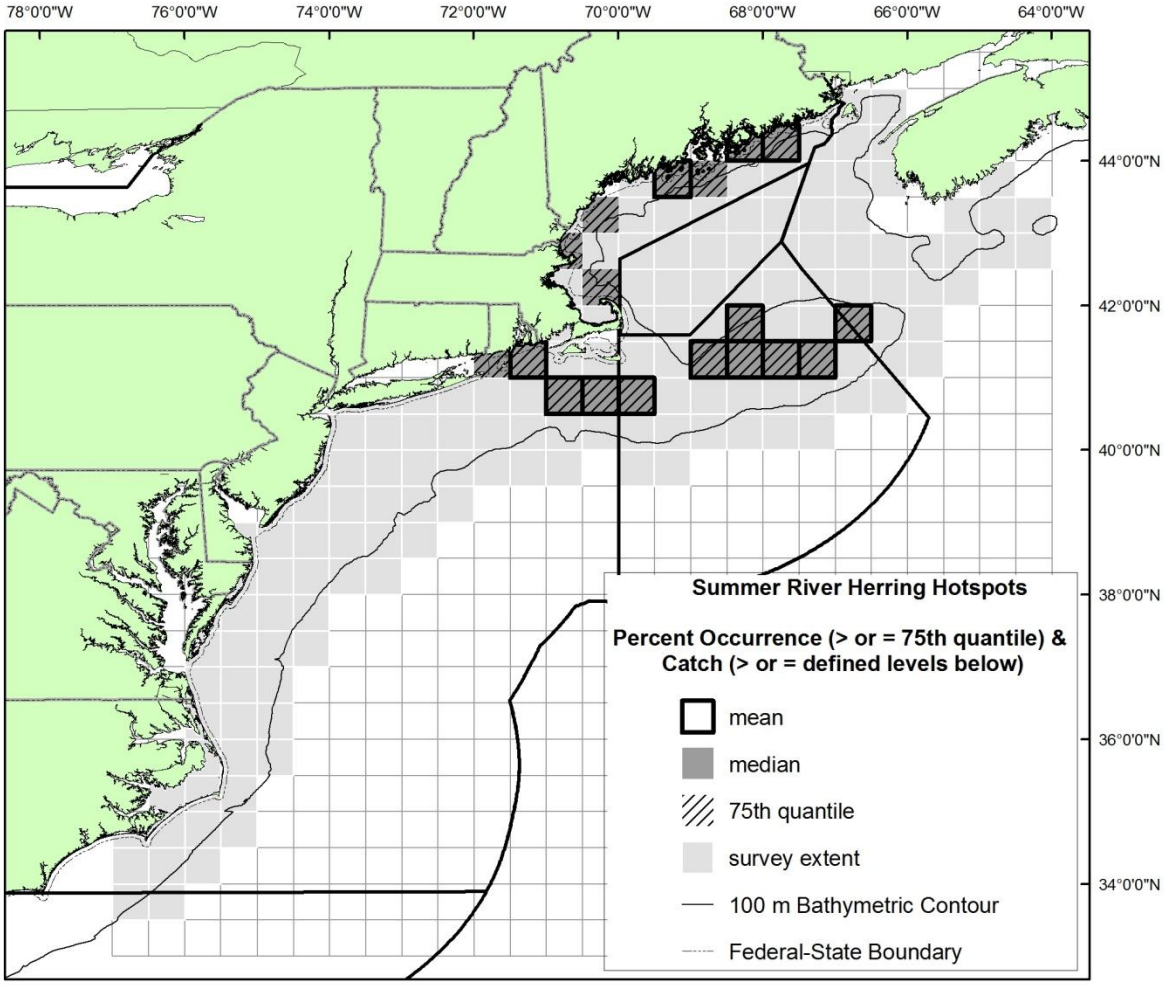


Figure A36: Summer candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables (yellow outlined squares), percent occurrence and median catch in number ≥ the 75th quantiles of both variables (red squares), and percent occurrence and catch in number ≥ the 75th quantiles of both variables (hatched squares). Source: Summer 1948-1995 NMFS bottom-trawl surveys.

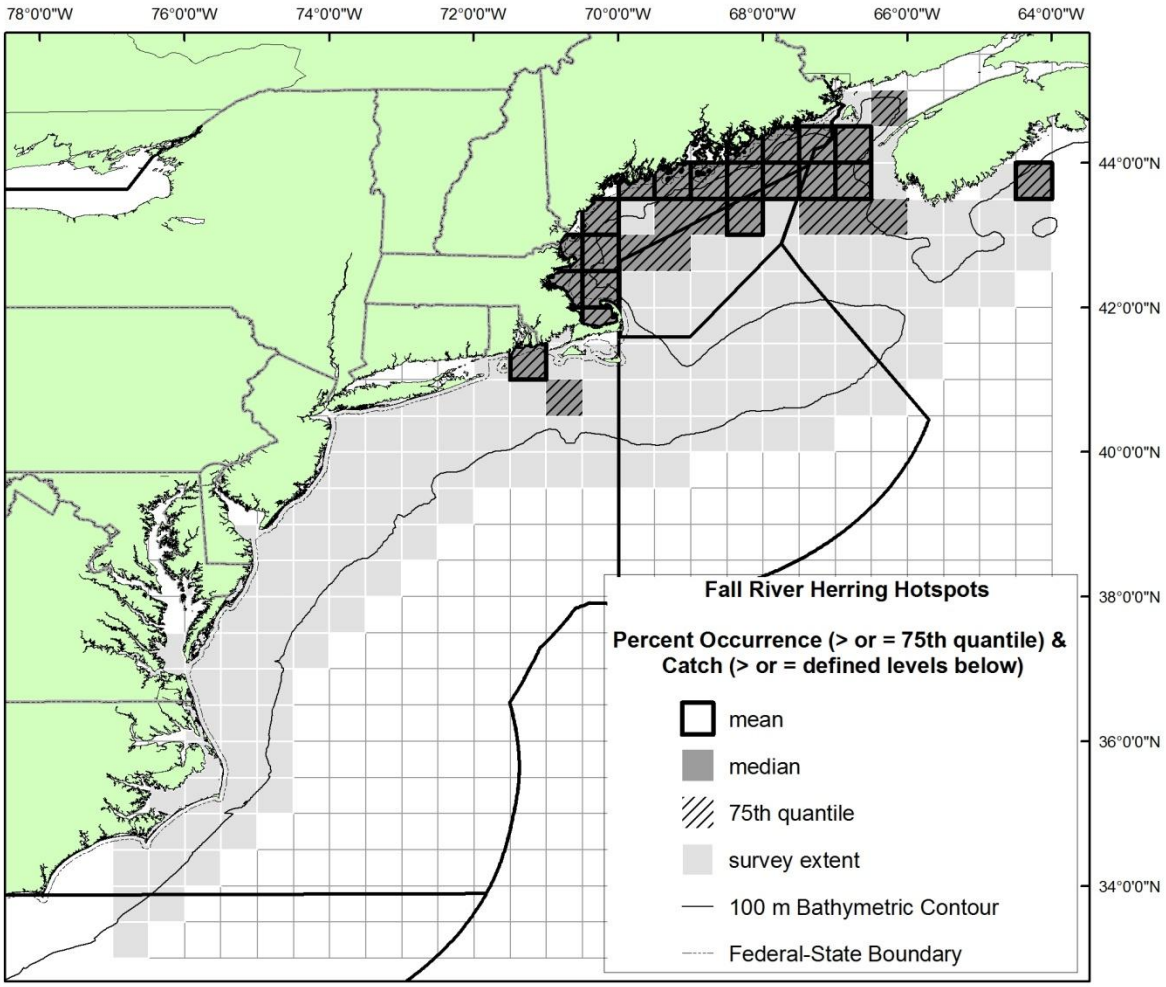


Figure A37: Fall candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables (yellow outlined squares), percent occurrence and median catch in number ≥ the 75th quantiles of both variables (red squares), and percent occurrence and catch in number ≥ the 75th quantiles of both variables (hatched squares). Source: Fall 1963-2008 NMFS bottom-trawl surveys.

