Appendix
To Amendment 8 to the
Atlantic Herring Fishery Management Plan

Atlantic Herring Plan Development Team
Work in support of the Herring Committee
Regarding Localized Depletion and User Conflicts

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INTRODUCTION

In January 2016, the Herring Plan Development Team (PDT) was tasked by the Herring Committee (Committee) to provide data and analyses to support the development of a problem statement and related measures in Amendment 8 regarding localized depletion of Atlantic herring. Localized depletion has been a topic discussed in the herring management arena since at least the mid-2000s, when Amendment 1 to the Atlantic Herring FMP was developed. Through Amendment 1, midwater trawl (MWT) gears were excluded from Herring Management Area 1A in June-September. At that time, no data linking MWTs to localized depletion were used to support that action. The Council's rationale was to ensure access to herring for the purse-seine and fixed gear components of the fishery and to address concerns raised by the public and the Scientific and Statistical Committee about concentrated catch inshore and need for precaution due, in part, to lack of data on the inshore resource. There was a concern that MWT was particularly prone to causing localized depletion (NEFMC 2006).

For the development of Amendment 8, the following definition of localized depletion has been used, as described in the Council's public scoping document for Amendment 8:

> *"In general, localized depletion is when harvesting takes more fish than can be replaced either locally or through fish migrating into the catch area within a given time period."*

The occurrence of localized Atlantic herring depletion suggests that the removal of herring from a given area would either leave its relatively immobile predators (e.g., monkfish) with insufficient prey for some time, or that relatively mobile predators (e.g., cod, tuna) would leave the area in search of alternative prey. To the degree that temporal and spatial fishery catch data are available, it is relatively simple to describe where and when fishing has occurred for herring and its predators. It is more challenging to empirically identify if and how herring's predators and their fisheries have been impacted by herring catches. There are many constraints that determine where and when a fishery is prosecuted (e.g., area closures, weather windows, mobility of fish) that need to be understood in an investigation of whether there is causality to any correlations.

In the March 25, 2016, PDT memo to the Committee on localized depletion, the PDT noted many limits to existing data that may hinder a full evaluation of the existence and extent of localized depletion:

> *"Even if correlations are found between herring removals and a signal in a predator fishery or business (i.e., whale watching) that may suggest that localized depletion is occurring, the PDT expects it will be difficult to identify a causal link, using just the data available. It is not a trivial undertaking."*

On March 30 2016, the Committee considered the PDT input and developed the following problem statement, which was approved by the Council in April:

> *"Scoping comments for Amendment 8 identified concerns with concentrated, intense commercial fishing of Atlantic herring in specific areas and at certain times that may cause detrimental socioeconomic impacts on other user groups (commercial, recreational, ecotourism) who depend upon adequate local availability of Atlantic herring to support business and recreational interests both at sea and on shore. The Council intends to further explore these concerns through examination of the best available science on localized depletion, the spatial nature of the fisheries, reported conflicts amongst users of the resources and the concerns of the herring fishery and other stakeholders."*

The Committee further tasked the PDT with additional analyses to support the development of measures in Amendment 8 regarding localized depletion of Atlantic Herring. This appendix summarizes the PDT work on these tasks, which was also contained in memos to the Committee dated March 25 and August 9, 2016. In addition to the regular PDT members, Dr. Walt Golet (University of Maine/Gulf of Maine Research Institute); Mr. Brad McHale, Ms. Dianne Stephan and Mr. Dean Szumylo (NMFS GARFO); and Dr. John Manderson and Mr. Chris Sarro (NEFSC) contributed to this work.

MARCH 25, 2016 MEMO

This memo is intended to improve understanding of herring management and the footprint in time and space of the herring fisheries as well as fisheries or businesses (e.g., whale-watching) that rely on the predators of herring. The memo also identifies limits to existing data that may hinder a full evaluation of the existence and extent of localized depletion. The work herein is not intended to be definitive and should likely be amended (e.g., applied at different spatial and temporal scales) or expanded (e.g., use different datasets) to be more definitive.

In this memo, the PDT defines localized depletion as described in the Council's public scoping document for Amendment 8:

> *"In general, localized depletion is when harvesting takes more fish than can be replaced either locally or through fish migrating into the catch area within a given time period."*

The occurrence of localized depletion suggests that the removal of prey from a given area would either leave relatively immobile predators (e.g., monkfish) with insufficient prey for some time, or that relatively mobile predators (e.g., cod, tuna) would leave the area in search of alternative prey.

To the degree that temporal and spatial fishery catch data is available, it is relatively simple to describe where and when fishing has occurred for predator fisheries. As described below, this may not be so straight forward for tuna fisheries and perhaps striped bass fisheries. It is challenging to identify if and how other fisheries have been impacted by herring catches. There are many constraints that determine where and when a fishery is prosecuted (e.g., area closures, weather windows, mobility of fish) that need to be understood in an investigation of whether there is causality to any correlations.

In Amendment 1 and more recently, much attention has been given to midwater trawls as the gear responsible for causing localized depletion. The method of removal, however, should not be relevant to the evaluation of localized depletion. If predators are responding only to herring abundance in an area, then given the same amount of catch, the same level of depletion occurs regardless of gear type and would subsequently have the same effect on predators. That said, as a relatively large and mobile gear, MTWs likely have different effects on predators than other gears commonly used to harvest similar amounts of herring (e.g., purse seines). Both gear types can be used to fish in a concentrated fashion. Issues of gear conflict should be kept distinct from issues of localized depletion. Are herring predators responding to depletion of herring (which should not depend on the gear used to remove herring), or are the predators responding to a trawl gear passing through an area (and would respond the same way regardless of herring depletion)? The former is localized depletion while the latter is not. These issues are also not mutually exclusive. Conducting field research would help determine if correlations indicate causality and avoid speculation.

TASK #1: Forage needs

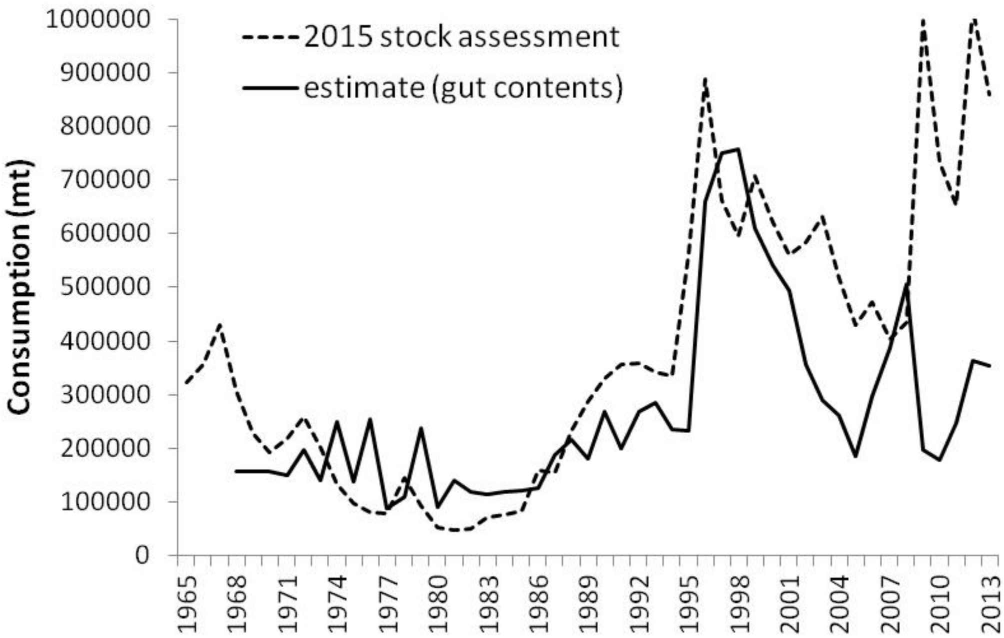
Clarify how much herring is currently set aside (e.g., in the stock assessment) to account for the forage needs of predators? What is the best estimate of how much herring is needed for forage?

In the Atlantic herring stock assessment, the amount of herring assumed to be ***taken*** by predators (e.g., piscivorous fish, seabirds, highly migratory species, marine mammals) has varied annually (Figure 1, dashed line). The 2015 stock assessment assumed that, during 2009-2013, an annual average of 852,000 mt of Atlantic herring was eaten by predators, which equaled 44% of average total biomass (1.92 million mt) over the same period. The amount of herring assumed to be consumed by predators in the assessment is based on natural mortality rates and estimates of herring consumption largely based on gut contents data, which also vary annually (Figure 1, solid line), with an annual average of 268,000 mt during that time. The gut contents data are from NMFS surveys, and are highly imprecise and likely biased. The short-term projections used to provide catch advice (overfishing limit, acceptable biological catch) assume a similar amount of herring are consumed as assumed in the stock assessment. More information is available in the 2015 Atlantic Herring Operational Assessment report (Deroba 2015).

The Ecosystem-Based Fishery Management PDT report on scientific advice for accounting for ecosystem forage requirements (NEFMC 2015a) and assessment reports (e.g., Deroba 2015) may be referenced for sample estimates of predator consumption. In recent years, marine mammal consumption of herring is similar to commercial fishery landings, averaging 105,000 mt/year. Bluefin tuna and blue sharks have recently consumed 20-25,000 mt/year. Seabirds consume a relatively small amount of herring, conservatively estimated at about 3-5 mt/year. According to the NEFSC diet database, herring constitutes roughly 20% of the diet of cod and spiny dogfish. There is also some evidence which suggest it is not just volume of herring available, but the age structure of that forage base that is important in the energy budgets of predators (Diamond & Devlin 2003; Golet et al. 2015).

The PDT assumes that the amount of Atlantic herring ***needed*** for forage is the amount below which predators are negatively impacted. Estimates of this need do not currently exist and would vary by the abundance of predators and other prey. To summarize, consumption estimates can be generated, but that is different than what is necessary – which is a difficult question to answer definitively.

Figure 1 - Atlantic herring consumption by predators



Source: Deroba (2015).

<u>*TASK #2: Footprint of the Atlantic herring and predator fisheries*</u>

Identify herring fishing locations, by season and gear type; identify any evidence of pulse fishing (i.e., multiple herring vessels in a concentrated time/area).

Within the 12 nm territorial sea line, identify areas (e.g., Ipswich Bay, Nantucket Shoals) where herring fishing seasonally intensifies.

Determine and compare midwater trawl trip catches over time in each area, considering variation in tow-specific catches (accounting for tow time, number of tows, and trip duration).

Determine if, over the time of intensified fishing, catches could only be maintained by longer tows, more tows and/or longer trips, thereby indicating local depletion (e.g., F much higher than F set for entire stock).

Identify predator fishery (e.g., striped bass, tuna) locations, by season and gear type.

Due to time constraints, the PDT has partially completed these tasks as reported here. Data for the bottom trawl fishery are not included here, neither is an analysis of tow-specific catches over time, or predator fisheries by gear type. Information at other time scales could be provided in future as well. Data limitations are noted.

Heat maps

To locate effort by different fisheries in recent years, the PDT developed "heat maps" of herring revenue by midwater trawl vessels from 2000 to 2014, using a method generated by the NEFSC Social Sciences Branch (DePiper 2014). These maps use a statistical model to match Vessel Trip Report (VTR) data with observer data. The model compares haul-level observer data with the VTR point location to model the probability that an observed haul is within a particular distance of a VTR point. The model results are then applied to the VTR data to construct concentric rings. The lat/lon data of the trip is used along with other data, primarily days absent.

A benefit to this approach is that it does not just take a VTR point and expand it to a stat area, but takes into account the trip length, gear used, and general area of the ocean. All subtrips with a lat/lon point are used, not just observed trips. This approach is a way to resolve the limitations of having one VTR point per trip.

This probability mapping approach is a means to use the VTR position data on a grid finer than statistical area, but there should be caution in interpreting results and ensuring appropriate time scales are used. It is not possible, however, to identify catch per tow. These maps can be generated for different gears and time intervals, and for all fisheries that are in the VTR database. Maps for revenue and effort (trips) are also readily available.

Map 1 to Map 12 show, by month, the estimated landings by geographic areas fished for the herring MWT and herring purse seine (PUR) fisheries, as well as the commercial fisheries for cod, pollock), and spiny dogfish.

In January, there is a bit of overlap between the MWT fleet and both cod and pollock fisheries east of Cape Cod. It also overlaps with cod near Block Island. The same patterns exist from February through April, but there is a bit less fishing for herring than in January.

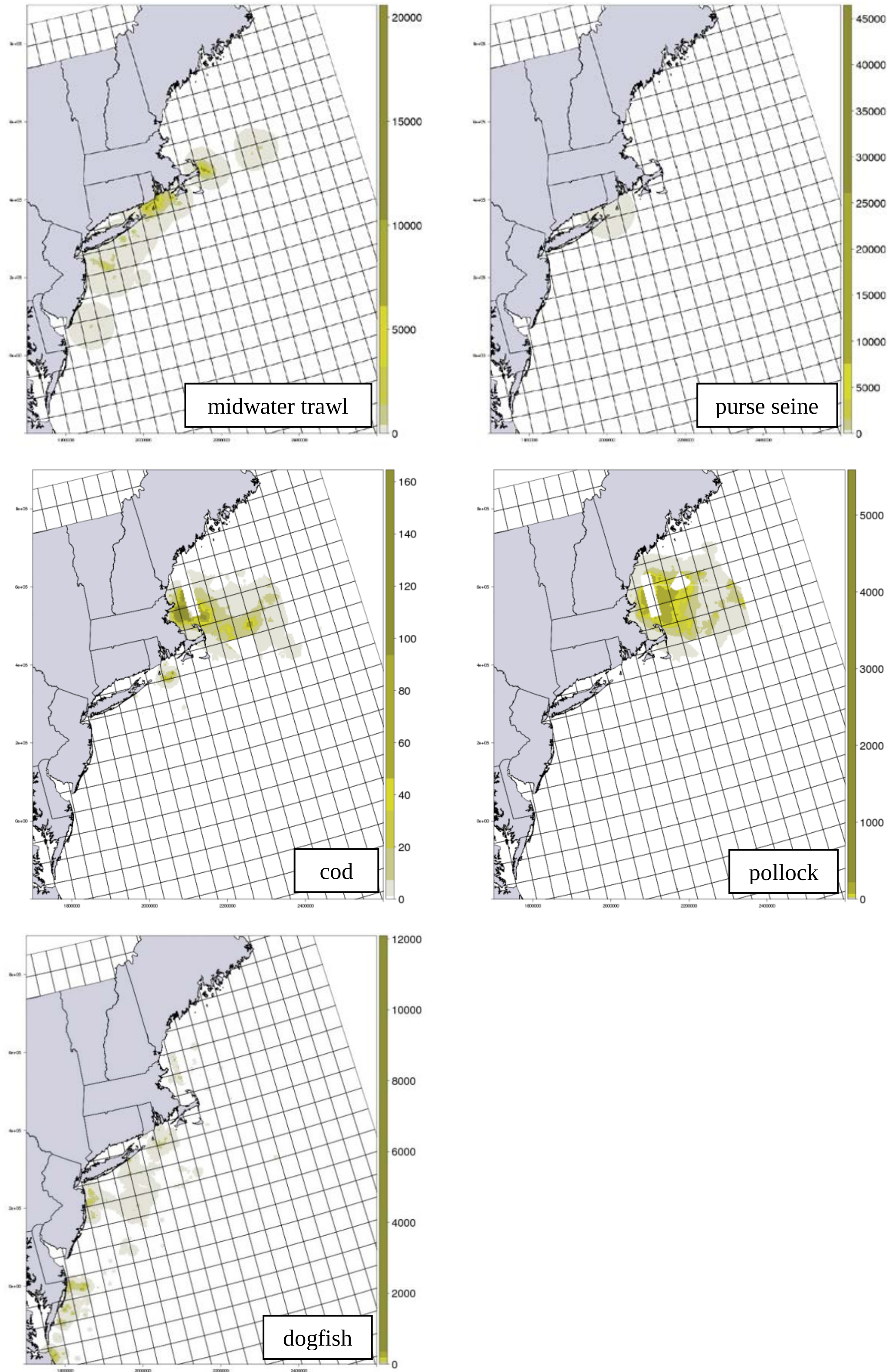
In May, there is a bit of overlap between the MWT fleet and both cod and pollock fisheries east of Cape Cod.

In June, the MWT fishery has moved mostly to Georges Bank and maybe a bit of MWT fishing in the Great South Channel. There may be a bit of overlap between the trawl fishery in block 113 with both cod and pollock fisheries. Spiny dogfish are being caught east and southeast of Cape Cod (Blocks 114 and 98), but the herring fishery is not using these areas extensively in June. July is qualitatively similar.