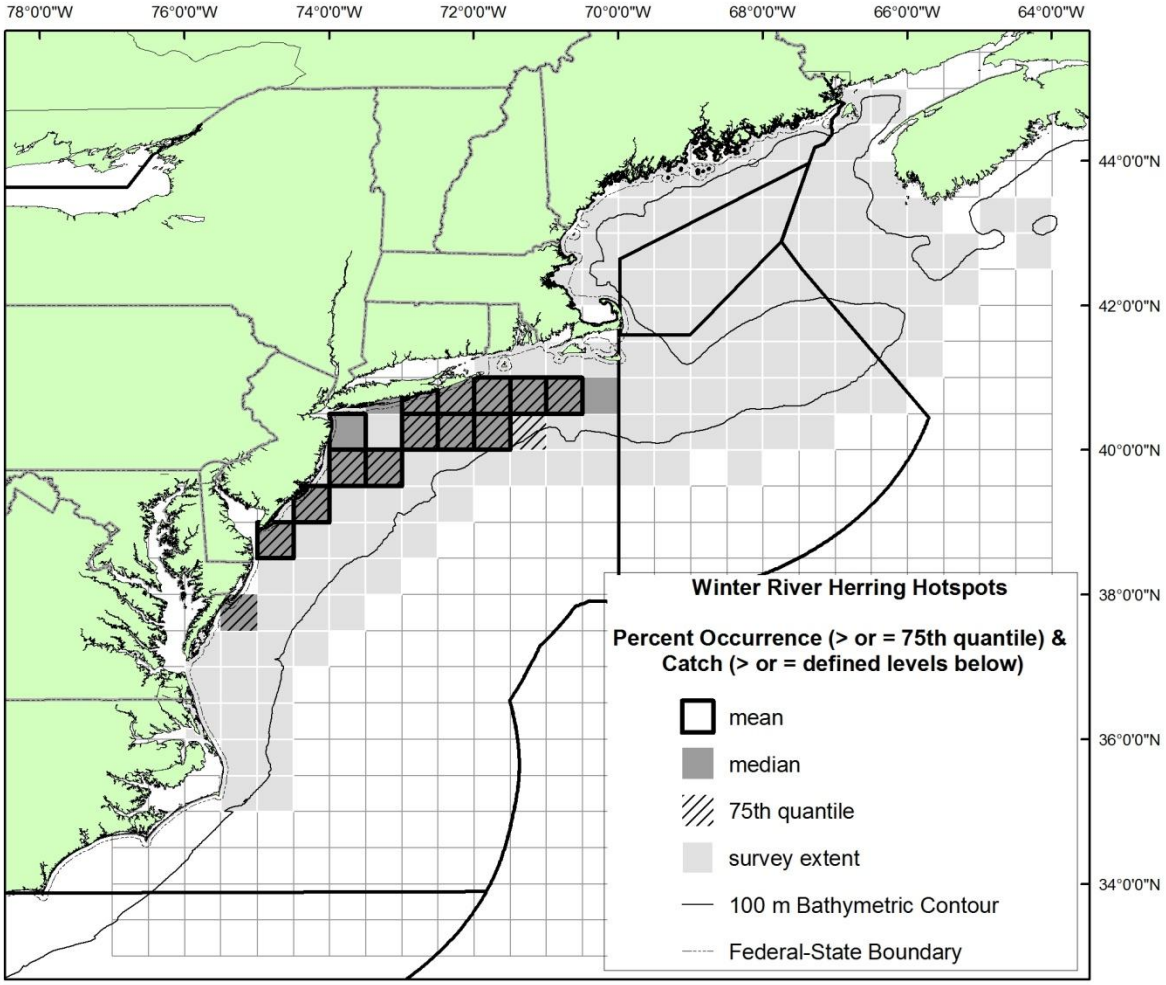


Figure A38: Winter candidate “hot spot” quarter degree squares identified as squares with percent occurrence and mean catch in number ≥ the 75th quantiles of both variables (yellow outlined squares), percent occurrence and median catch in number ≥ the 75th quantiles of both variables (red squares), and percent occurrence and catch in number ≥ the 75th quantiles of both variables (hatched squares). Source: Winter 1963-2007 NMFS bottom-trawl surveys.

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SUPPLEMENTAL MATERIAL

UPDATE: Identification of river herring hotspots at sea using fisheries dependent and independent datasets

Prepared for the Atlantic Herring PDT

by

Jamie Cournane[1]

Steven Correia[2]

[1]University of New Hampshire and Environmental Defense Fund

[2]Massachusetts Division of Marine Fisheries

August 2010

Jan-Feb	Gear Category			
River Herring Weight (lbs)	OT	PR	PS	ALL
0	22	181	0	203
> 0.5 - 40	23	3	0	26
> 40 - 129	15	16	0	31
> 129 - 358	14	17	0	31
> 358 - 1233	16	12	0	28
> 1233 - 69004	10	21	0	31
maximum= 69,004 ALL	100	250	0	350

Jul-Aug	Gear Category			
River Herring Weight (lbs)	OT	PR	PS	ALL
none	21	154	147	322
> 0.5 - 40	13	1	0	14
> 40 - 129	0	0	3	3
> 129 - 358	0	0	2	2
> 358 - 1233	0	0	0	0
> 1233 - 69004	0	0	0	0
maximum= 358 ALL	34	155	152	341

Mar-Apr	Gear Category			
River Herring Weight (lbs)	OT	PR	PS	ALL
none	4	94	0	98
> 0.5 - 40	0	5	0	5
> 40 - 129	0	5	0	5
> 129 - 358	0	9	0	9
> 358 - 1233	0	6	0	6
> 1233 - 69004	0	2	0	2
maxium= 12,339 ALL	4	121	0	125

Sep-Oct	Gear Category			
River Herring Weight (lbs)	OT	PR	PS	ALL
none	22	365	63	450
> 0.5 - 40	3	2	0	5
> 40 - 129	2	4	0	6
> 129 - 358	0	2	0	2
> 358 - 1233	0	4	0	4
> 1233 - 69004	0	5	0	5
maximum= 13,280 ALL	27	382	63	472

May-Jun	Gear Category			
River Herring Weight (lbs)	OT	PR	PS	ALL
none	0	132	67	199
> 0.5 - 40	0	4	1	5
> 40 - 129	0	1	0	1
> 129 - 358	0	0	1	1
> 358 - 1233	0	1	0	1
> 1233 - 69004	0	0	0	0
maximum= 384 ALL	0	138	69	207

Nov-Dec	Gear Category			
River Herring Weight (lbs)	OT	PR	PS	ALL
none	11	184	4	199
> 0.5 - 40	0	6	0	6
> 40 - 129	1	14	0	15
> 129 - 358	1	15	0	16
> 358 - 1233	2	20	0	22
> 1233 - 69004	1	21	0	22
maximum= 19,680 ALL	16	260	4	280

Table S1: Frequency table of river herring bycatch (lbs) in observed hauls and sets for directed herring trips by gear type and bimonthly blocks. Gear categories include bottom otter-trawls (OT), purse seines (PS), and mid-water trawls-single and paired (PR). Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Note this table corresponds with the scaled pink circles in Appendix Figs. A1-A6. Source: NEFOP Database 2005-2009.

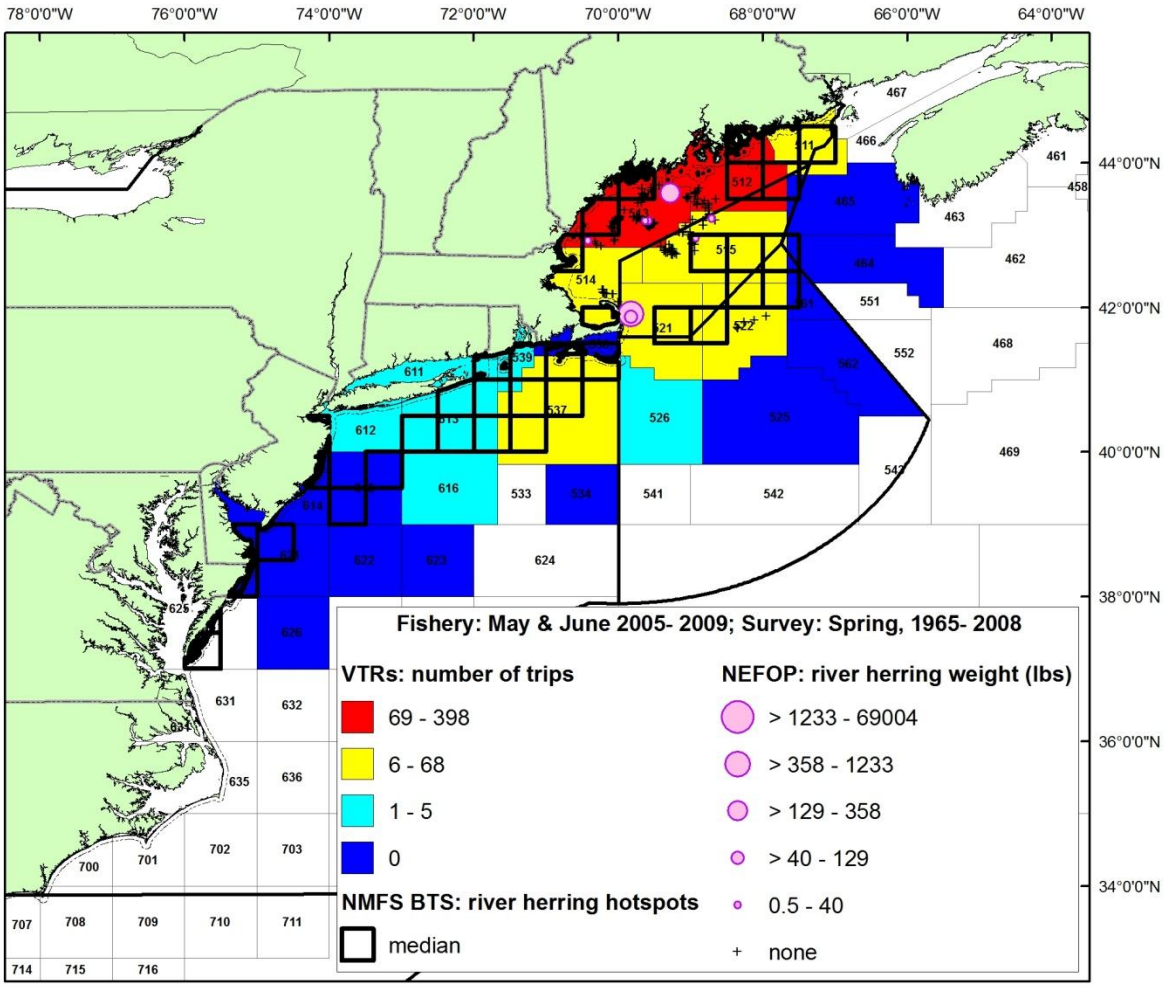

Figure S1: Reported trips (VTR) and observed hauls and sets (NEFOP) during May and June, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-398 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Spring candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Spring 1965-2008 NMFS bottom-trawl surveys.

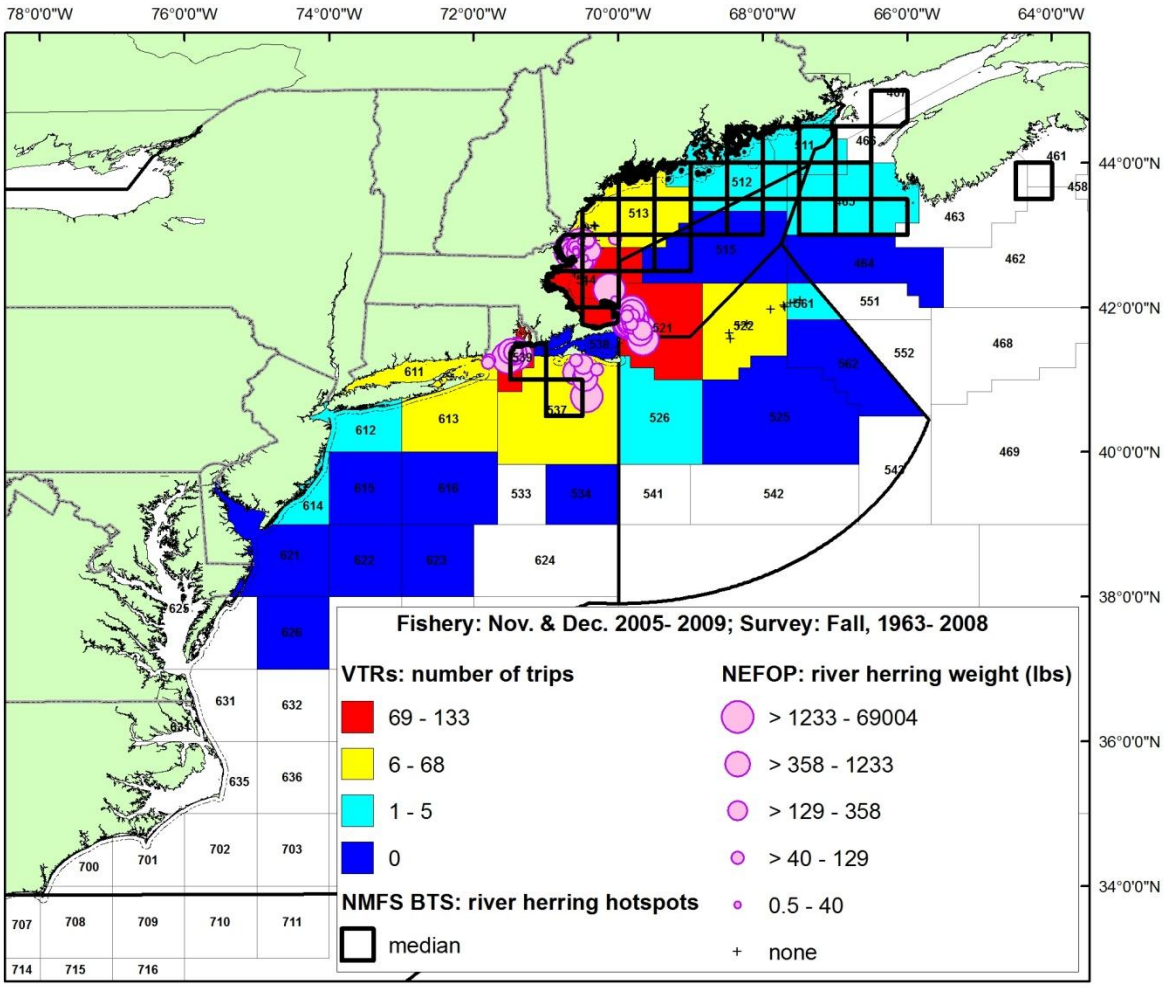

Figure S2: Reported trips (VTR) and observed hauls and sets (NEFOP) during November and December, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-133 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Fall candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Fall 1963-2008 NMFS bottom-trawl surveys.