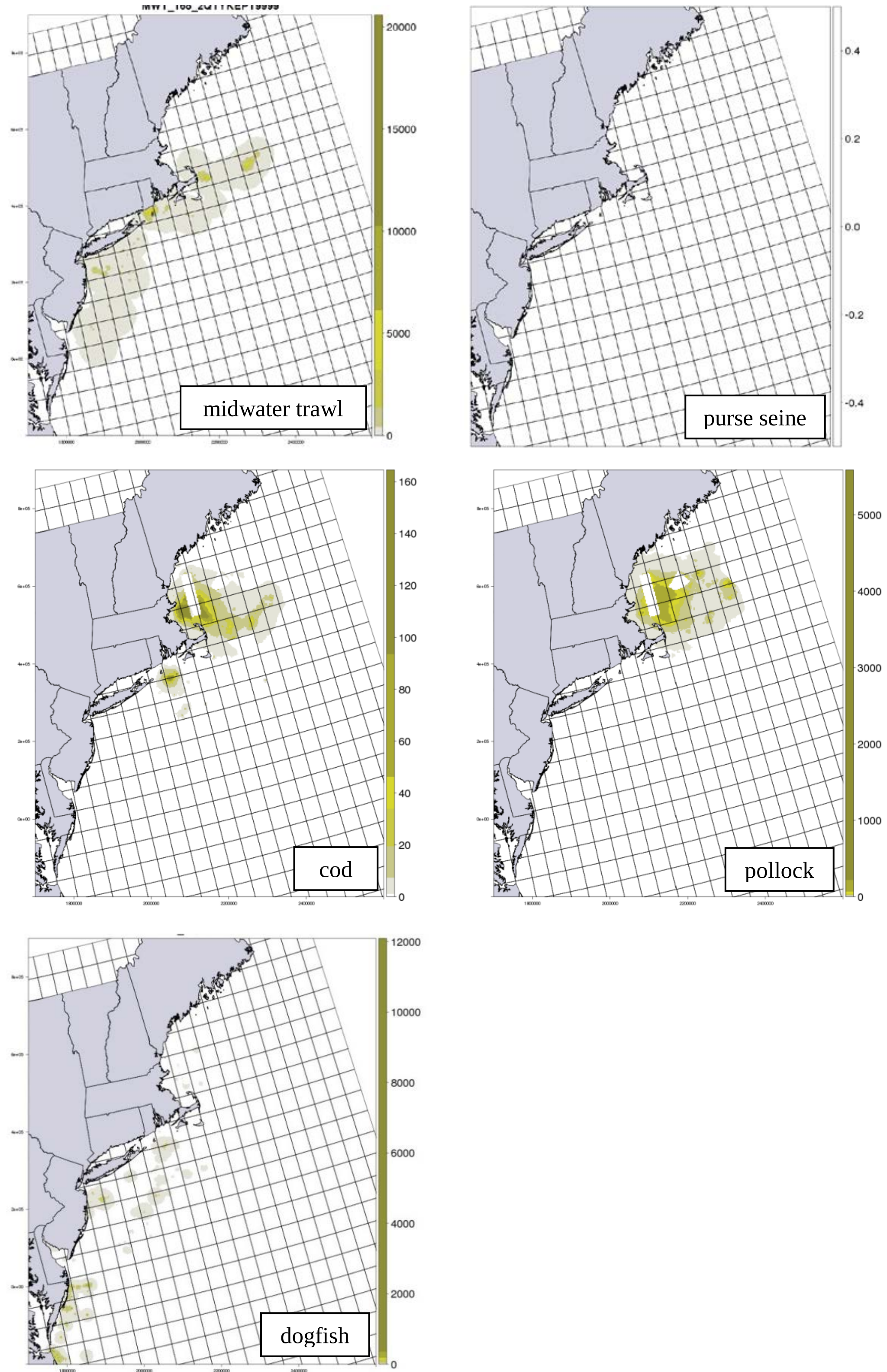
In August, herring, cod, pollock, and spiny dogfish are all being caught in Block 114, east of Cape Cod. There is also may be a bit of overlap between the pollock and purse seine gear just northeast of the Western Gulf of Maine Area. September is similar.

By October, the MWT fishery has moved back into Area 1A, so there is some overlap between herring MWT vessels and the three predator fisheries. This continues into November. By December, there may be a bit of overlap again, east of Cape Cod.

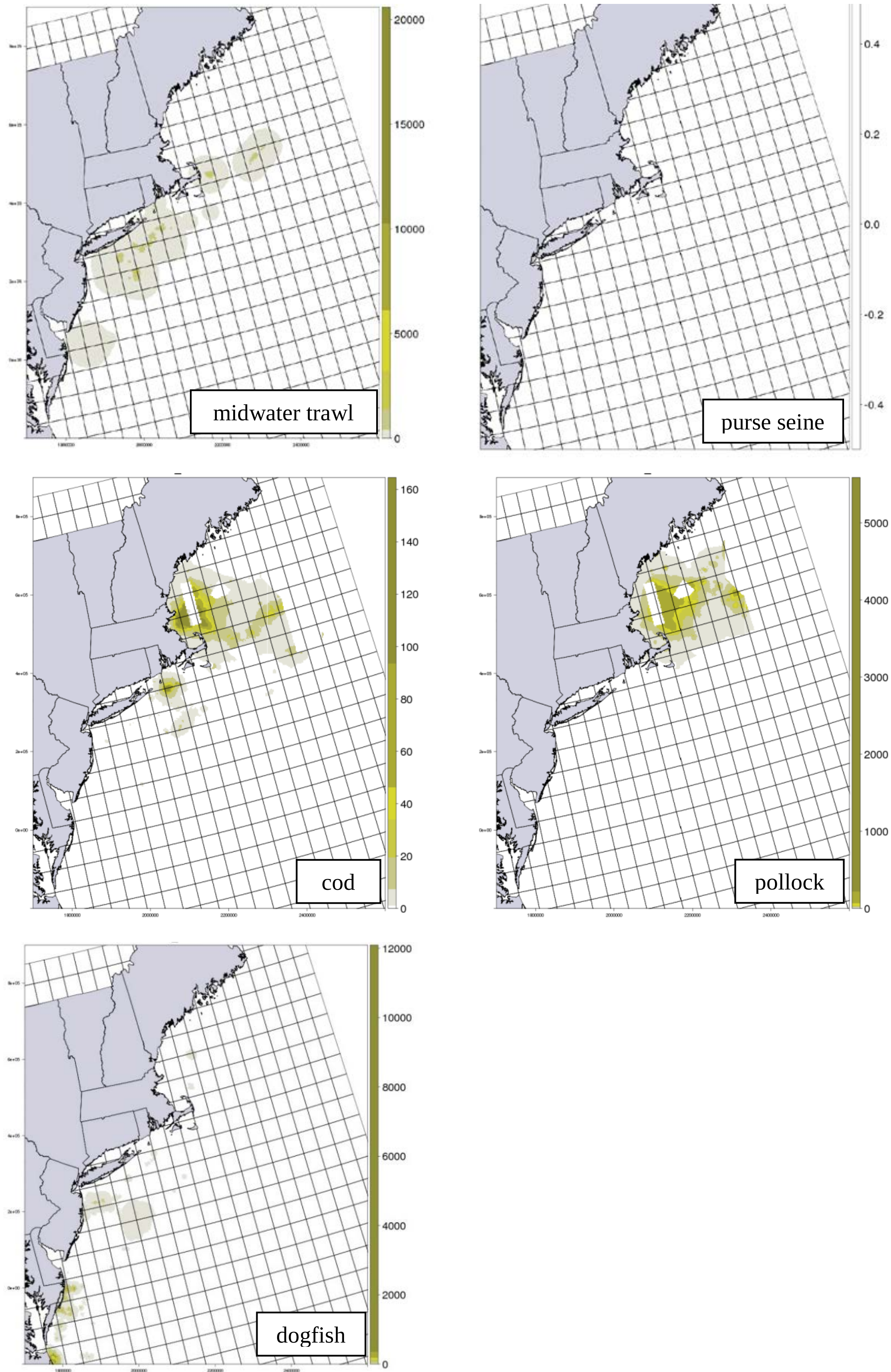
Map 1 - January landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



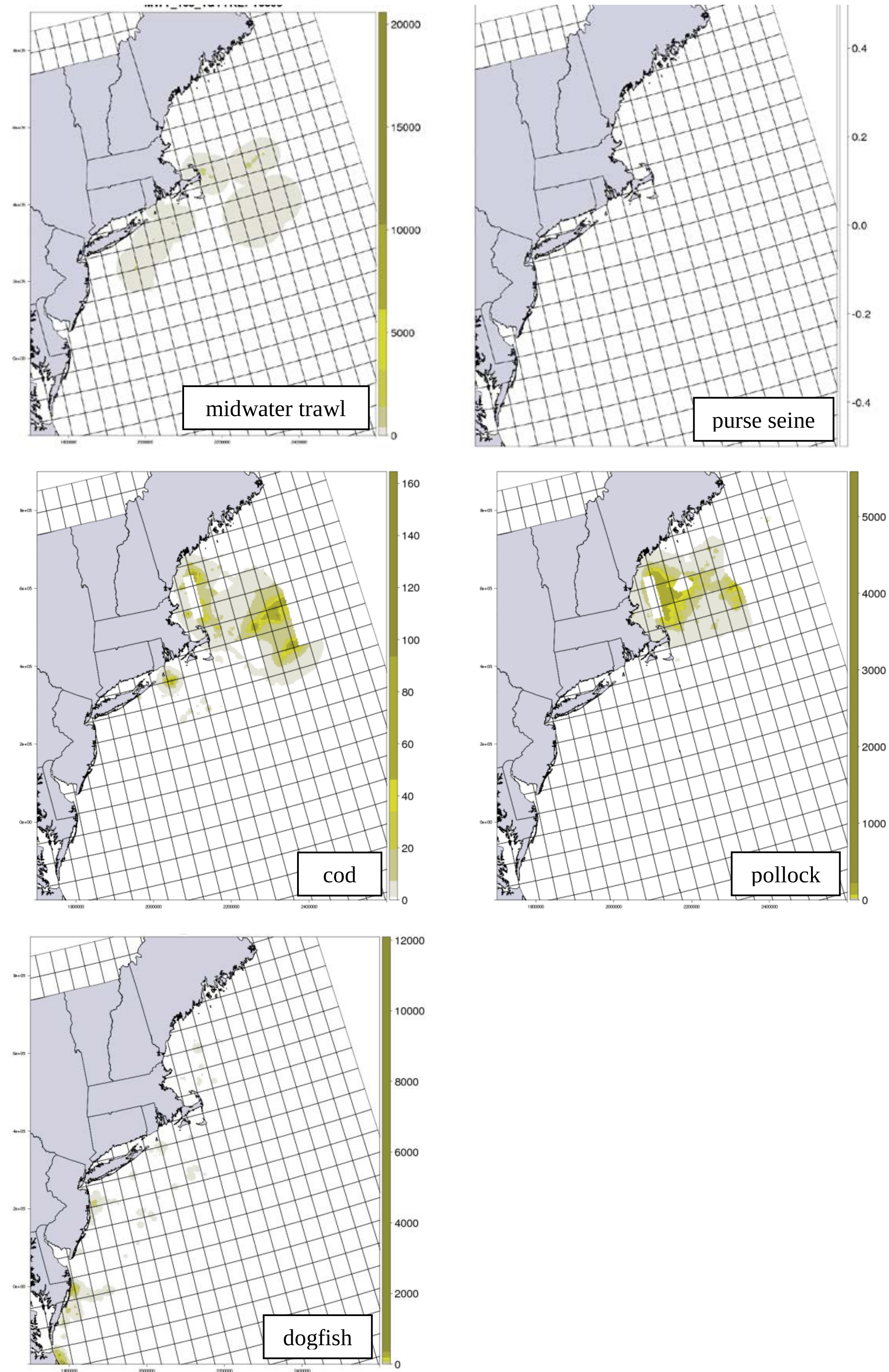
Map 2 - February landings 2010-2014 (pounds landed per quarter km²). For reference, the 30 minute squares are shown.



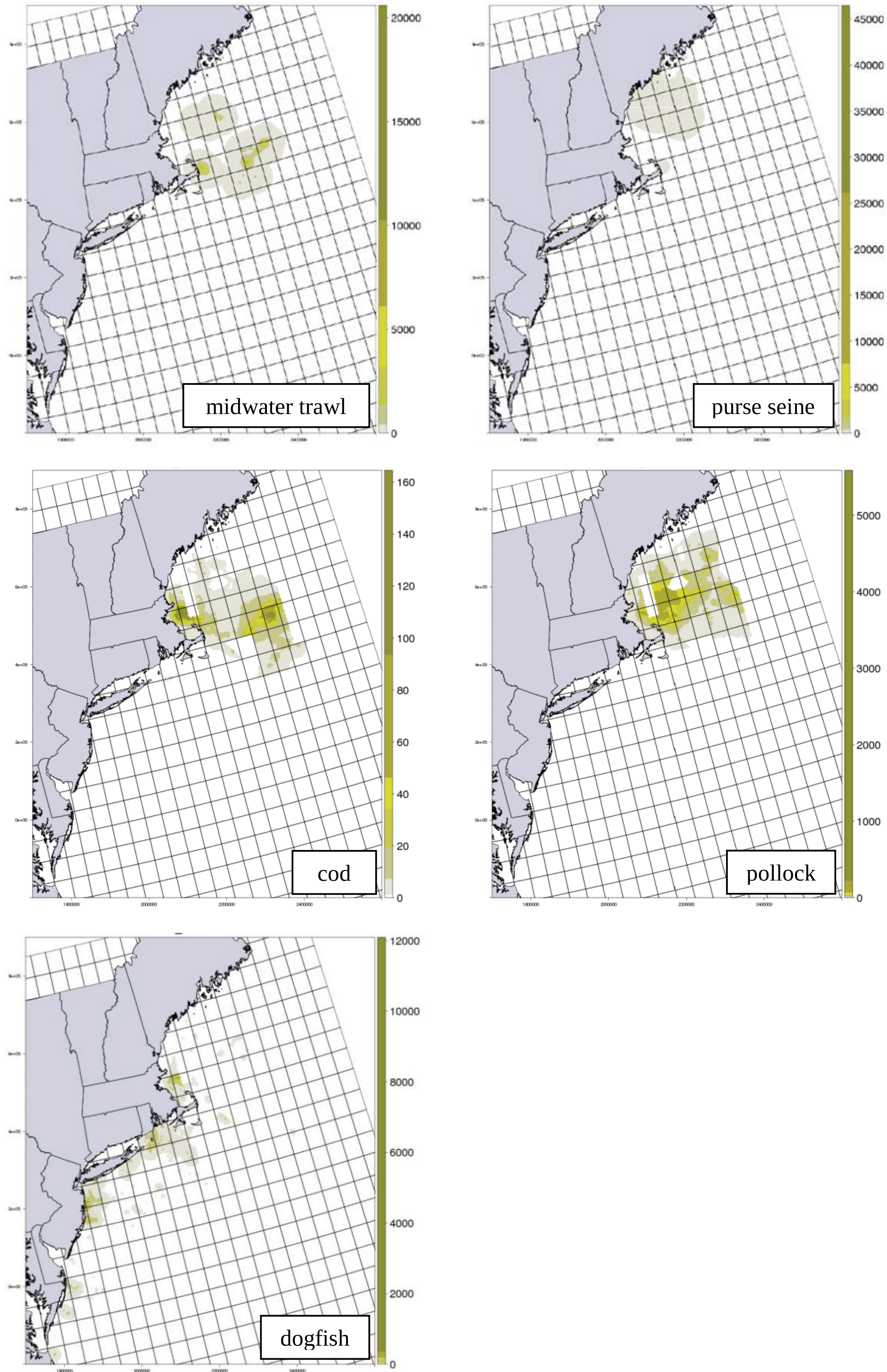
Map 3 - March landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