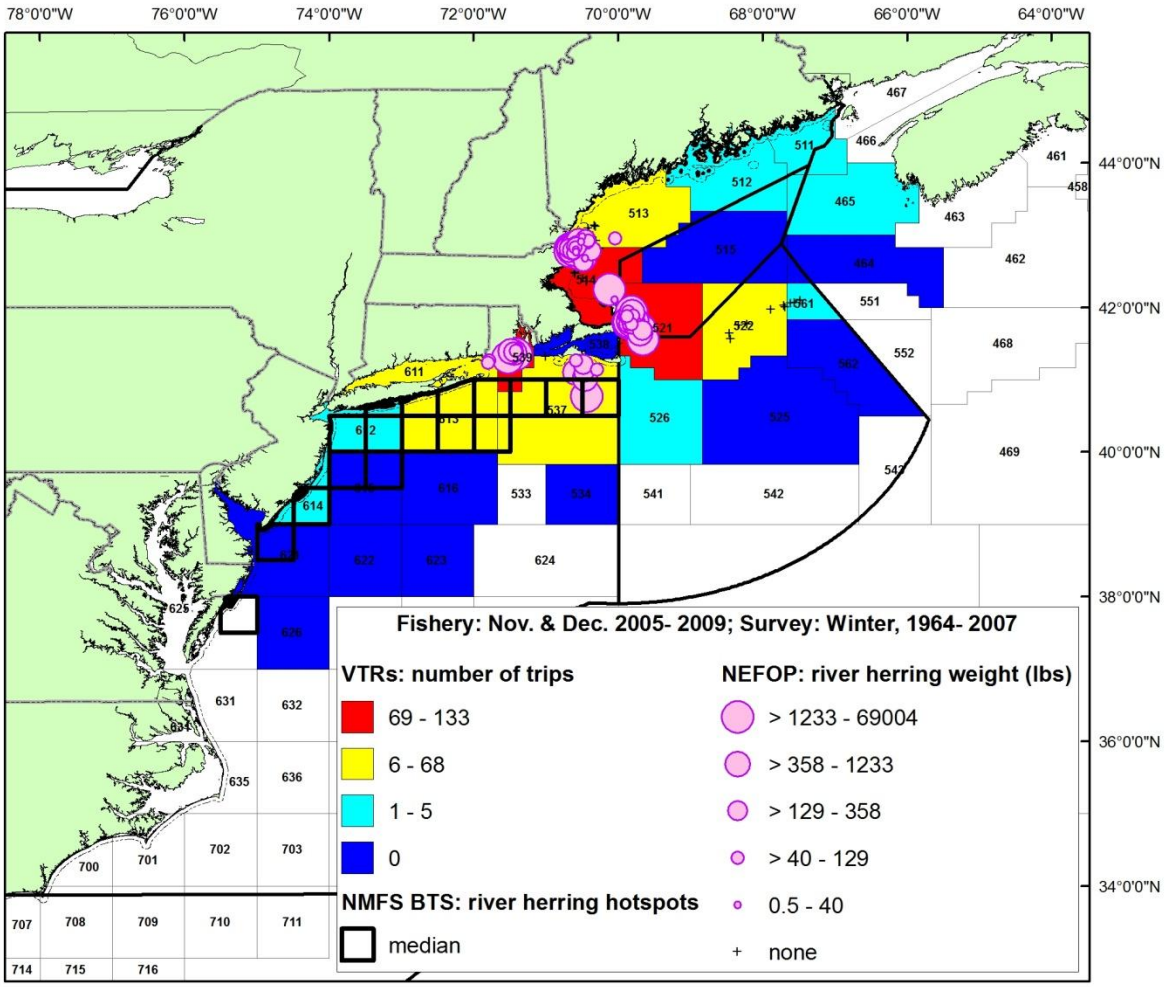

Figure S3: Reported trips (VTR) and observed hauls and sets (NEFOP) during November and December, 2005-2009 for directed herring trips by bottom otter-trawls, purse seines, and mid-water trawls (single and paired). Trips by statistical area are grouped from 69-133 (red), 6-68 (yellow), 1-5 (aqua), and 0 (dark blue) trips. Scaled pink circles represent river herring bycatch (lbs) in observed hauls and sets for directed herring trips. A "+" signifies that an observed haul or set did not catch river herring. Directed herring trips are defined as 2,000 lbs of kept Atlantic herring on a trip. Winter candidate river herring “hot spot” quarter degree squares identified as squares with percent occurrence and median catch in number ≥ the 75th quantiles of both variables (bold outlined quarter degree squares). Sources: VTR Database 2005-2009, NEFOP Database 2005-2009, and Winter 1963-2007 NMFS bottom-trawl surveys.

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Spatial Management Alternatives to Address

River Herring Bycatch in the Directed Atlantic Herring Fishery

Prepared for the Atlantic Herring PDT

by

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Steven J. Correia

Massachusetts Division of Marine Fisheries, New Bedford, MA

December 2010

Purpose

The current Atlantic Herring Fishery Management Plan (FMP) Amendment 5 (A5) draft discussion document contains several management alternatives to address river herring (alewife, *Alosa pseudoharengus*, and blueback herring, *Alosa aestivalis*) bycatch in the directed Atlantic herring, *Clupea harengus*, fishery (NEFMC 2010). The management alternatives under consideration include 100% monitoring, Closed Area I provisions, a move-along rule, implementing the Sustainable Fisheries Coalition (SFC) project through a Framework Adjustment (FW), and closed areas. Several of these alternatives have sub-options based on 100% or less than 100% observer coverage. These alternatives would apply in bimonthly river herring hotspots using a two-stage approach, based on three hotspot configuration options from fishery (stage 1) and research survey hotspots (stage 2). Recently, the Plan Development Team (PDT) has been encouraged to streamline the river herring hotspot analysis (Cournane and Correia 2010a-c).

Spatial Management Alternatives to Address River Herring Bycatch

In general, the management alternatives fall under three broad management goals: monitoring, avoidance, and protection. These three management goals can be linked to the design of spatial management alternatives (Table 1). Here in the proposed framework, the existing A5 management "alternatives" become management "options" under the spatial management alternatives.

Management Goal	Spatial Management Alternative	Management Option
Monitoring	1. River Herring Monitoring Areas	A.100% monitoring B. Closed Area I provisions
Avoidance	2. River Herring Avoidance Areas	A. Move-along rule B. SFC project/FW adjustment
Protection	3. River Herring Protected Areas	A. Closed areas

Table 1: Reframing A5 management "alternatives" as management "options" under spatial management alternatives linked to specific management goals.

Goal

Here, the goal is to design spatial management alternatives to address river herring bycatch in the directed Atlantic herring fishery that are ecologically based, simple to understand, and enforceable. The alternatives should also link directly to the management measures under consideration in A5.

Design Considerations

Depending on the management goal, configurations for spatial management alternatives might include using existing Atlantic Herring FMP management areas, Fisheries Statistical Areas, extending the timing of the inshore Atlantic Herring spawning closure, or creating new spatial

management areas. However, spatial management alternatives should be based on the river herring hotspot analysis, maintaining the bimonthly stratification. Selection of areas for inclusion should focus on the fishery hotspots, but also consider the survey hotspots based on management goals. Therefore, creating new spatial management areas based on fisheries encounters with river herring and the expected distribution of river herring should be the focus.

The size and the shape of the spatial management alternatives should reflect the management goals. In general, the size of a river herring monitoring or avoidance area might be greater than a river herring protected area. In addition, contiguous areas might be preferred to several disconnected discrete areas to achieve monitoring or avoidance goals.

Example Configurations

The following bimonthly maps display possible spatial management alternatives linked to specific management goals to address river herring bycatch in the Atlantic Herring Fishery (Figures 1-12). Table 2 summarizes the design elements of the possible spatial management alternatives. In addition, possible river herring monitoring areas were scaled up to the level of statistical areas for reference (Figures 1-6).

Spatial Management Alternative	Stage 1 Hotspots	Stage 2 Hotspots	Figures
River Herring Monitoring Areas	> 40 lbs	YES	1- 6
River Herring Avoidance Areas	> 40 lbs	NO	7- 12
River Herring Protected Areas	> 1233 lbs	NO	13- 16

Table 1: Example design of possible spatial management alternatives using the river herring hotspot analysis. Stage 1 (fishery) hotspots are identified as quarter-degree squares within a bimonthly block with at least one river herring encounter in the directed Atlantic herring fishery greater than the specified threshold level (here 40 lbs or 1233 lbs), based on observer data. Stage 2 (survey) hotspots are identified as quarter-degree squares within a seasonal survey with relative high percent occurrence and high catch of river herring, based on NMFS bottom-trawl surveys.

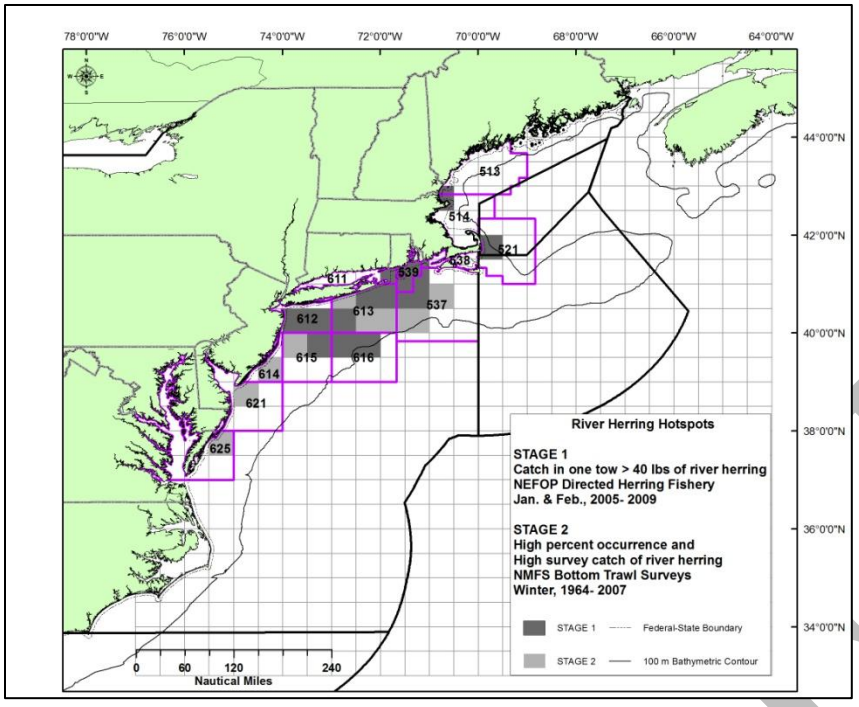

Figure 1: River herring monitoring areas alternative, January- February.

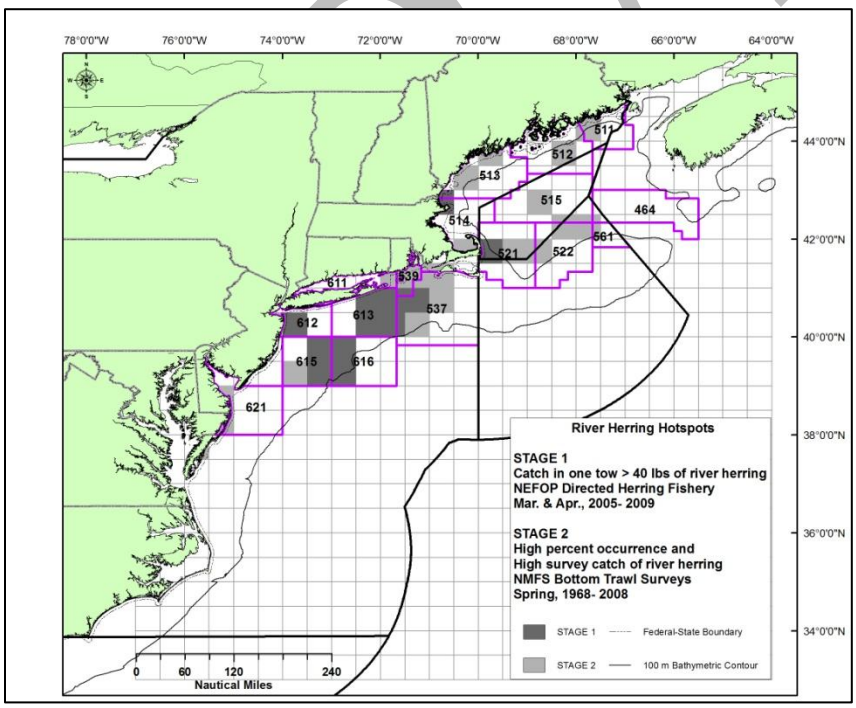

Figure 2: River herring monitoring areas alternative, March- April.

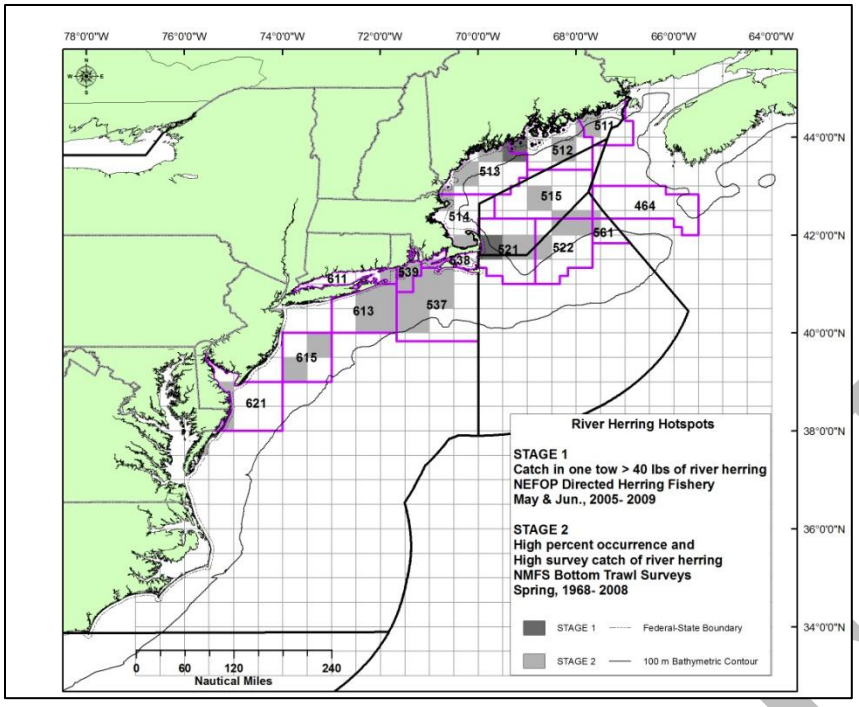

Figure 3: River herring monitoring areas alternative, May- June.

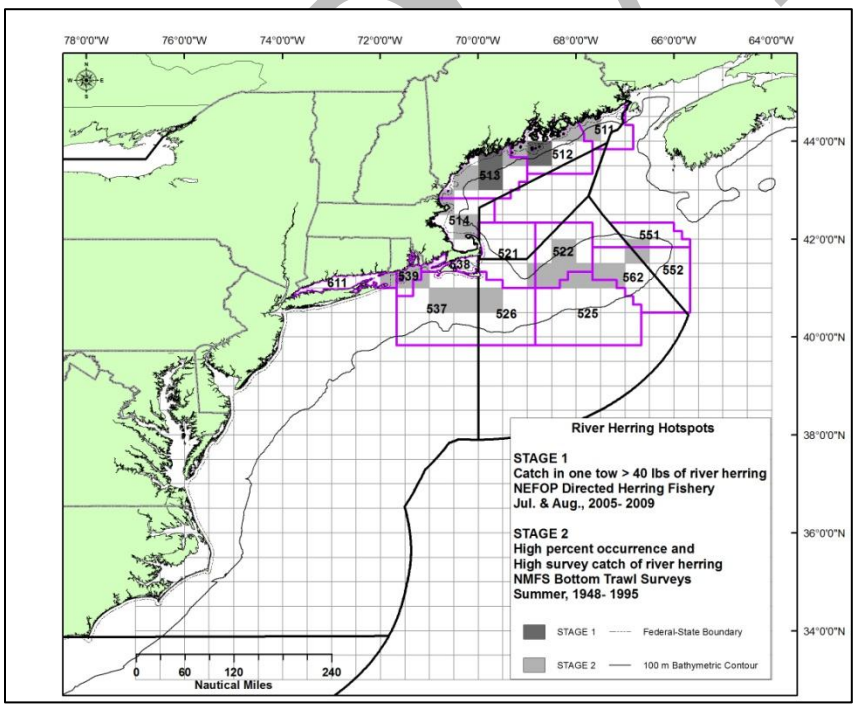

Figure 4: River herring monitoring areas alternative, July- August.