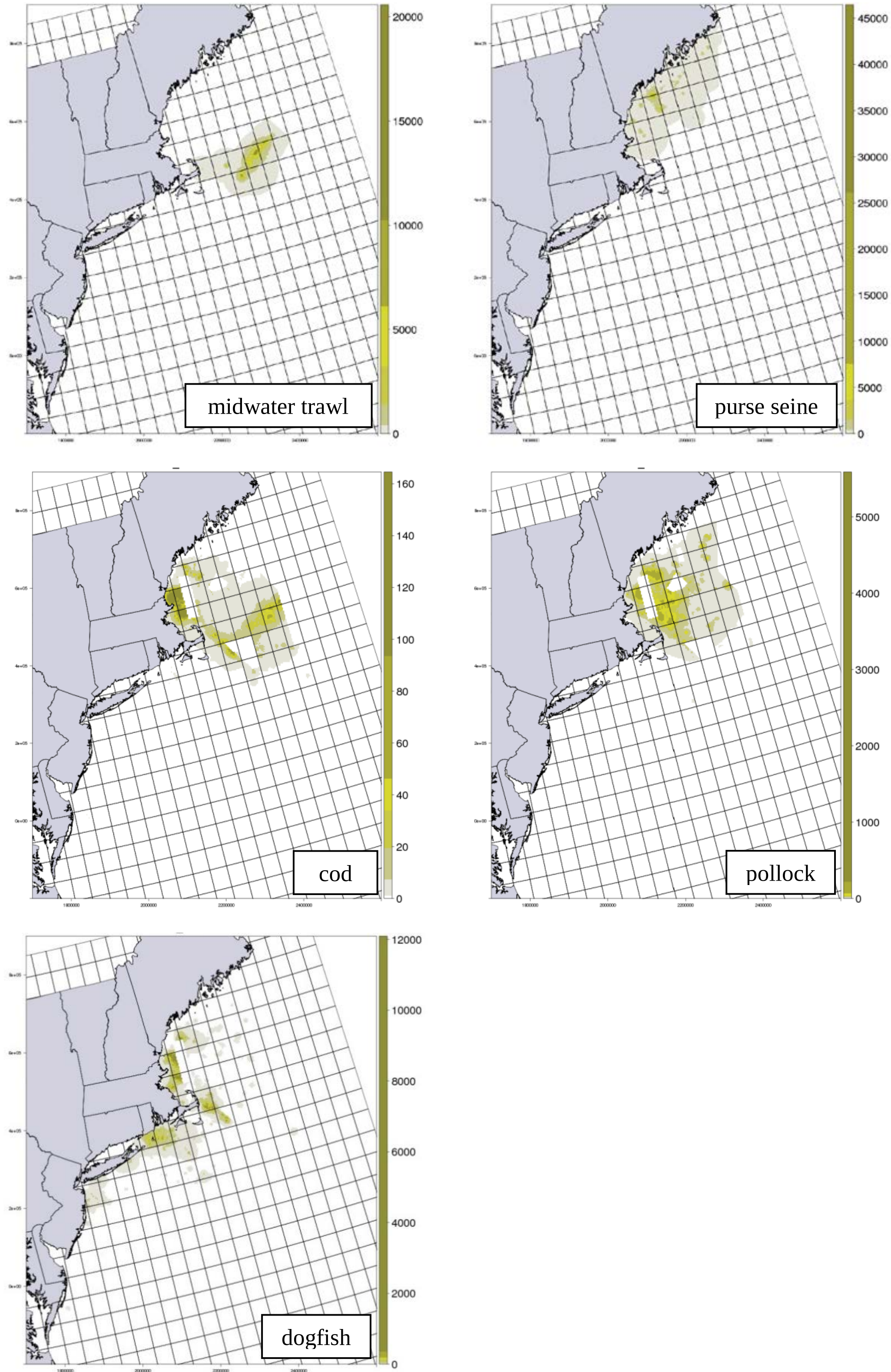
Map 4 - April landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



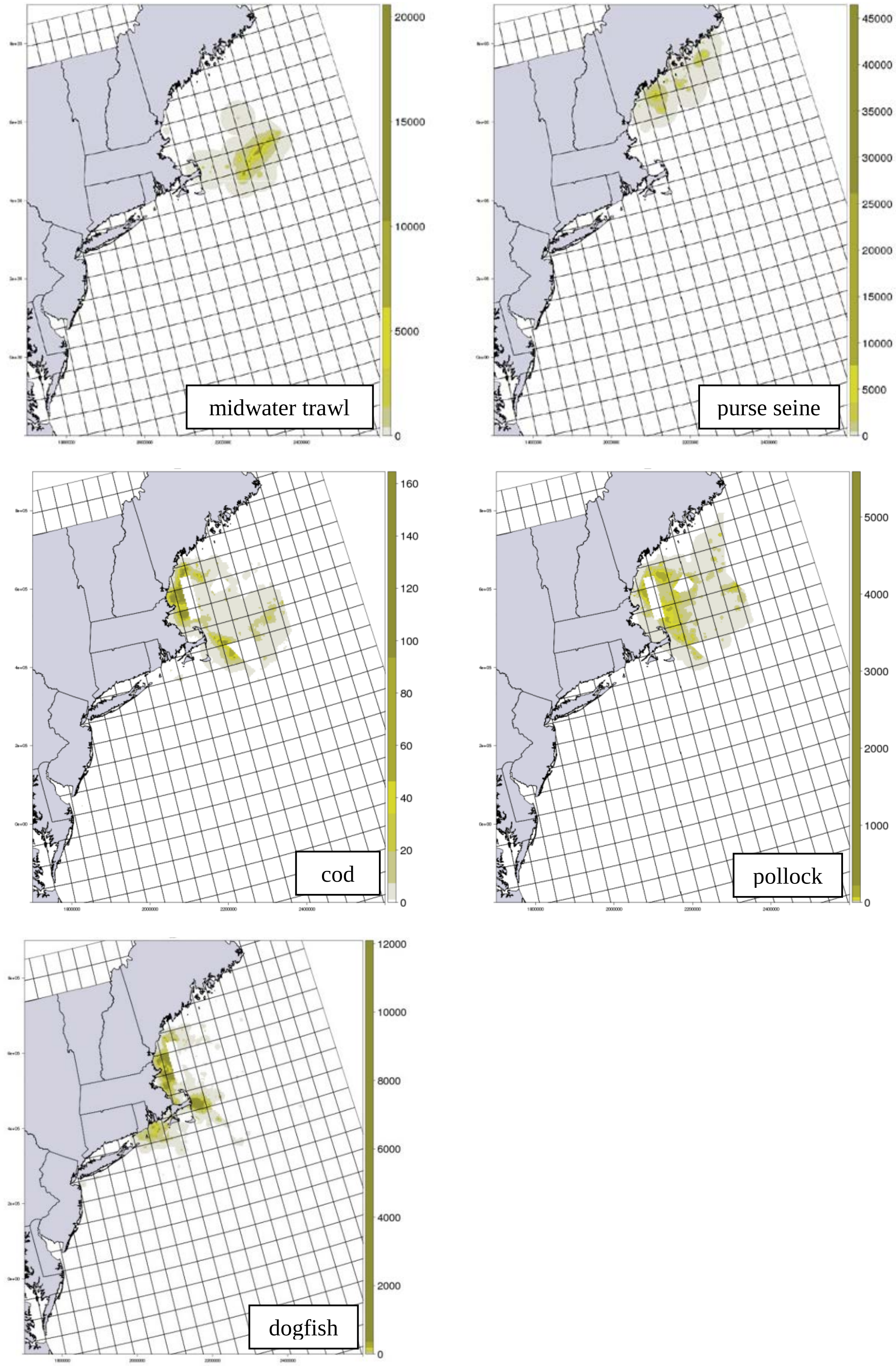
Map 5 - May landings 2010-2014 (pounds landed per quarter km²). For reference, the 30 minute squares are shown.



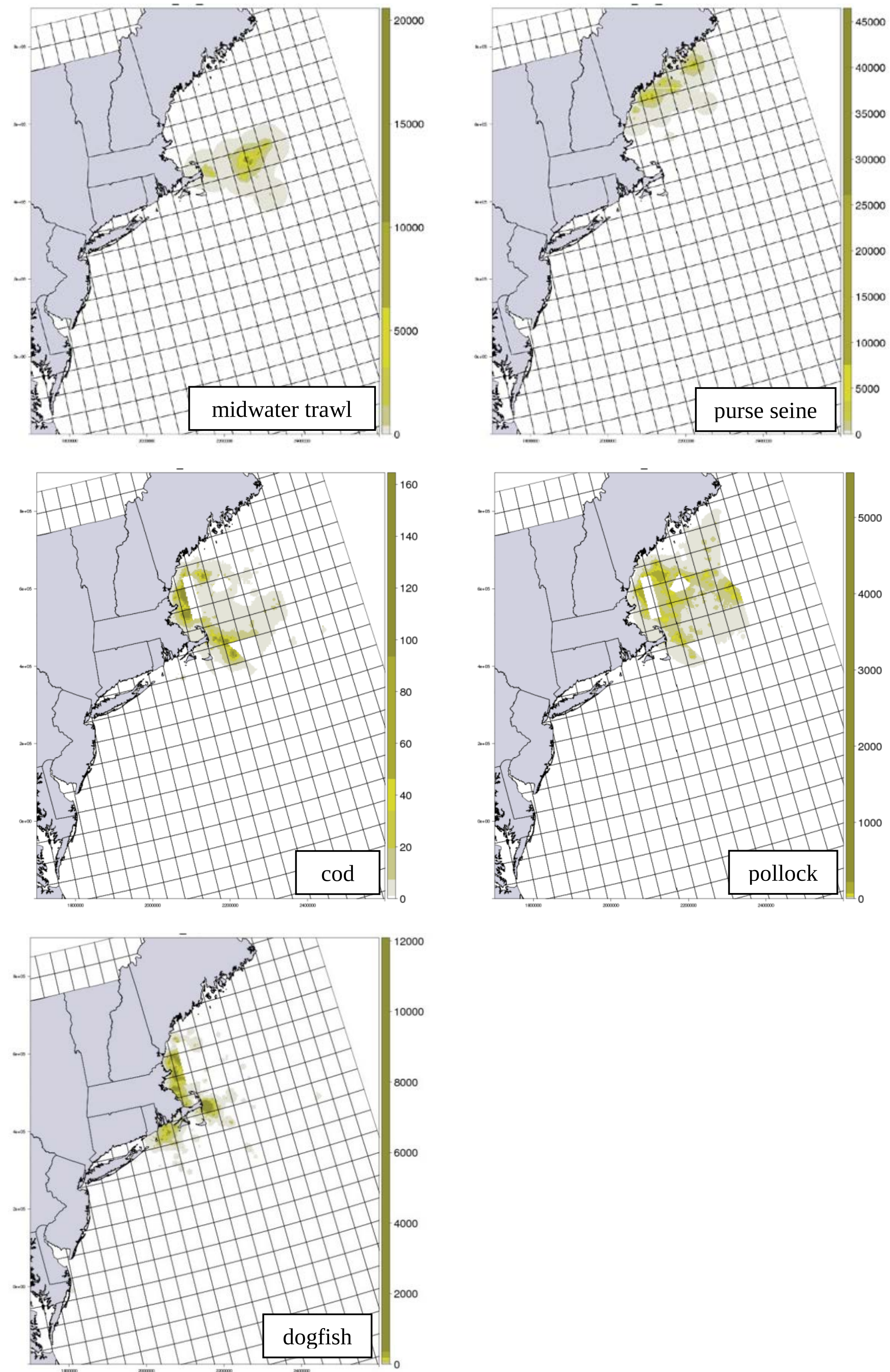
Map 6 - June landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



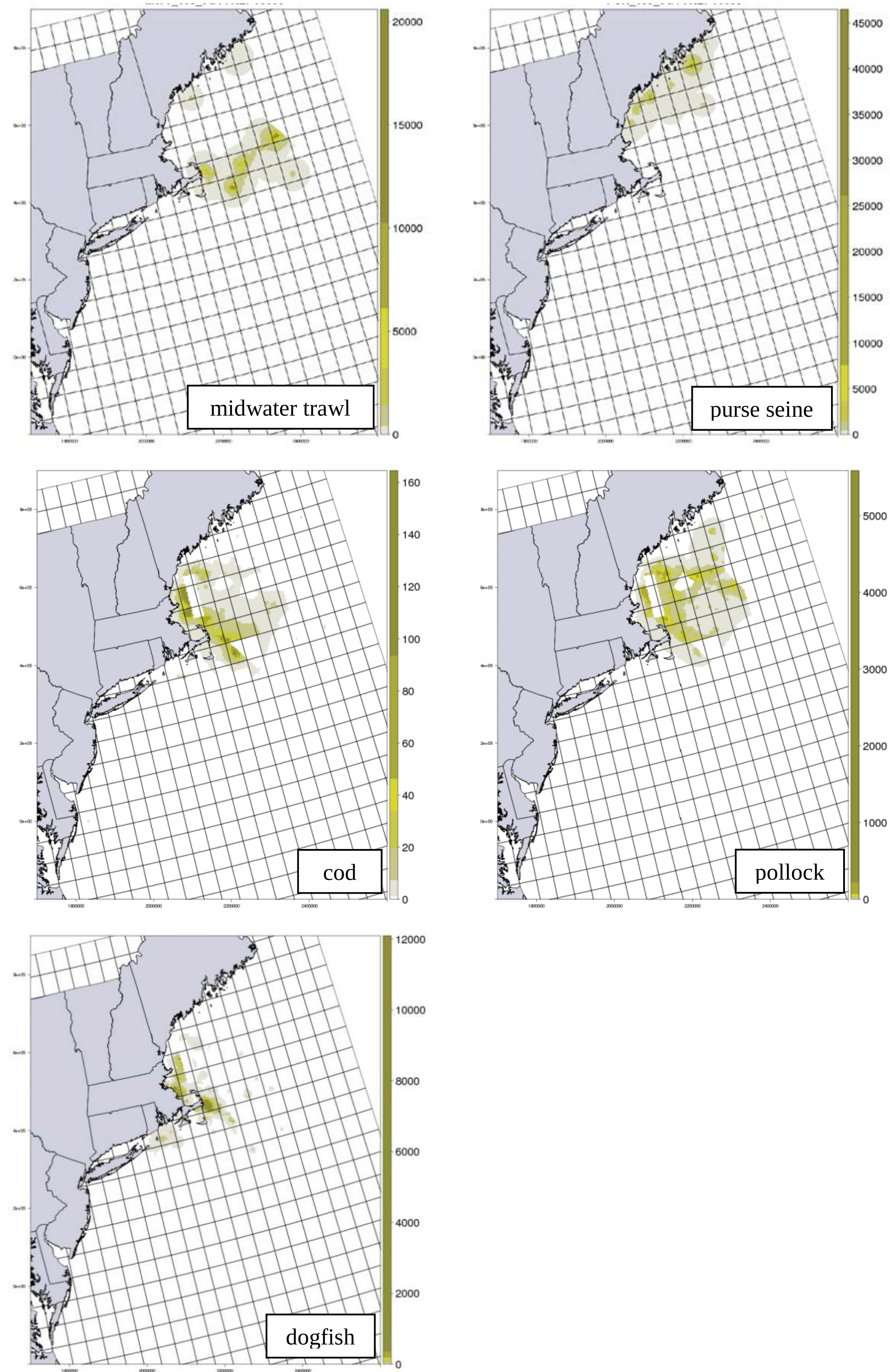
Map 7 - July landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



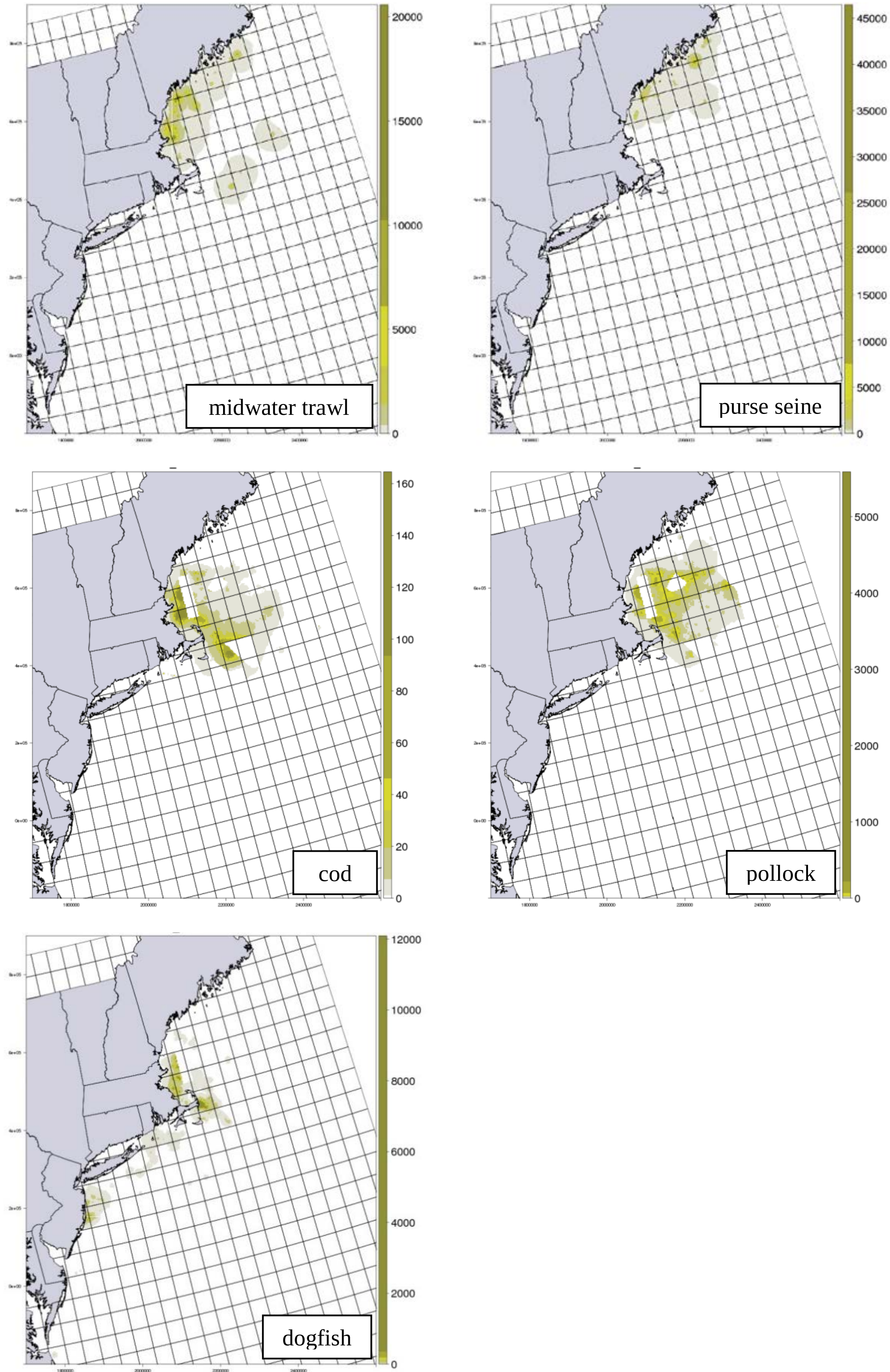
Map 8 - August landings 2010-2014 (pounds landed per quarter km²). For reference, the 30 minute squares are shown.