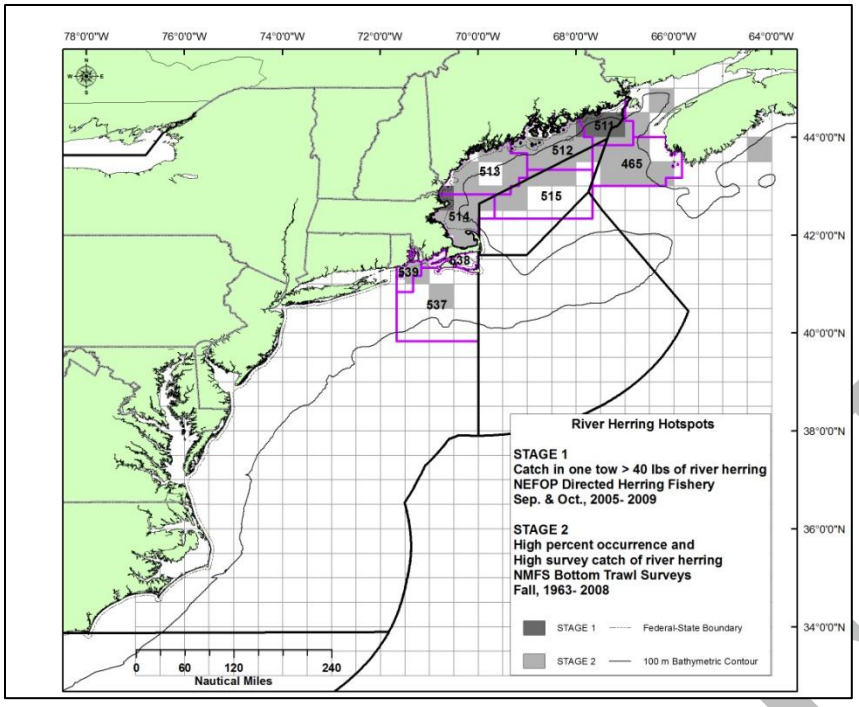

Figure 5: River herring monitoring areas alternative, September- October.

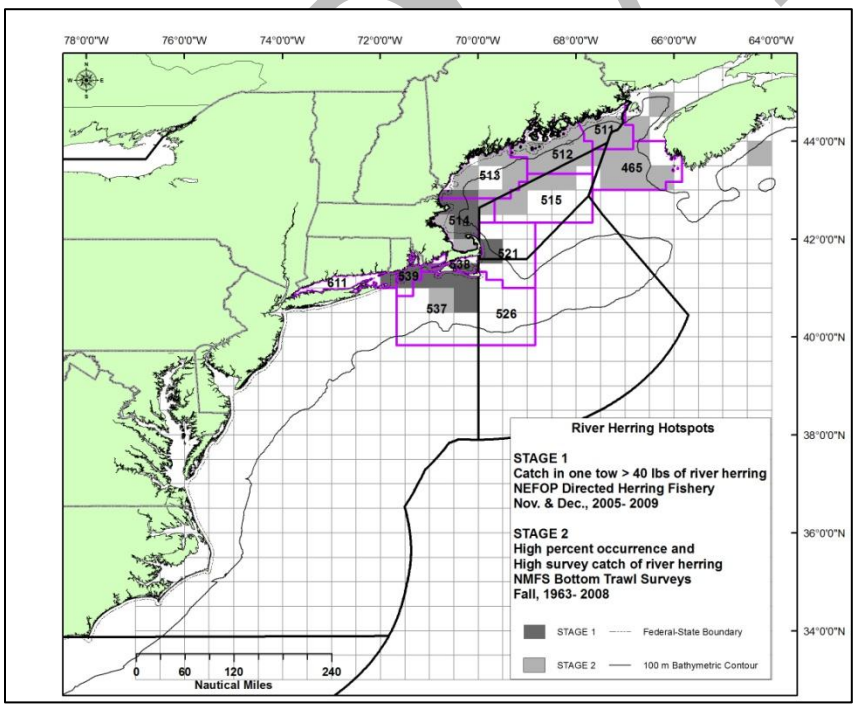

Figure 6: River herring monitoring areas alternative, November- December.

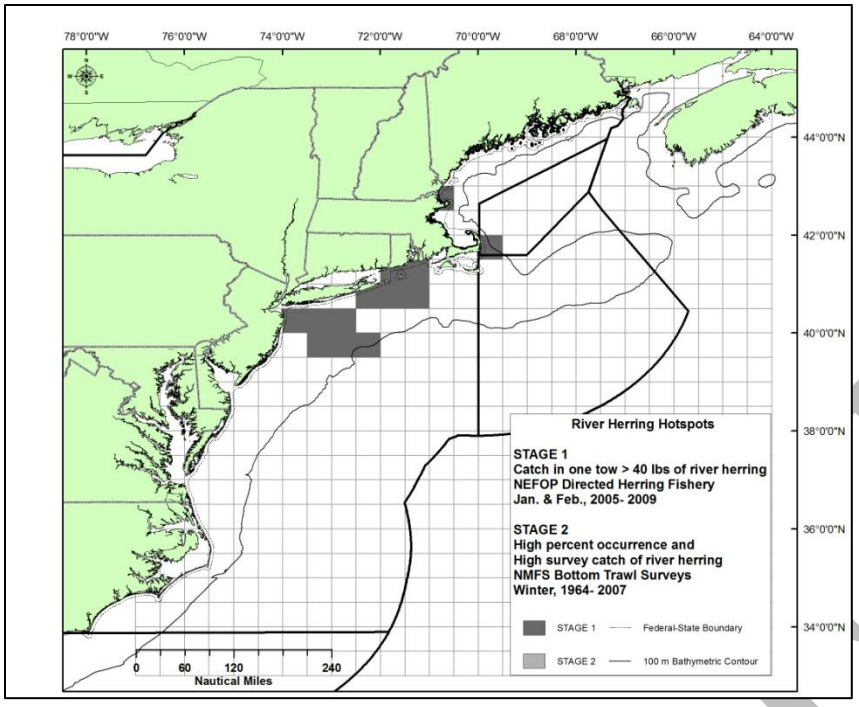

Figure 7: River herring avoidance areas alternative, January- February.

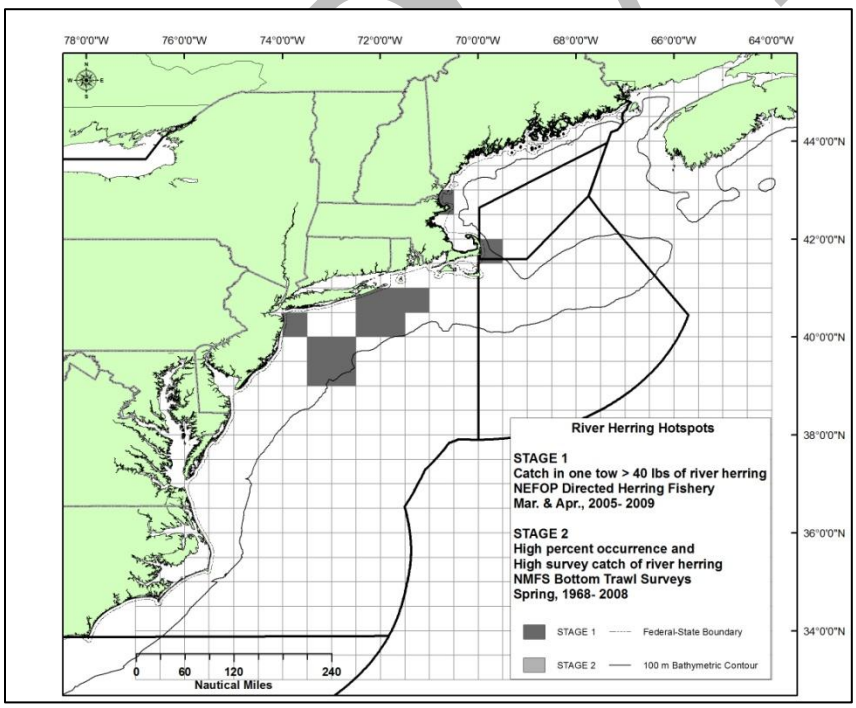

Figure 8: River herring avoidance areas alternative, March- April.