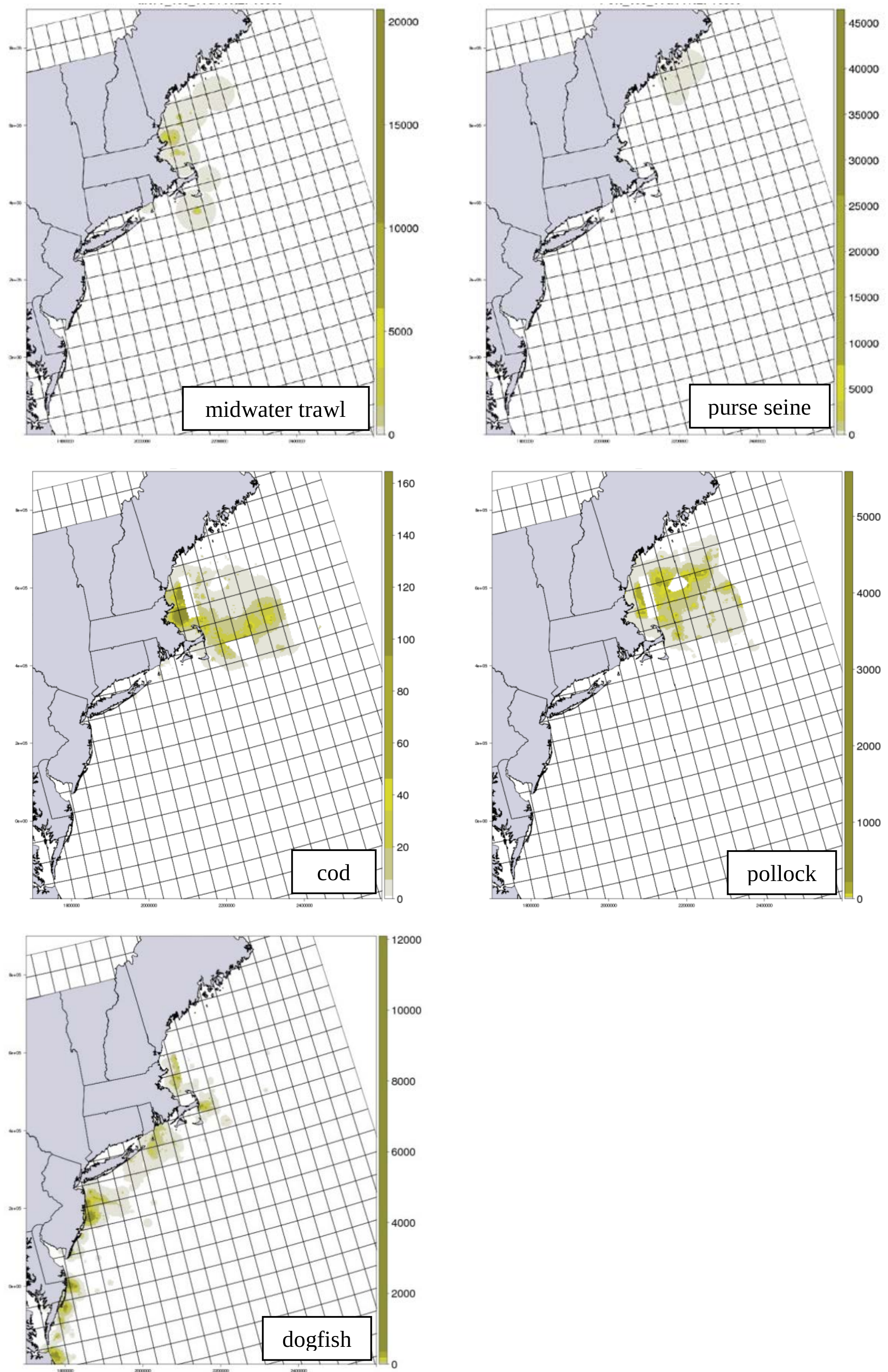
Map 9 - September landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



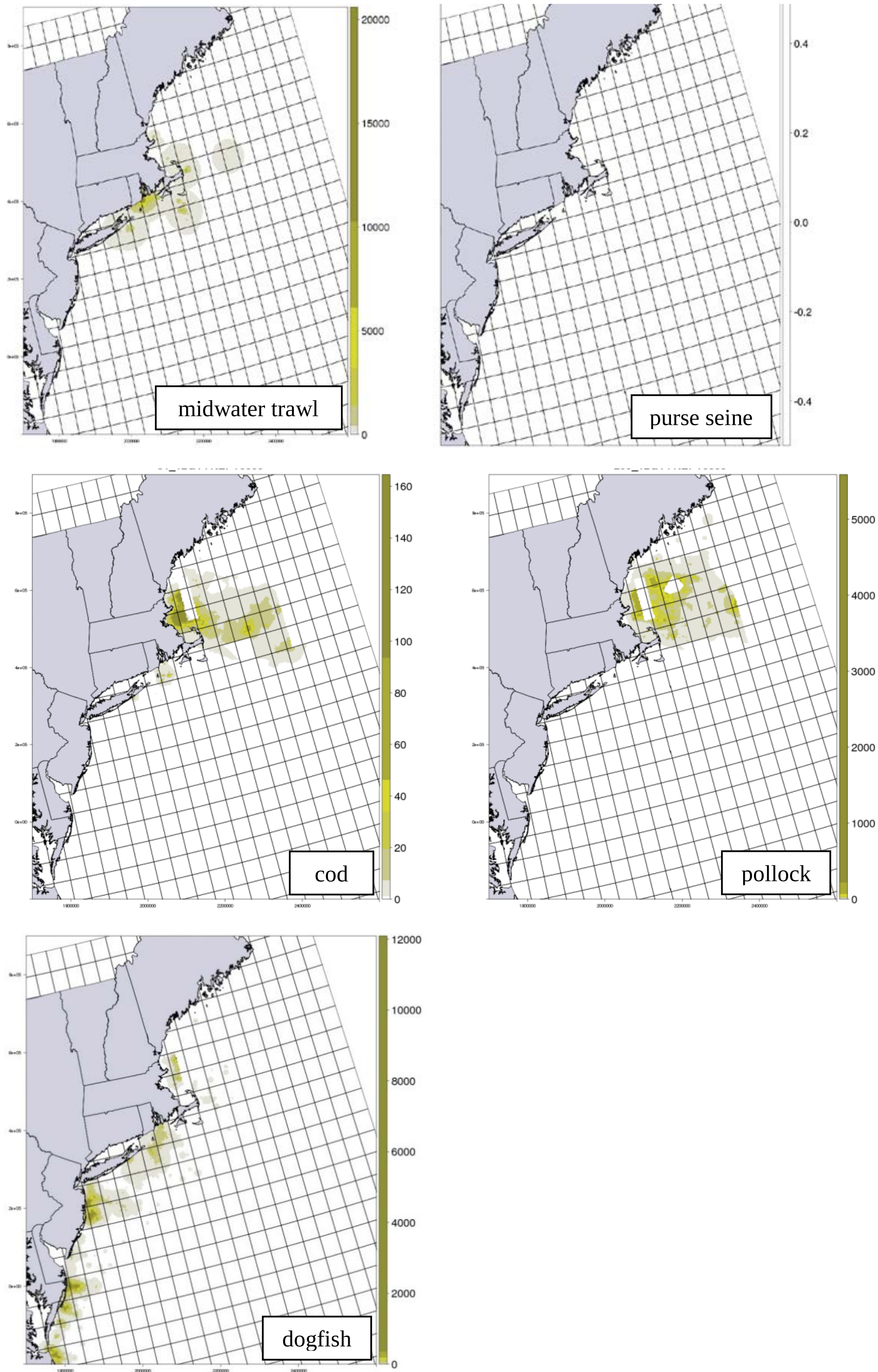
Map 10 - October landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



Map 11 - November landings 2010-2014 (pounds landed per quarter km²). For reference, the 30 minute squares are shown.



Map 12 - December landings 2010-2014 (pounds landed per quarter km^2). For reference, the 30 minute squares are shown.



Area 1A

The Atlantic herring fishery has undergone multiple changes to its management structure in Area 1A and elsewhere since 2007. Chiefly, midwater trawls were excluded from Area 1A in June-September, starting in 2007. Additionally quota reduction in Area 1A and elsewhere have also impacted the fishery. To identify how catch and effort distributions have changed, a series of plots and graphs were produced. The goal was to examine catch and effort by area and season both before and after the series of management changes. The VTR (Vessel Trip Report) System was queried for catch and effort by gear type, location, and date. Data were only queried for catch >6,600 lbs to represent the directed fishery. From this data set, a series of graphs and maps were produced to examine changes in catch and effort across the fishery.

Examination of catch by area (Figure 2) suggests a marked change in removals by area. Post 2007 catches in the offshore areas (Areas 2 & 3) increased while catches inshore decreased. This is likely due to a number of factors, including the reduction in Area 1A quota from ~60,000 mt in 2005 to ~27,000 by 2010. Catches over all have decreased and then increased, due in part to changes in Optimum Yield and overall quotas fishery-wide.

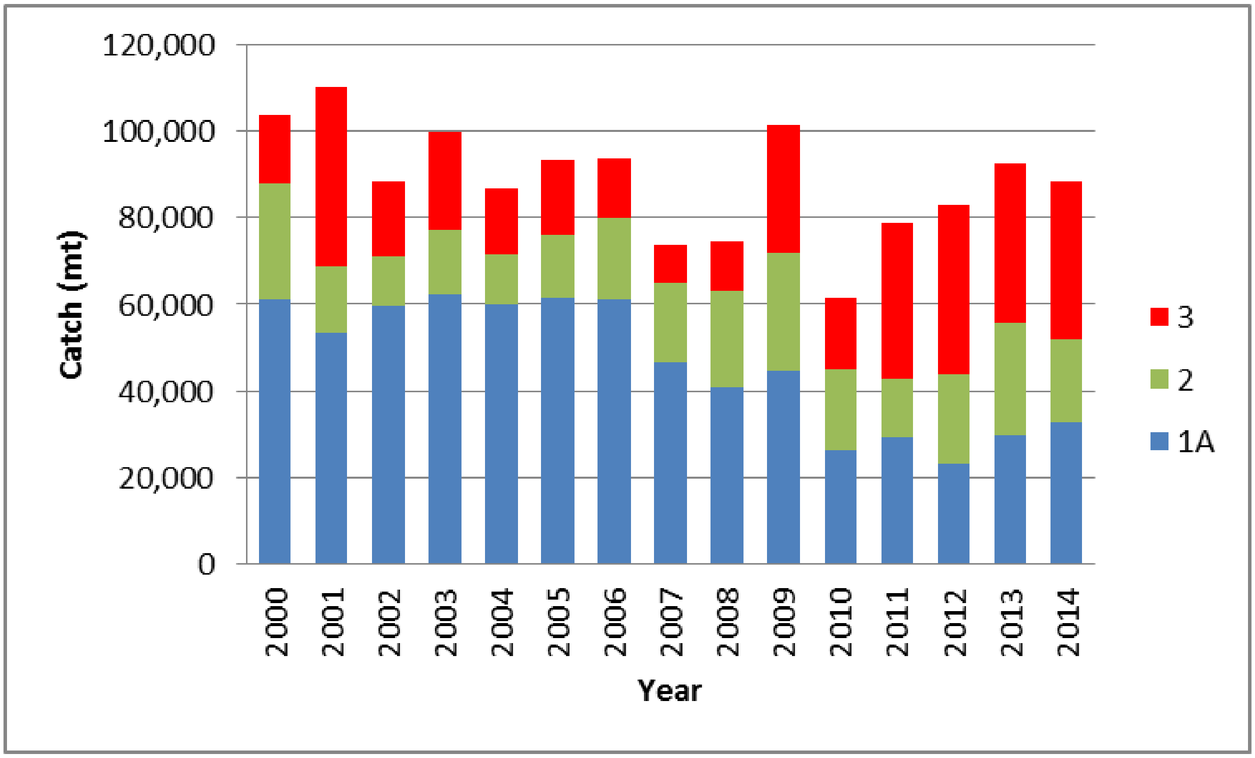
Overall catch fishery wide has declined since 2000, while price has increased from $0.05 to over $0.15 per pound, a three-fold increase (Figure 3). This increase is thought to be largely due to the reductions in overall catch, the shift to more off-shore harvest and consolidation of the fleet given management action to control access.

Within Area 1A, catch and number of active permits has declined, due in part to reductions in quota, limited access, and exclusion of MWTs June through September (Figure 4). Despite those reductions, catch by purse seine gear per trip has increased since 2010 (Figure 5), but is variable over the time series since 2000. This suggests that, while the number of trips by purse seiners has remained fairly stable, purse seine catch has increased overall since 2010 (Figure 6, Figure 7). However, it should be noted that catch per trip by purse seine gear in Area 1A is less than what it was prior to the seasonal removal of the mid-water fleet (Figure 5). Care should be taken to not draw conclusions on stock status from catch-per unit effort data.

In Area 1A June to September, the overall number of active permits has declined, in part due to management changes listed above. However, total removal by permits has increased (Figure 8). Given the aforementioned change in price per pound, this translates into a larger ex-vessel revenue per permit since 2010: from $100,000 per permit to over $800,000 per permit in June through September (Figure 9).

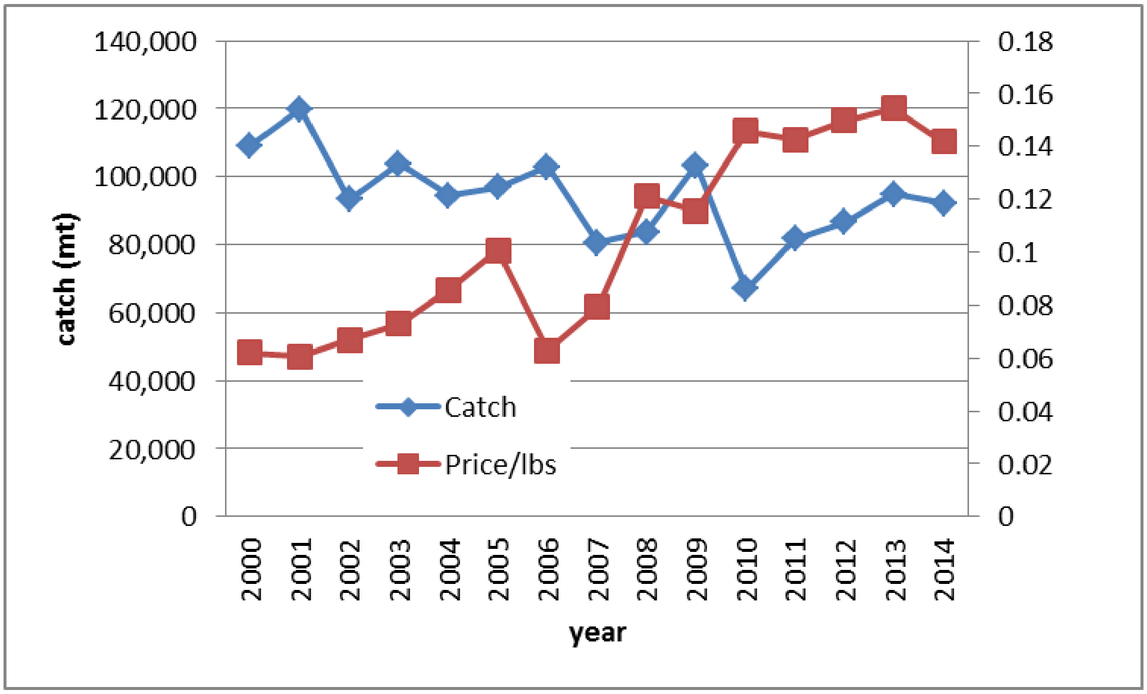
An examination of map prior to and after 2007 shows some interesting changes for the purse seine fleet. Overall, catch locations have remained the same, but there seems to be an indication of a move south and west along the Maine coast in terms of intensity (Figure 10 to Figure 12). This change appears consistent June through September.

Figure 2 – Atlantic herring catch by all gear types by herring management area by year



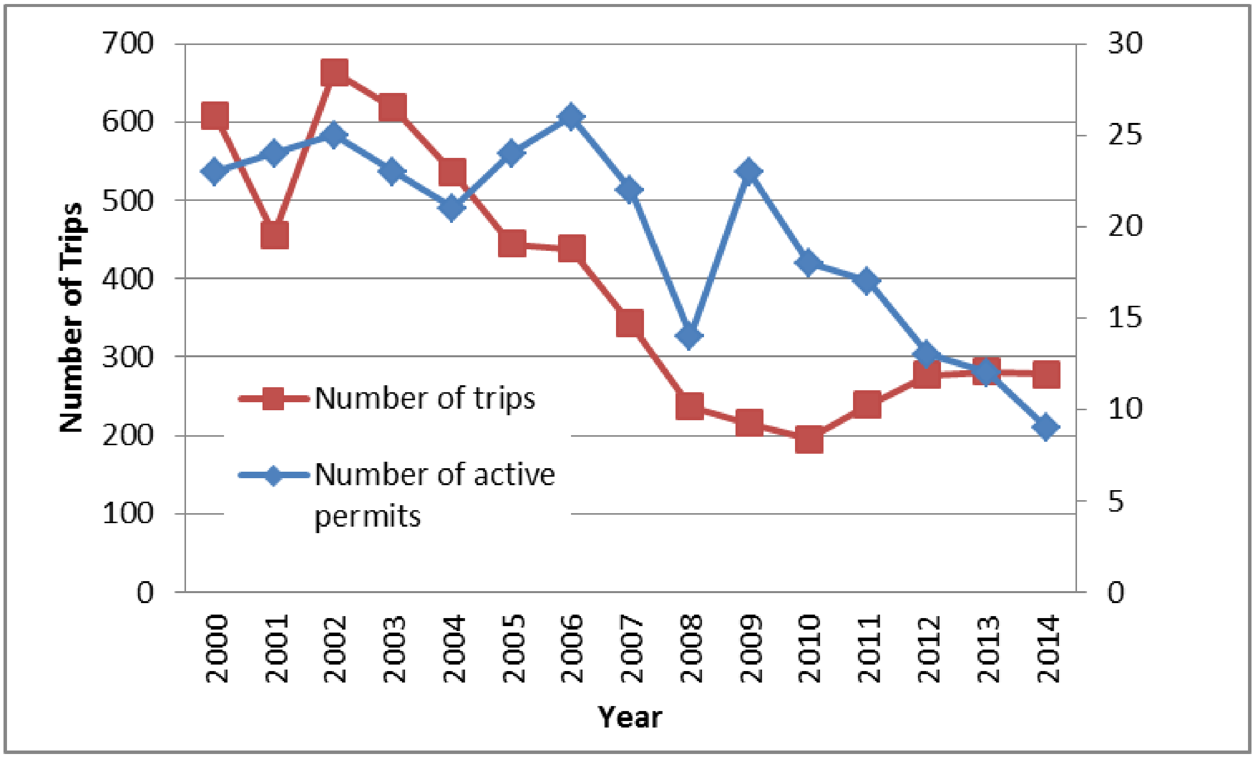
Note: Only catches >6,600 lbs are included. Area 1B excluded.

Figure 3 – Atlantic herring catch and price per lbs, all gears all areas



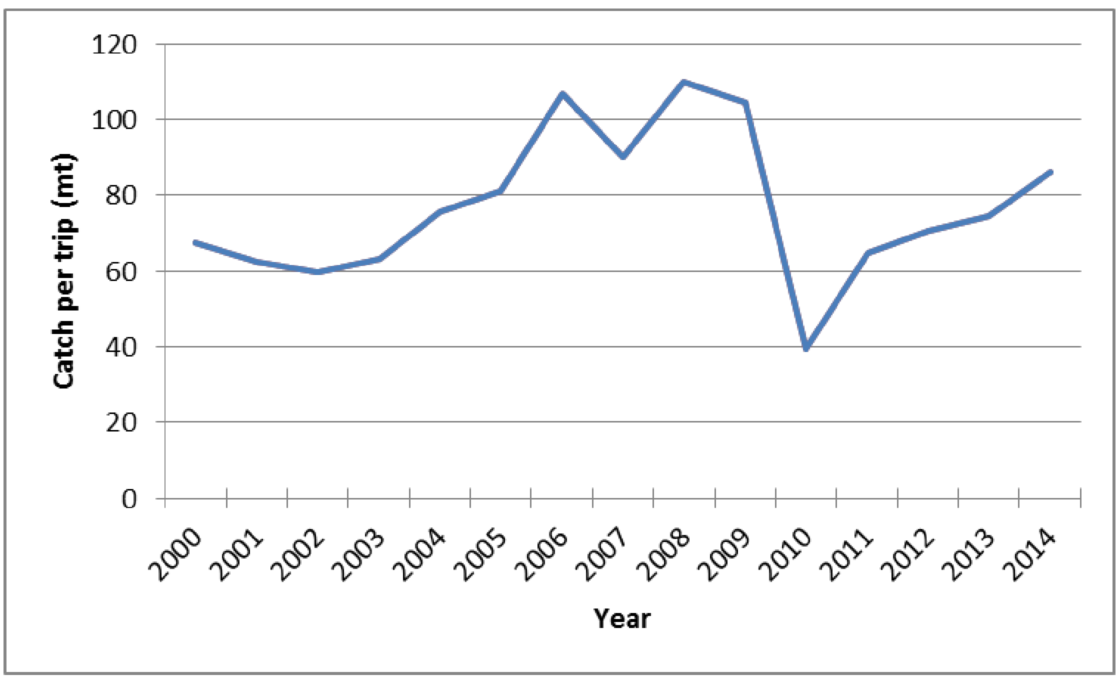
Note: Only catches >6,600 lbs are included.

Figure 4 – Atlantic herring catch and number of active permits in Area 1A by year, June-September



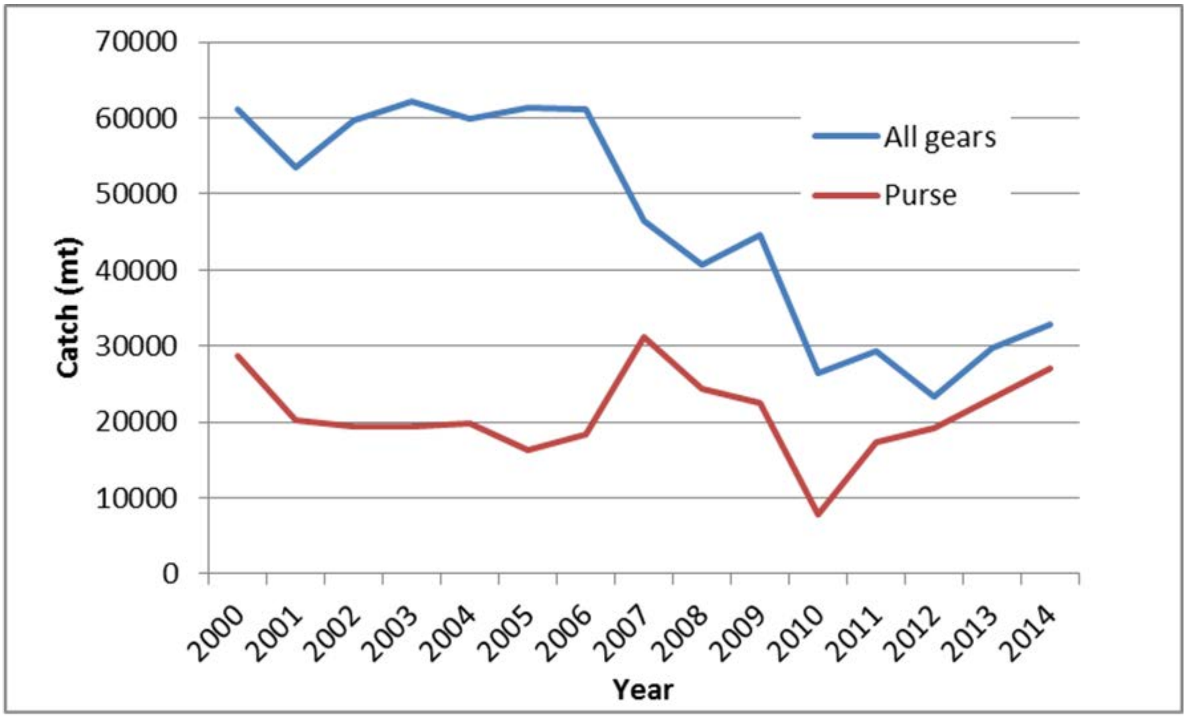
Note: Only catches >6,600 lbs are included.

Figure 5 - Average Atlantic herring catch per trip for purse seine vessels in Area 1A, June through September



Note: Only catches >6,600 lbs are included.

Figure 6 - Annual Atlantic herring catch in Area 1A for purse seines and all gears



Note: Only catches >6,600 lbs are included.

Figure 7 - Annual number of trips in Area 1A for purse seines and all gears

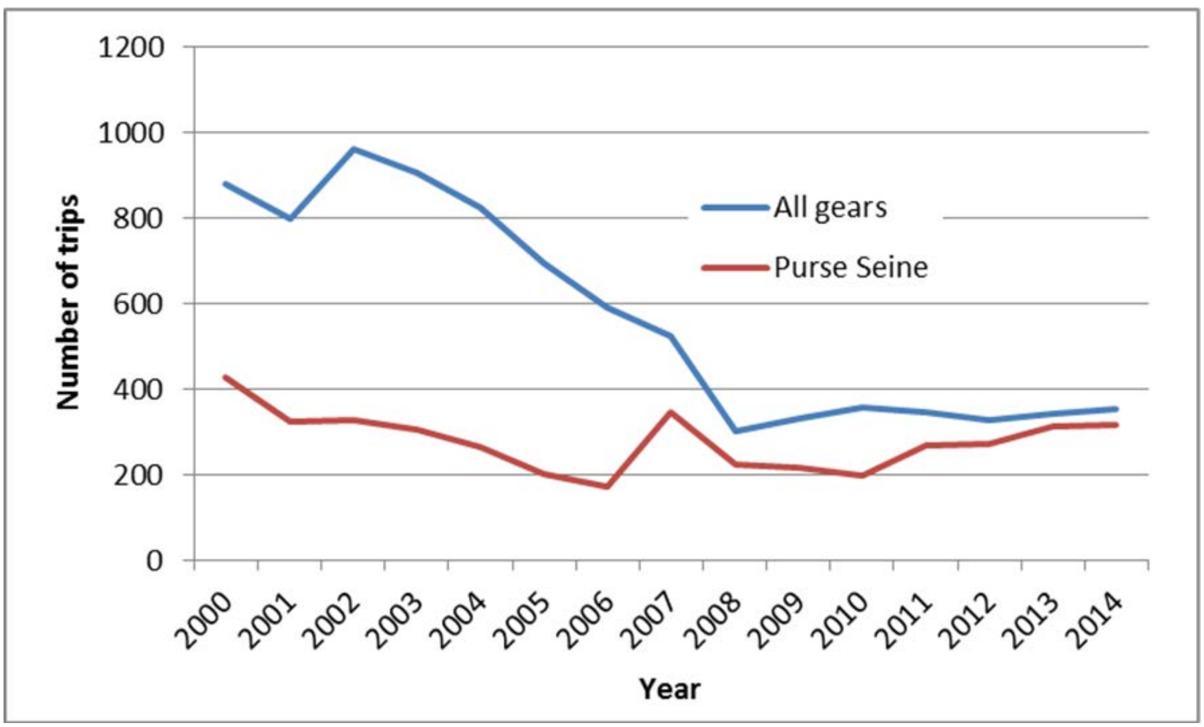


Figure 8 – Atlantic herring catch and number of active permits in Area 1A, June through September by year

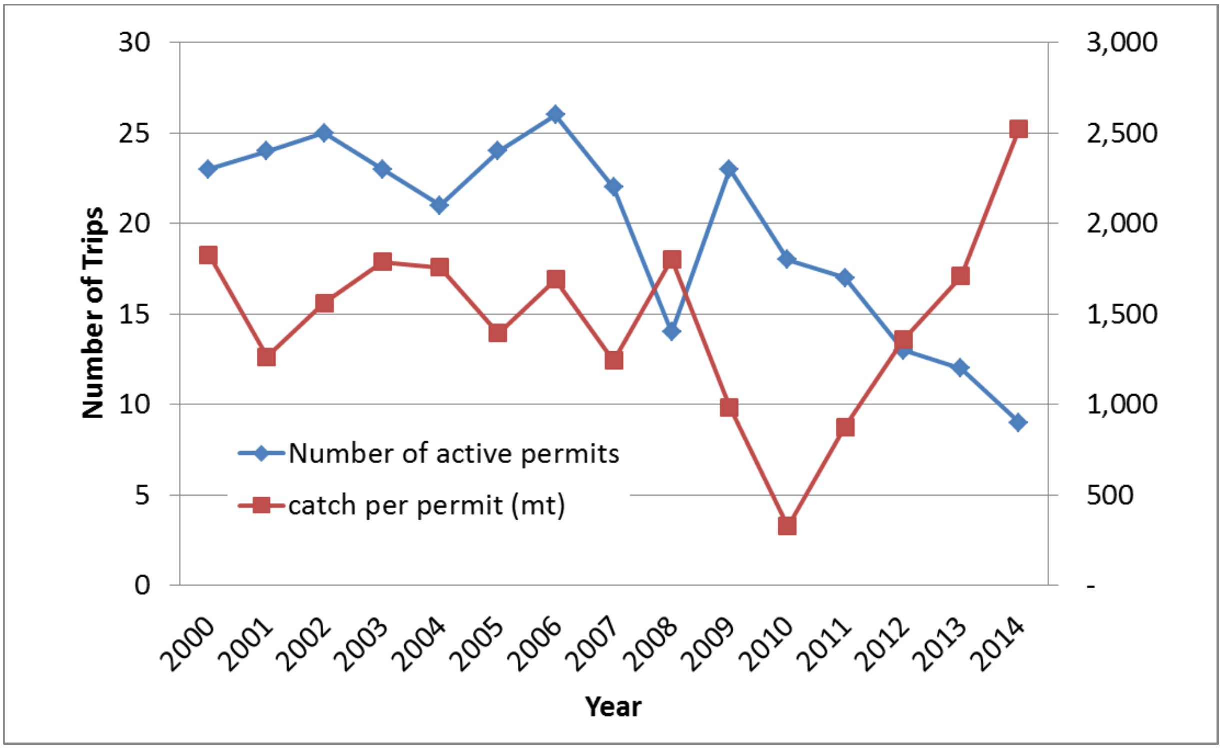


Figure 9 - Number of active permits and average total revenue (average catch times average price/lbs summed) in Area 1A, June through September by year

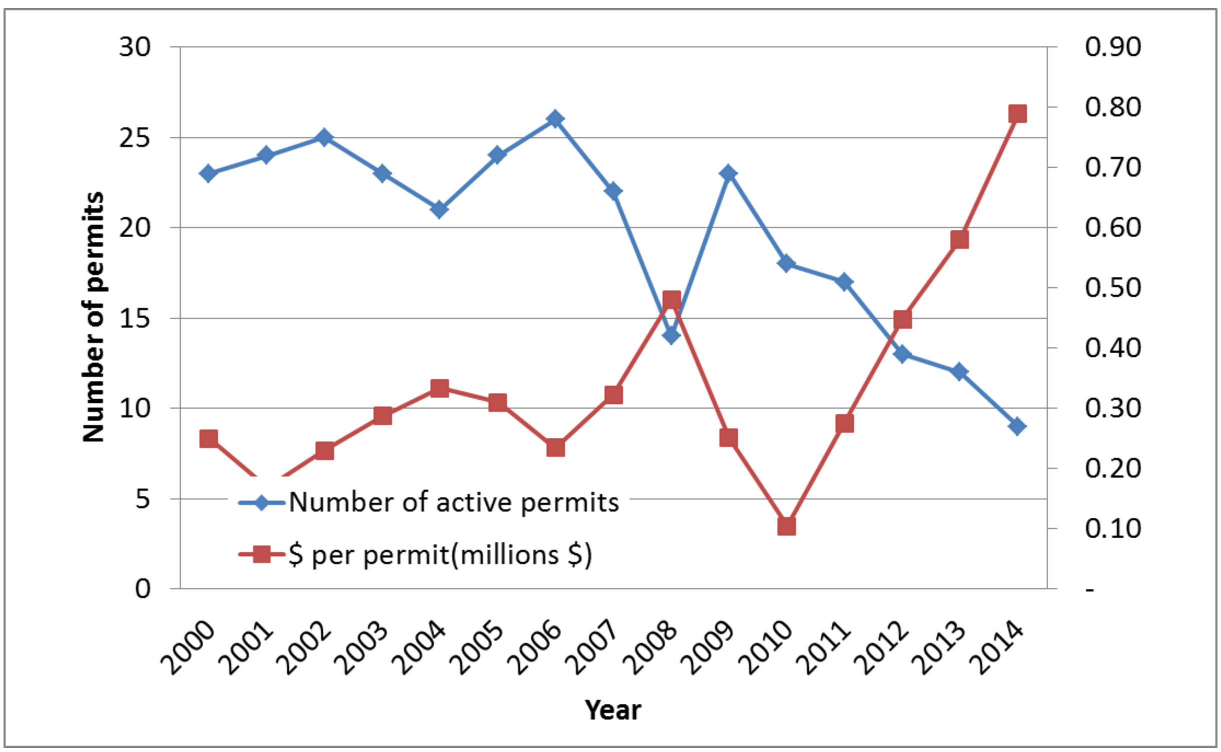


Figure 10 - Area 1A kernel density plots of herring seiner landings (>6,000lbs/trip) locations for May-June, 2000-2007 and 2008-2014