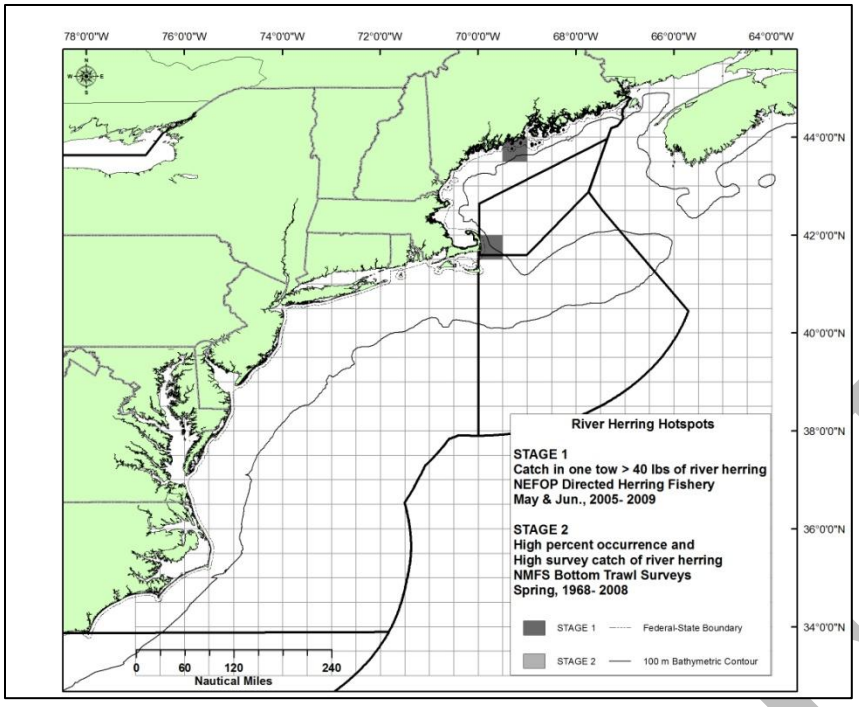

Figure 9: River herring avoidance areas alternative, May- June.

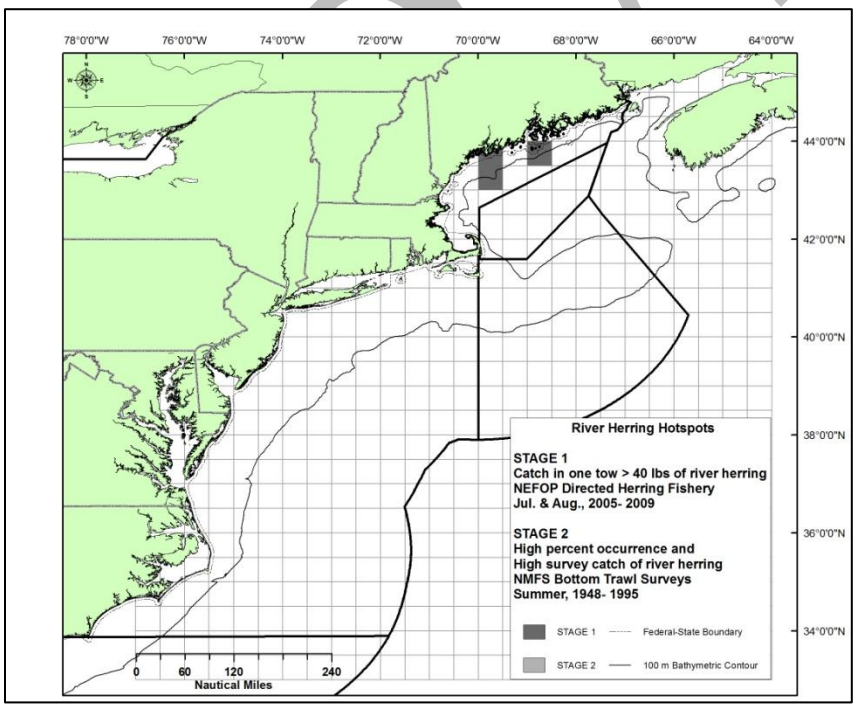

Figure 10: River herring avoidance areas alternative, July- August.

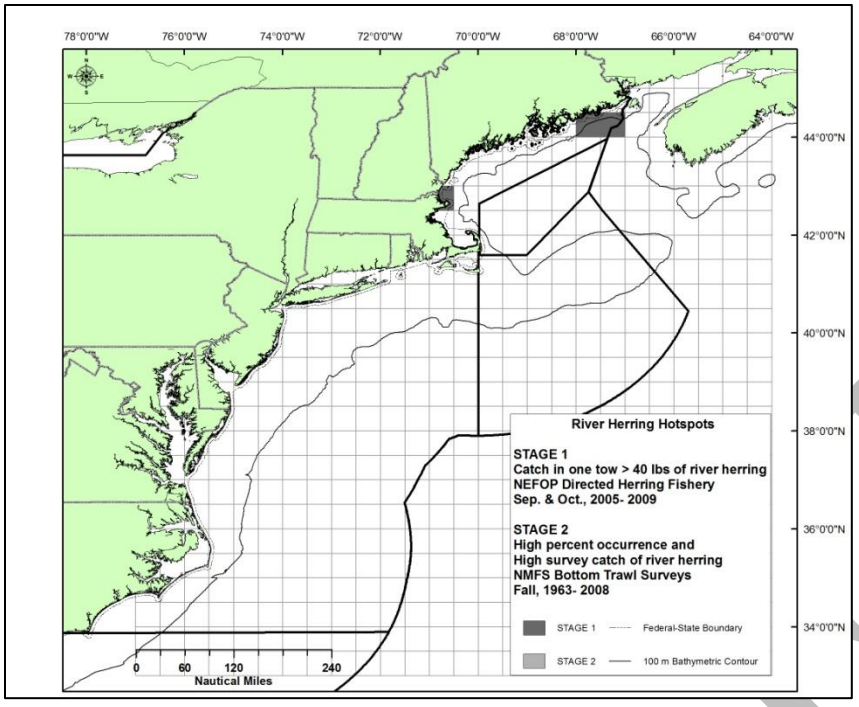

Figure 11: River herring avoidance areas alternative, September- October.

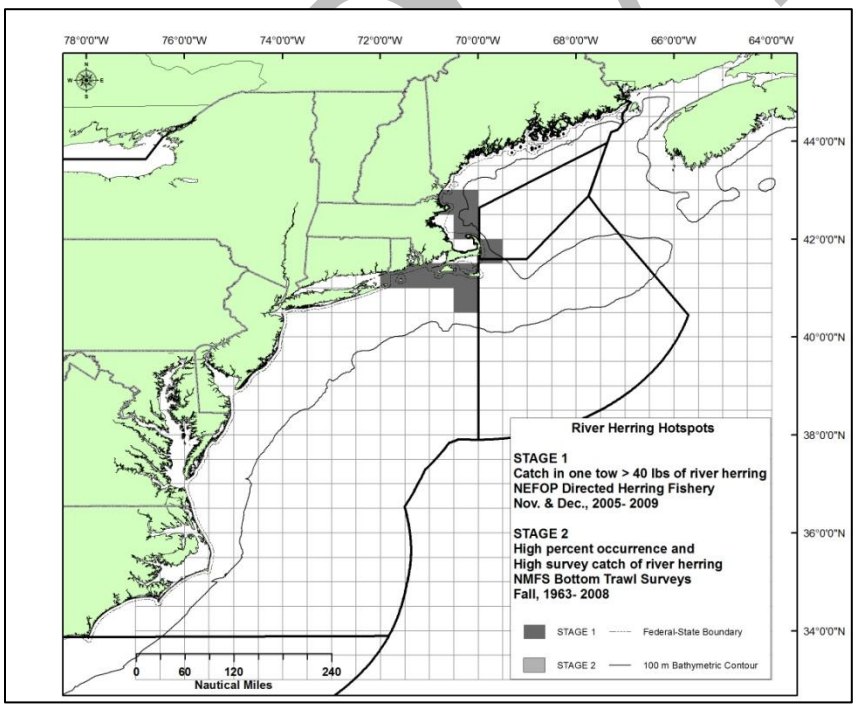

Figure 12: River herring avoidance areas alternative, November- December.