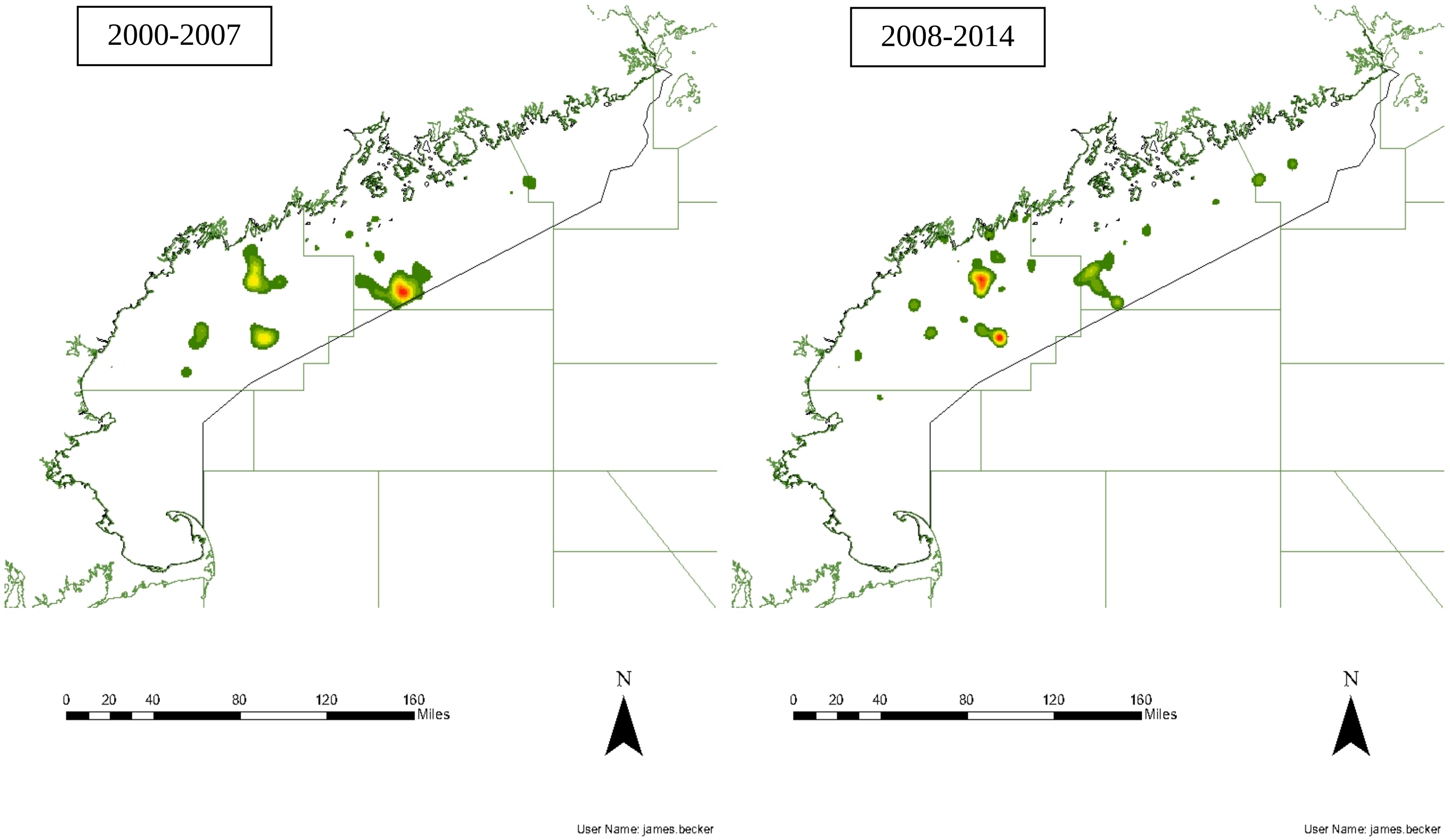
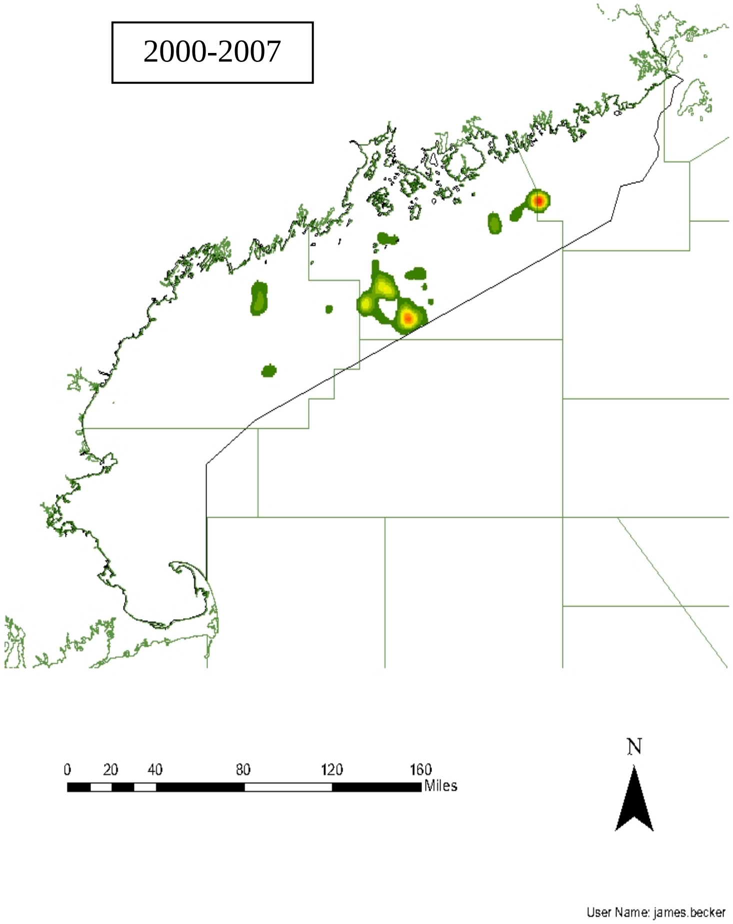


Figure 11 - Area 1A kernel density plots of herring seiner landings (>6,000lbs/trip) locations for June-July, 2000-2007 and 2008-2014



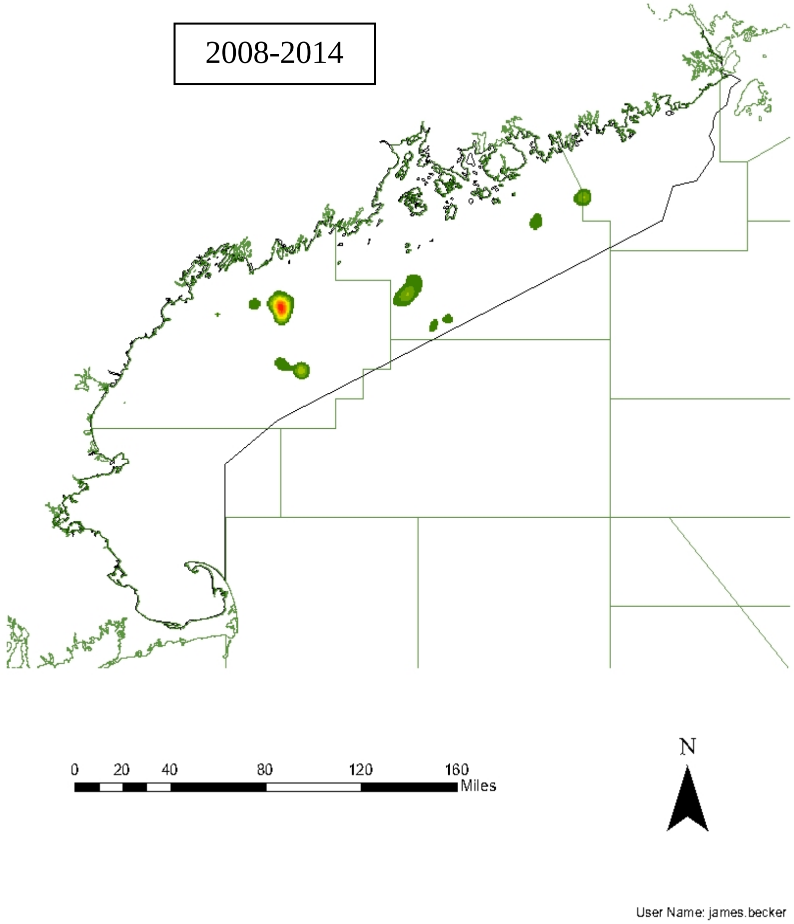
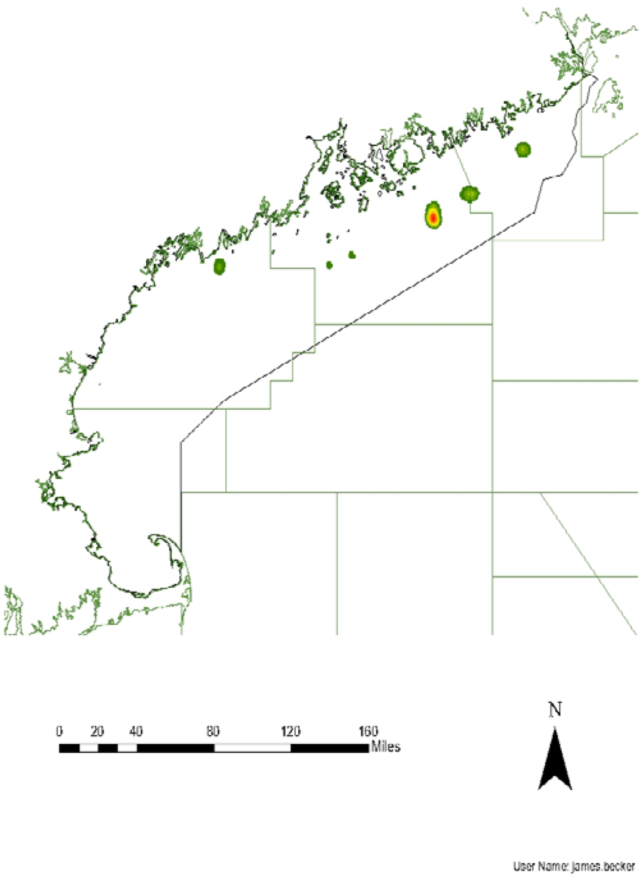
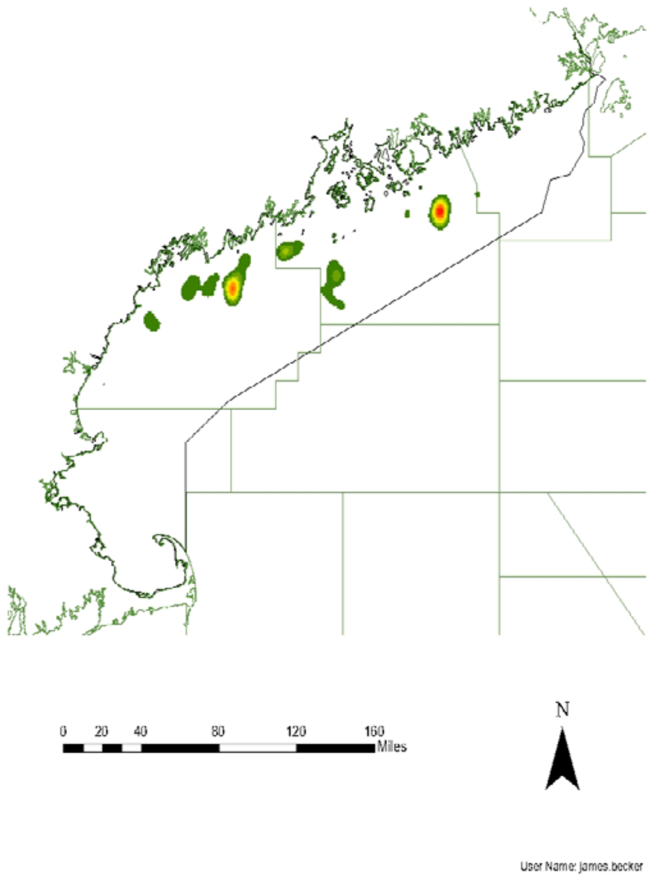


Figure 12 - Area 1A kernel density plots of herring seiner landings (>6,000lbs/trip) locations for August to September, 2000-2007 and 2008-2014





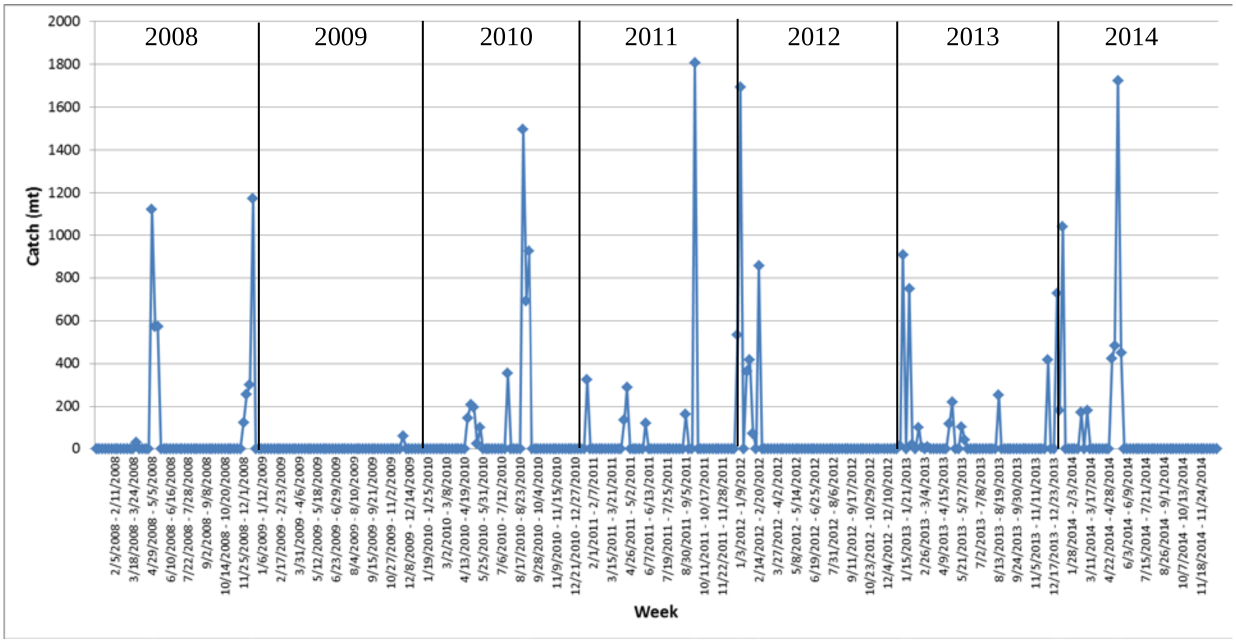
Back side of the Cape

Atlantic herring catch data from the area directly seaward of Cape Cod (Figure 13) was examined to observe the spatial-temporal distribution of effort within about 12 nautical miles of Cape Cod, to provide background to the Council for Amendment 8. For this area, Atlantic herring catches generally occur early in spring or very late in the fall to early winter. Overall, catches are episodic (Figure 11), and rarely occur more than two weeks in a row. Given that most of the catches occur during the spring and fall herring migration, it is likely that the fishery exploits herring while they are in the vicinity, but that schools of herring move too quickly through the area for sustained catches to occur; unlike the summer-time catch in the Gulf of Maine when the herring are more resident.

Figure 13 - Map showing area of inquiry (red line) to the east of Cape Cod, Massachusetts

Source: Google earth (2016).

Figure 14 – Atlantic herring catch by week for vessels catching >6,600 lbs of Atlantic herring from the area within 12 nautical miles of Cape Cod, 2008-2014



Striped bass

Information about the striped bass fishery is limited. For the recreational fishery, which occurs within the state waters of Maine, New Hampshire, and Massachusetts, the only data are collected through the Marine Recreational Information Program (MRIP). However, MRIP includes no spatial data for catch. There is no commercial fishery for striped bass in Maine, New Hampshire, Rhode Island, and Connecticut. The Massachusetts commercial fishery occurs within state waters in the summer.

The Massachusetts Division of Marine Fisheries manages the fishery using 14 statistical areas within state waters. Figure 15 and Figure 16 map the landings and CPUE (pounds per fishing hours) within each area from 2010 to 2014. Area 9, to the east of Cape Cod, has had relatively high landings throughout the time series, and areas to the east and south of Cape Cod have had relatively high CPUE. Figure 17 tracks the landings and CPUE over time each year, showing that most of the landings have occurred between mid-July and mid-August. Decreased CPUE over the length of the season could be an indicator of decreased striped bass availability, but the landings data do not show consistent increases or decreases in CPUE across seasons.

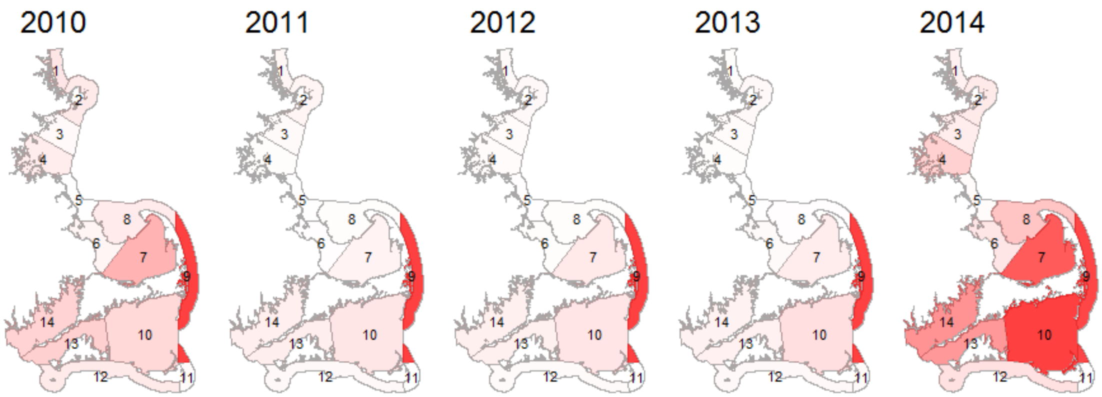
Striped bass are typically present in Massachusetts waters between May and October, yet the commercial fishery (the only source of spatial fishery-dependent data) occurs over a much narrower timeframe (Kneebone et al. 2014b). Prior to 2014, the commercial striped bass fishery began each year on July 11 and closed when the quota was exhausted, which was typically in 5-7 weeks. In 2013, the fishery closed after 5 weeks, and then reopened for an additional two weeks in late August, after it became evident that there was quota remaining. In 2014, regulations changed the fishery start date to June 23rd, and a reduced trip limit led to a more protracted season (11 weeks).

Neither recreational nor commercial striped bass fishing is allowed outside of state waters, per federal law. However, striped bass are abundant in federal waters and frequently cross this state/federal jurisdictional boundary (Kneebone et al. 2014a). Coastwide, the recreational fishery accounts for 60-70% of total removals in recent years. In Massachusetts, the recreational/commercial ratio is approximately 85%/15%.

As part of an effort to estimate the predation mortality of striped bass on Atlantic menhaden, all available data sources for diet composition of striped bass were assembled and summarized (SEDAR 2015). A total of 28 data sources were identified that included over 40,000 individual stomachs examined. On a coastwide and annual basis, herring species comprise <10% of striped bass diets. At specific times and regions (e.g., Gulf of Maine in summer/fall), Atlantic herring may comprise up to 30% of the diet.

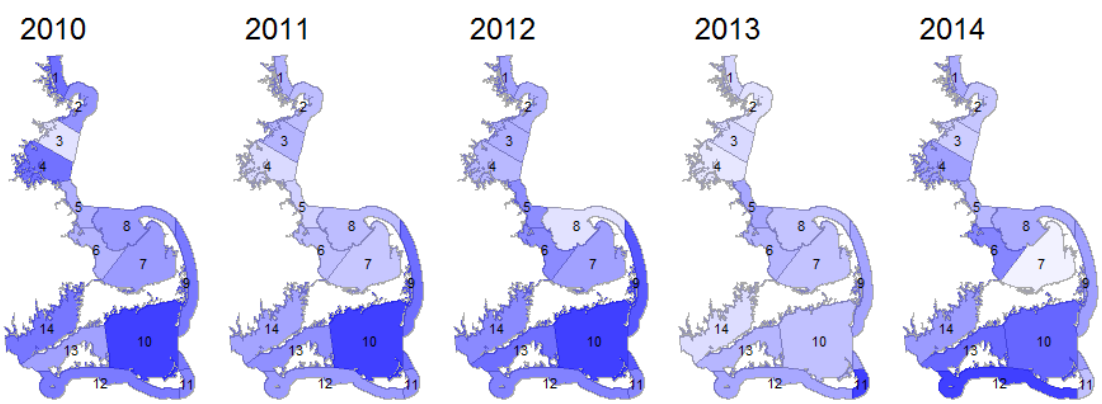
While there are no specific rules that explicitly prevent herring MWTs in Massachusetts state waters, there are regulations that effectively prohibit this activity: 1) There is no exemption from the 6" minimum mesh size for herring fishing (as there is for the whiting and squid fisheries); and 2) A "coastal access permit" is required to fish with mobile gear in MA state waters, which has a maximum vessel length of 72 feet. There are very few coastal access permits (CAP), and there has been a moratorium on issuing new CAP permits since 1995.

Figure 15 - Spatial pattern in landings (pounds) for Massachusetts striped bass commercial fishery, 2010-2014



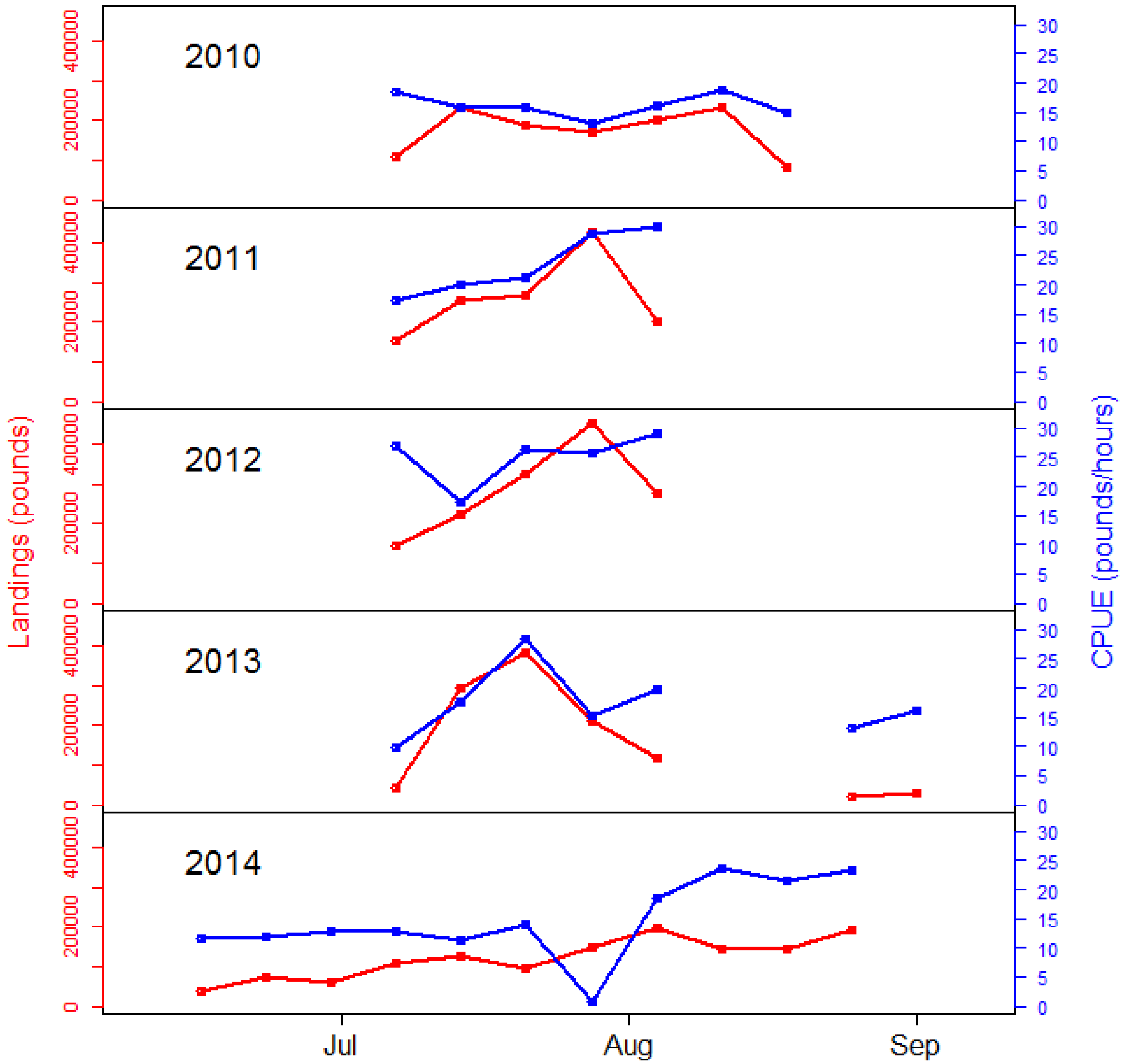
Source: MADMF (2016).

Figure 16 - Spatial pattern in CPUE (pounds / fishing-hours) for Massachusetts striped bass commercial fishery, 2010-2014



Source: MADMF (2016).

Figure 17 - Seasonal profile of Massachusetts commercial striped bass fishery, 2010-2014



Source: MADMF (2016).

Bluefin Tuna

Unless specifically stated in an exempted fishing permit, commercial bluefin tuna fisheries in the Gulf of Maine begin June 1st. There are three main gear types in the Gulf of Maine: general (rod and reel), harpoon, and purse seine. Bluefin tuna fishermen work off an annual TAC which is divided up amongst the categories. The general category receives the largest allocation and has within season allocations (e.g., X% of quota can be caught between June 1 and August 31). If the catch limit is reached before August 31, the fishery will close and reopen again in September. September has its own quota as does October, and then there is a winter allocation. The fishery has not closed due to reaching any of these within season quotas since the 1990s. Historically, the bluefin season runs from June through October, even into November and, in recent years, December. The length of the season is dependent on the catch rate in any particular year.

The bluefin tuna fishery is located throughout the entire Gulf of Maine. Historically, large catches of bluefin have been landed in the Kettle, Cape Cod Bay, Stellwagen Bank, Jeffreys Ledge, Great South Channel, Ipswich Bay, Platts Bank, Cashes Ledge, Georges Bank, Wilkinson's Basin, and the Schoodic Ridges. This is not a comprehensive list, rather a highlight of some of the areas which have yielded large landings.

The Highly Migratory Species Division has informed the PDT that high resolution spatial data for bluefin tuna catches is limited. There is some spatial data for the recreational fishery as collected by the Large Pelagic Survey. The commercial catch location is recorded in the bluefin dealer data and trip reports, but the bluefin tuna reporting areas are broader in scope and differ from GARFO Statistical areas. There is some level of overlap with vessels holding both bluefin tuna and GARFO permits thereby triggering the VTR requirement, but that overlap and consistency in reporting bluefin in the VTRs has yet to be assessed.

Dr. Walt Golet (GMRI/UMO) has not examined localized depletion questions specifically, but has done a lot of research on bluefin migration and diet, and has identified correlations between Atlantic herring and bluefin tuna schools (Golet et al. 2013). Golet has been given access by tuna fishermen and dealers to their logbooks, which has spatial catch data at a finer resolution than what is submitted to NMFS. However, these data are proprietary and not available to the PDT. The fishermen have told him that there has been some confusion over time whether they were supposed to report to NMFS the area that they fished or the area of their homeport (it's supposed to be the former). He indicated that an investigation of localized depletion would be possible, but would need to draw on many areas of expertise and involve using acoustics, vessels, and the logbook data, be a long-term project, and involve a diverse array of investigators to ensure that causality is appropriately attributed (e.g. tuna fishermen are constrained by weather windows). The biggest concern is study design; this would have to be carefully thought out and by a diverse team. Such an open process is critical for the transparency of results, the most efficient use of any funds which may be available to support this work, and for proper study design (e.g. to ensure causality is correctly identified).

Through current and prior work, Golet and colleagues have identified linkages between bluefin tuna and herring (Golet et al. 2013; Golet et al. 2015). Aggregations of bluefin and herring are associated with each other, though not all herring aggregations have bluefin present (Schick et al. 2004; Schick & Lutcavage 2009). Bluefin rely on herring for a substantial portion of their diet and come to the Gulf of Maine specifically to feed on herring as a lipid source (Golet et al. 2013; Logan et al. 2015). Bluefin has declined in mean weight and lipid reserves over time, and these changes appear connected to declines in herring weight and size-at-age, despite high herring abundance (Golet et al. 2015; Logan et al. 2015). Golet et al (2013) have correlated herring and tuna schools, but a more thorough analysis could be completed. To date, the data have not been examined on sufficiently fine spatial and temporal scales to determine the specifics of co-location.

Whale-watching

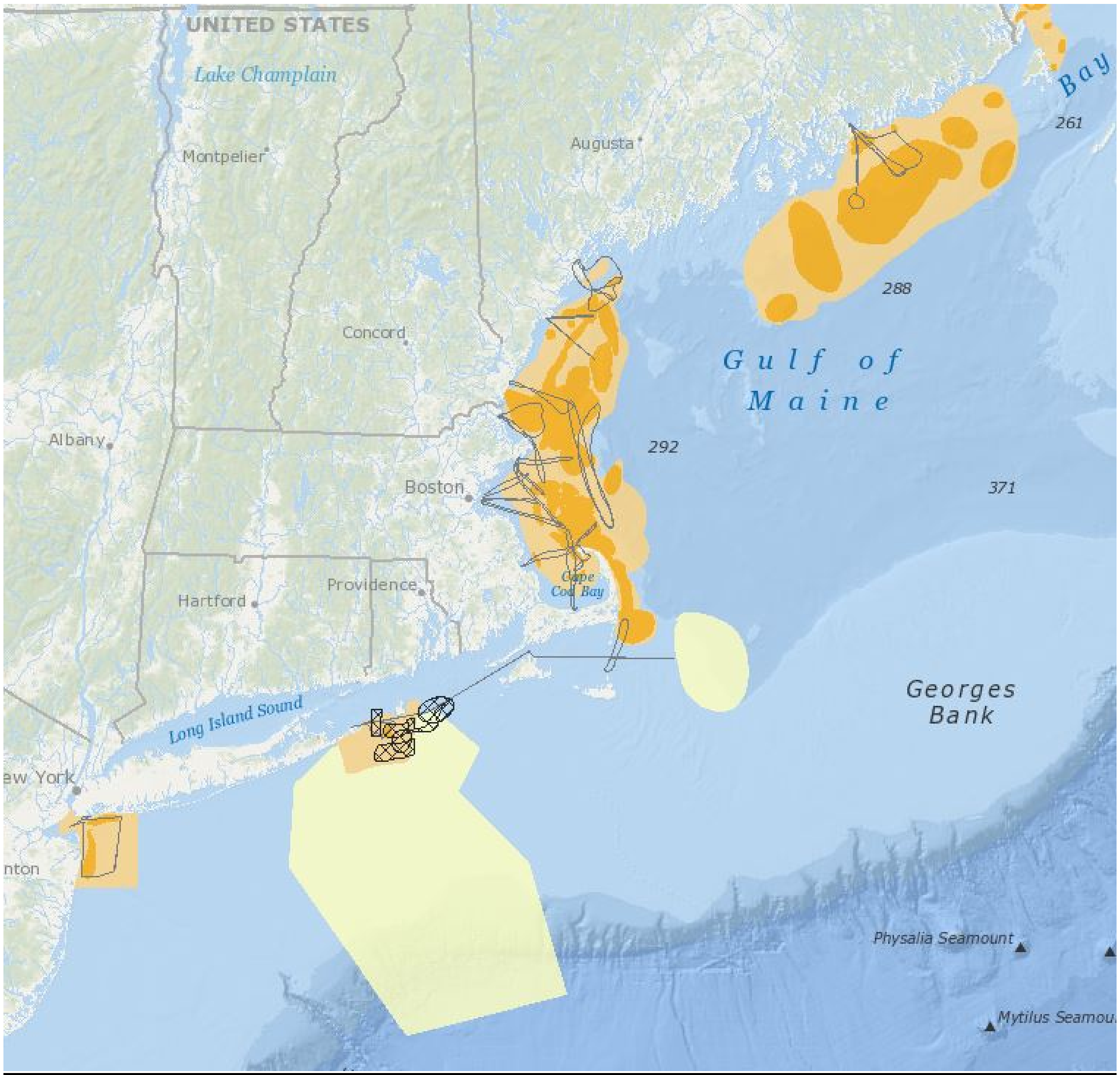
The GARFO Protected Species office has informed the PDT that whale watch companies do not report to NMFS where they go and what protected species they see. Many, if not all, whale watch vessels carry naturalists on board to collect data. The naturalists are from research or conservation organizations. The PDT contacted Mr. Zach Klyver, a current Herring Advisory Panel member and employee of Bar Harbor Whale Watch Company. This company has been collecting data (e.g., number of humpbacks and finbacks, location and date) since the 1990s, but in 2003, started carrying scientists from Allied Whale on every trip. Their data is digitized, and he has offered to help obtain the data. The Blue Ocean Society, The Whale and Dolphin Conservation, Provincetown Center for Coastal Studies, and College of the Atlantic also provide scientists for trips by other companies that do excursions to Jeffries Ledge, Stellwagen Bank, and other areas. Due to time limitations, the PDT was unable to pursue these potential data sources further.

Key whale species of interest to the whale watching industry are humpback, finback, and minke whales. Humpback whales are known to feed on herring, particularly in the Gulf of Maine. Humpbacks feed during the spring, summer and fall in the western North Atlantic (Waring et al. 2015). Their distribution in this region is largely correlated with prey species, though behavior and bathymetry are factors as well (Payne et al. 1986; Payne et al. 1990). Prey include herring, sand lance and other small fish (Waring et al. 2015).