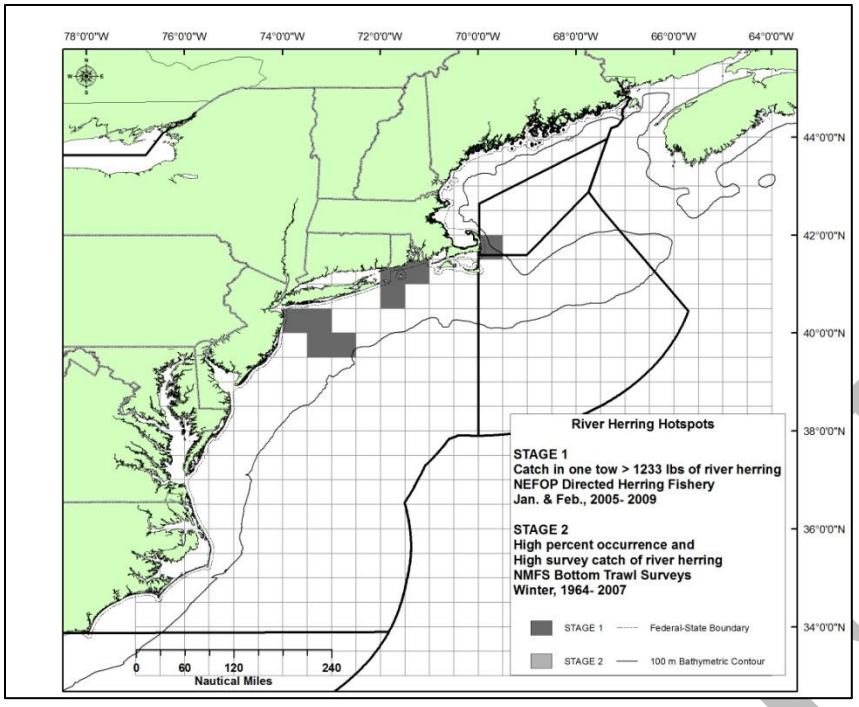

Figure 13: River herring protected areas alternative, January- February.

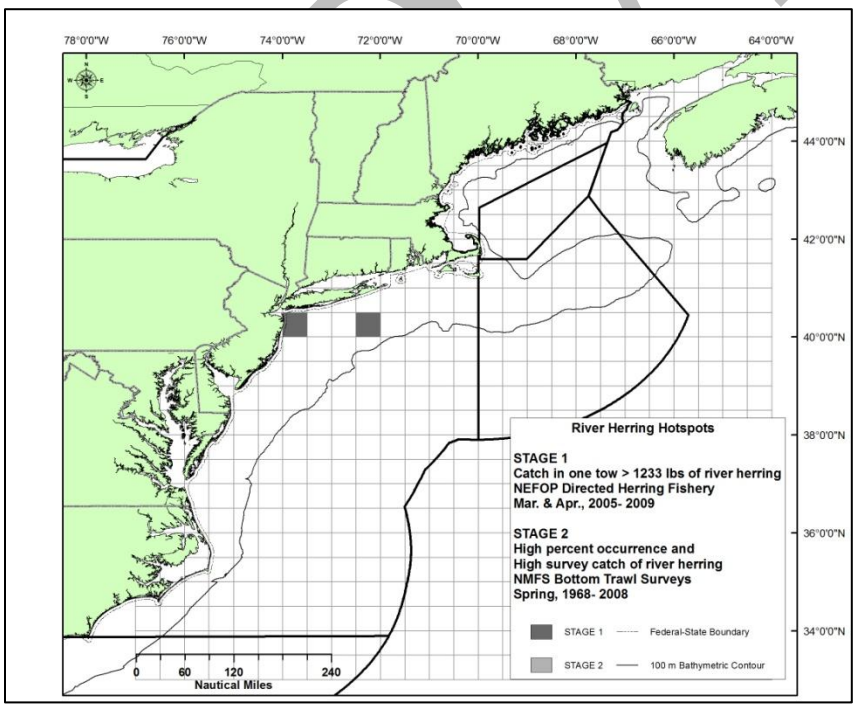

Figure 14: River herring protected areas alternative, March- April.

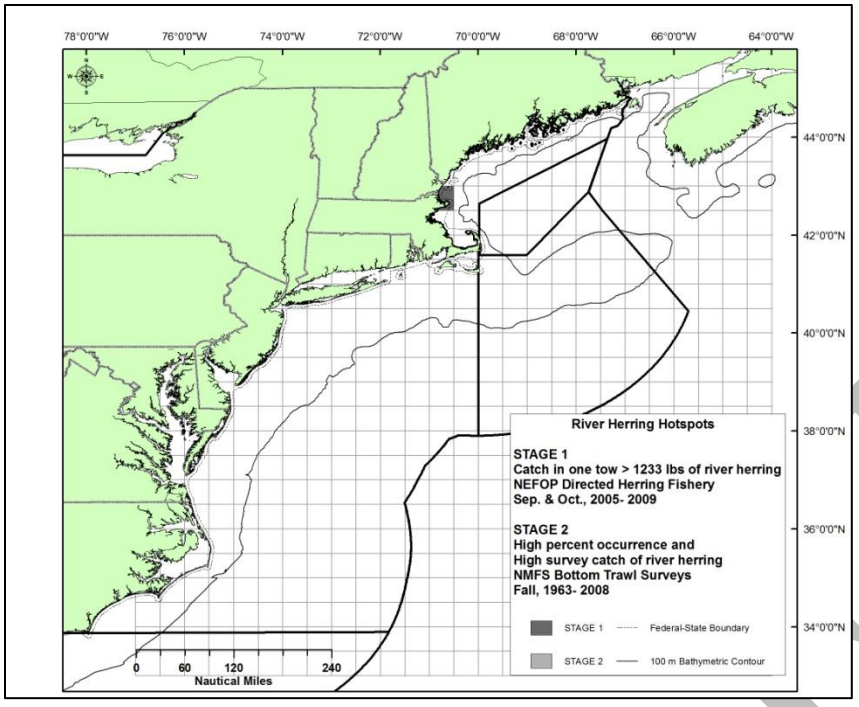

Figure 15: River herring protected areas alternative, September- October.

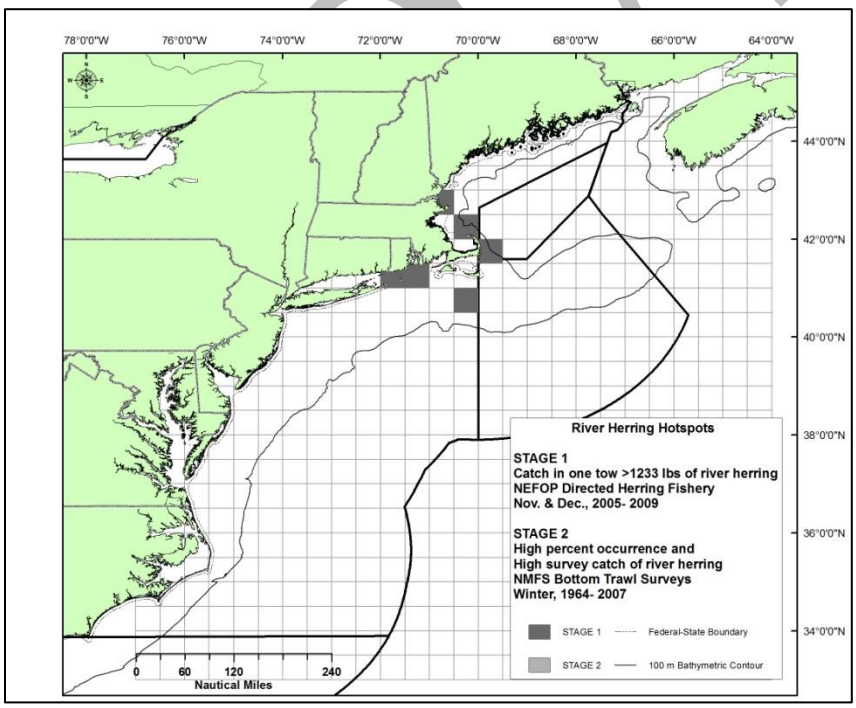

Figure 16: River herring protected areas alternative, November- December.

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