Map 13 shows commercial whale watching areas from the Northeast Ocean Data portal. As described on the portal, the map:

> *"depicts activity areas mapped by whale watch industry experts in the Northeast Coastal and Marine Recreational Use Characterization Study which was conducted by SeaPlan, the Surfrider Foundation, and Point 97 under the direction of the Northeast Regional Planning Body. Whale watch owners, operators, naturalists, and data managers attended participatory mapping workshops to map areas where whale watching takes place in the region, while also providing information about seasonality, species, and overall industry trends."*

Map 13 - Commercial whale watching areas



Source: Northeast Ocean Data Explorer, http://www.northeastoceandata.org/data-explorer/

Notes quoted from the Data Explorer:

"The data are classified by the following categories:

- **"General use areas** [light orange] reflect the full footprint of whale watch activity in the last 3 – 5 years (2010 – 2014) regardless of frequency or intensity
- **"Dominant use areas** [dark orange] include all areas routinely used by most users most of the time, according to seasonal patterns.
- **"Transit routes** [lines] include areas used for transit to and from general or dominant use areas
- **"Supplemental areas** [yellow] depict areas used for closely-related activities and infrequent specialty trips.
- **"RI Ocean Special Area Management Plan areas** [hatched] were mapped as part of the Rhode Island Ocean Special Area Management plan and are symbolized separately to reflect different data collection methodologies."

TASK #3: Relationships between catches of herring and predators

Expand the PDT analysis presented to the Committee in January 2016, which examined whether there are correlations between catches of herring and predators.

Examine Area 1A in years prior to 2006 (i.e., Amendment 1 implementation).

Examine catch of predators in the second week after herring catches (across the full time range).

Here, both the original information (January 2016) and more recent analysis are presented.

Methods

This analysis focused on the localized depletion scenario in which relatively mobile herring predators would leave a depleted area in search of alternative prey. Vessel Trip Reporting System (VTR) data were used to compare the catch of Atlantic cod, pollock, and spiny dogfish subsequent to herring catch. Catch per trip (CPT) of these three predators were calculated during the week of reported herring catch and compared with predator CPT for the first and second weeks following herring catches:

$$D_{y,s,p,w} = \frac{C}{T}_{y,s,p,w+1} - \frac{C}{T}_{y,s,p,w};$$

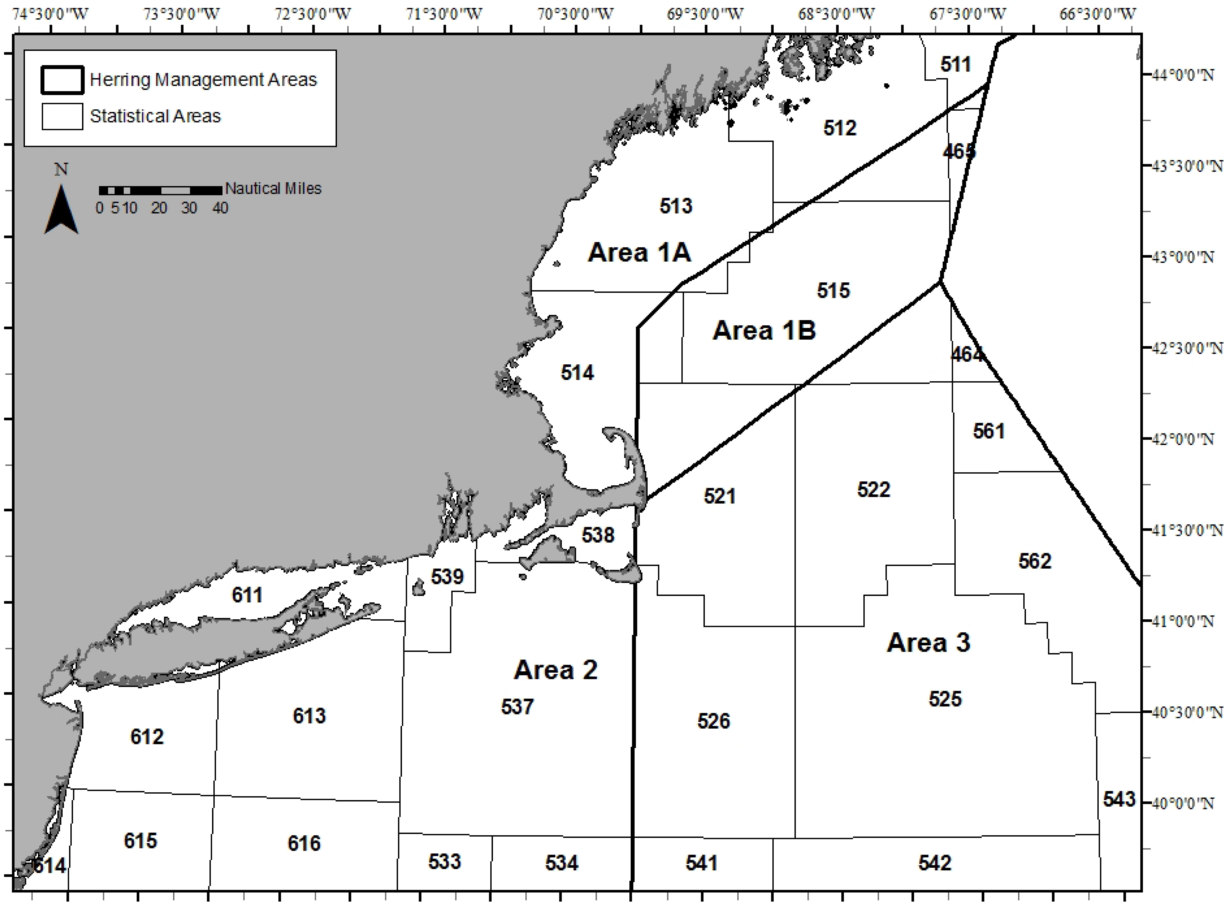
where C is the catch and T is the number of trips that caught any of the predators (*p*) in each year (*y*), statistical area (*s*), and week (*w*). x equaled either 1 or 2, depending on whether the analysis was conducted using a one week or two week lag. Map 14 shows the herring management areas and statistical areas for reference. These three predators were included because they are of commercial interest and gut contents data from National Marine Fisheries Service bottom trawl surveys suggest that these species prey heavily on herring.

A linear regression then was conducted with $D_{y,s,p,w}$ as the dependent variable and the catch of herring (h), $C_{y,s,h,w}$, as the independent variable. A consistent negative relationship would support localized depletion, while any other relationship would provide no evidence for localized depletion.

Analyses were also restricted to the years 1997-2014 to capture a range of years before and after Amendment 1, and to keep the number of comparisons manageable, and because each of these years has an adequate number of observations for the chosen statistical areas.

The analysis described above was also repeated: 1) for only predator trawl gears with the number of trips in the CPT estimate replaced with the number of tows, 2) using predator CPT from only bottom otter trawls, 3) using predator CPT from only bottom otter trawls, 4) using predator CPT from only sink gillnets, and 5) using predator CPT from only longlines. These additional analyses were intended to serve as a test of whether the effects of herring catches on the predators may vary depending on the gear type used to catch the predators. For example, if harvesting herring serves to scatter predators over a broader area, then a mobile trawl gear may maintain CPT (or per tow) by towing longer over a broader area, whereas maintaining CPT with fixed gillnets and longlines would require the predators to reaggregate in a given location. The fixed gears might also increase soak times, but that is not accounted for here.

Map 14 - Herring management areas and statistical areas



Results

Results among statistical areas were similar. Consequently, results from one statistical area from herring management areas 1A, 2, and 3 are provided (statistical areas 513, 521, and 537; Figure 18 to Figure 23). The gear-specific results were generally similar to those from using CPT from all predator gears combined, and so results for these sensitivities were not presented.

None of the regressions of were statistically significant except for statistical area 537 in 2012 and 2013 with a two week lag, (Figure 18 to Figure 23). The direction of the relationship between $D_{y,s,p,w}$ and $C_{y,s,h,w}$ was inconsistent (i.e., positive in some years and negative in others). These results provide no evidence of localized depletion for these predators at the scale of statistical area and one or two week time intervals.

Discussion

This analysis has several caveats. The spatial and temporal scale at which localized depletion operates has no specific definition and may depend on the predator. Here, localized depletion was examined on the scale of statistical area and week. So, if conditions within a statistical area were unchanged after one or two weeks, then no evidence of localized depletion would be found. This analysis also focused on three predators and combined them for analysis, but different predators may respond differently to the removal of herring. Conducting analysis by individual predator or groups of predators thought to react similarly to herring removals should likely be considered in the future. Likewise, varying the temporal and spatial scale of analysis by predator might also be considered, and other predators of interest could be examined. This analysis also used VTR data, which is self-reported and may contain errors (e.g., incorrect spatial assignments). Other data sources might be considered in the future. This method assumes that CPT is an index of predator abundance.

Data from all times of year were combined in this analysis, but perhaps analysis by season should be considered. Herring migrate during certain times of year, so localized depletion is unlikely to occur during these times because the herring will be in a different location in the near future regardless of catches. Analysis of a time of year when herring are likely to be confined in a single region might be more appropriate (summer feeding grounds or fall spawning). However, having included data from all times of year in this analysis would only increase the chances of finding a negative correlation, which may support the occurrence of localized depletion. Follow up analyses could include examining the data at finer time intervals than by year.

Figure 18 – Predator catches in sequential weeks, Statistical Area 513 (Area 1A)

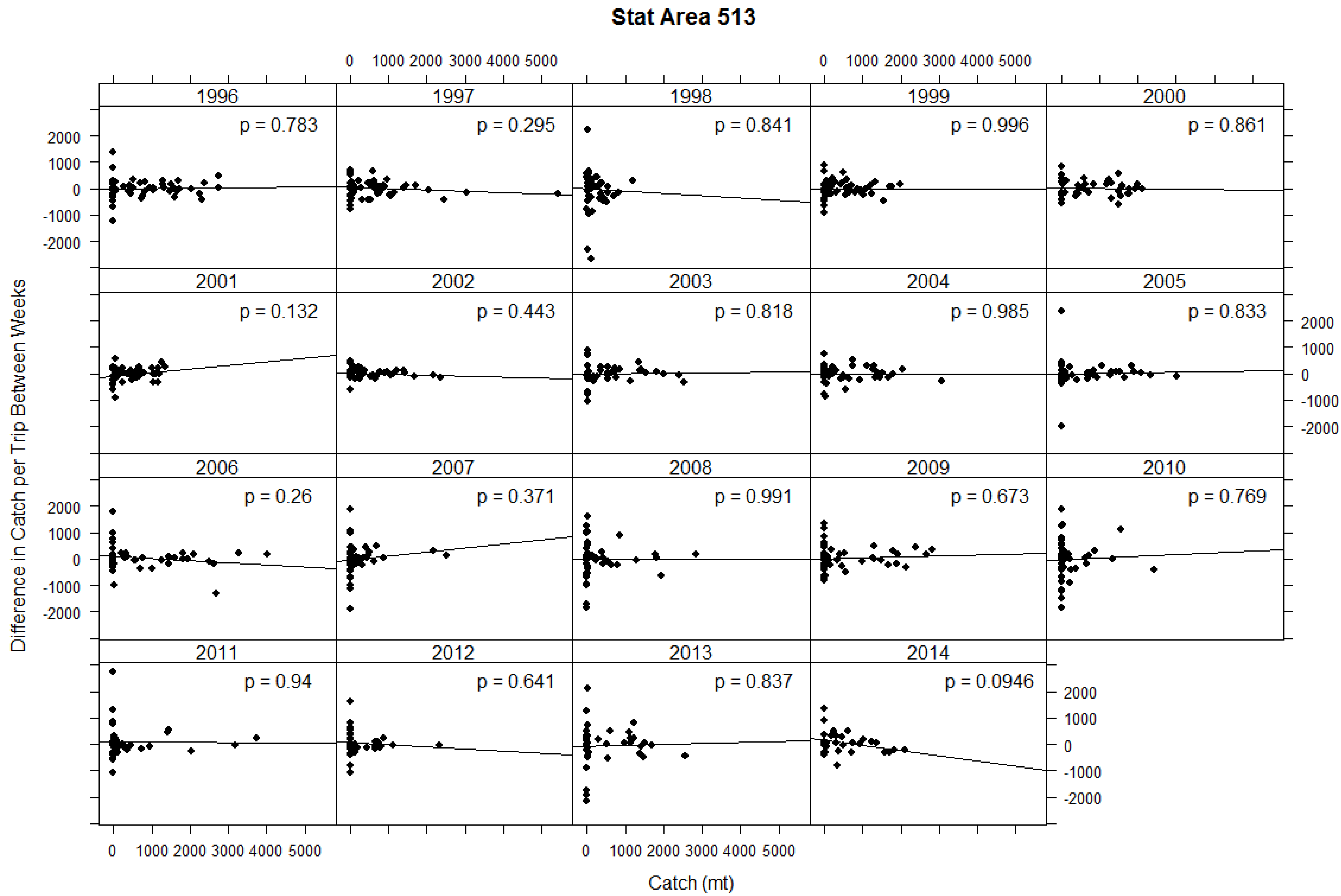


Figure 19 - Predator catches two weeks apart, Statistical Area 513 (Area 1A)

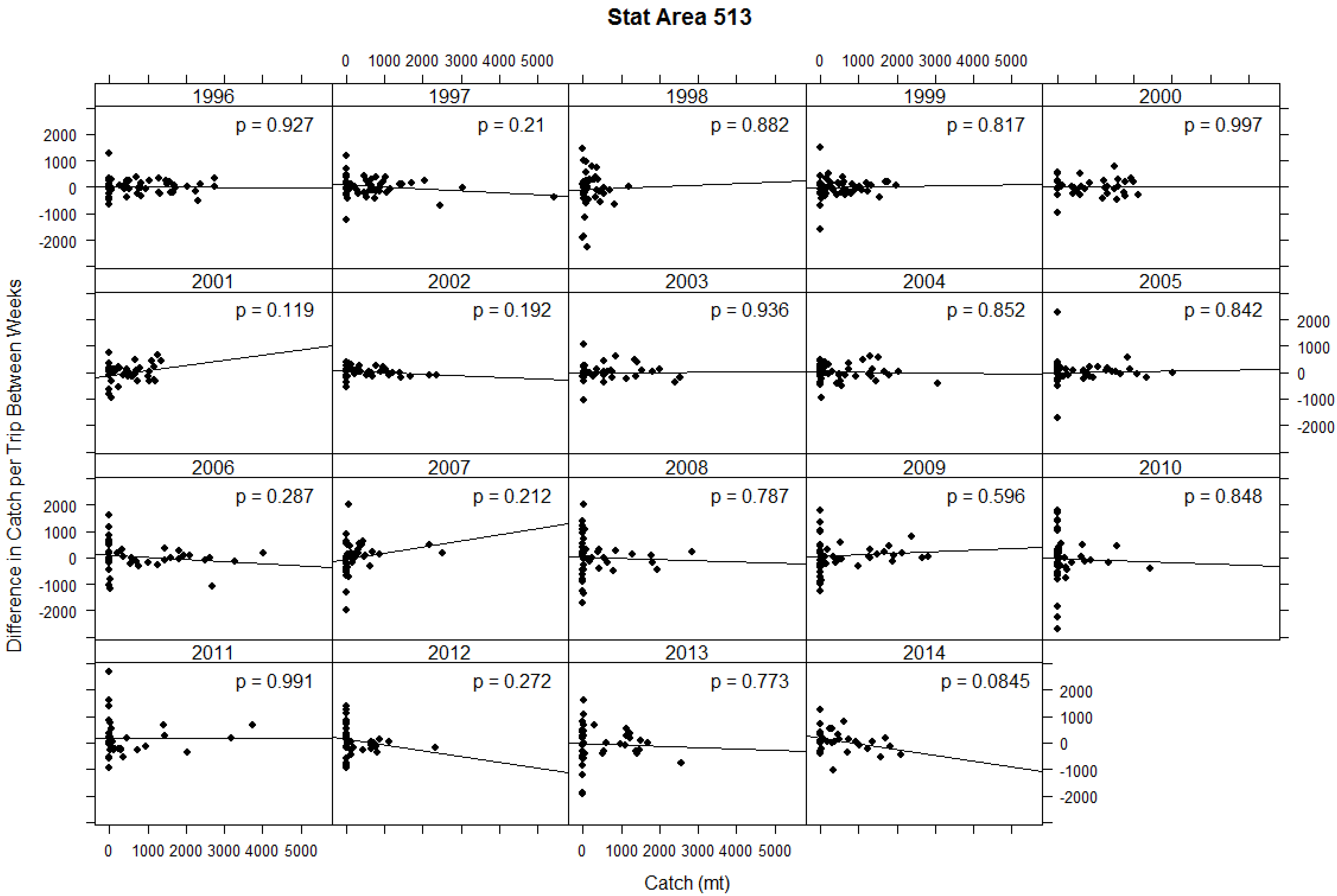


Figure 20 - Predator catches in sequential weeks, Statistical Area 521 (Area 3)

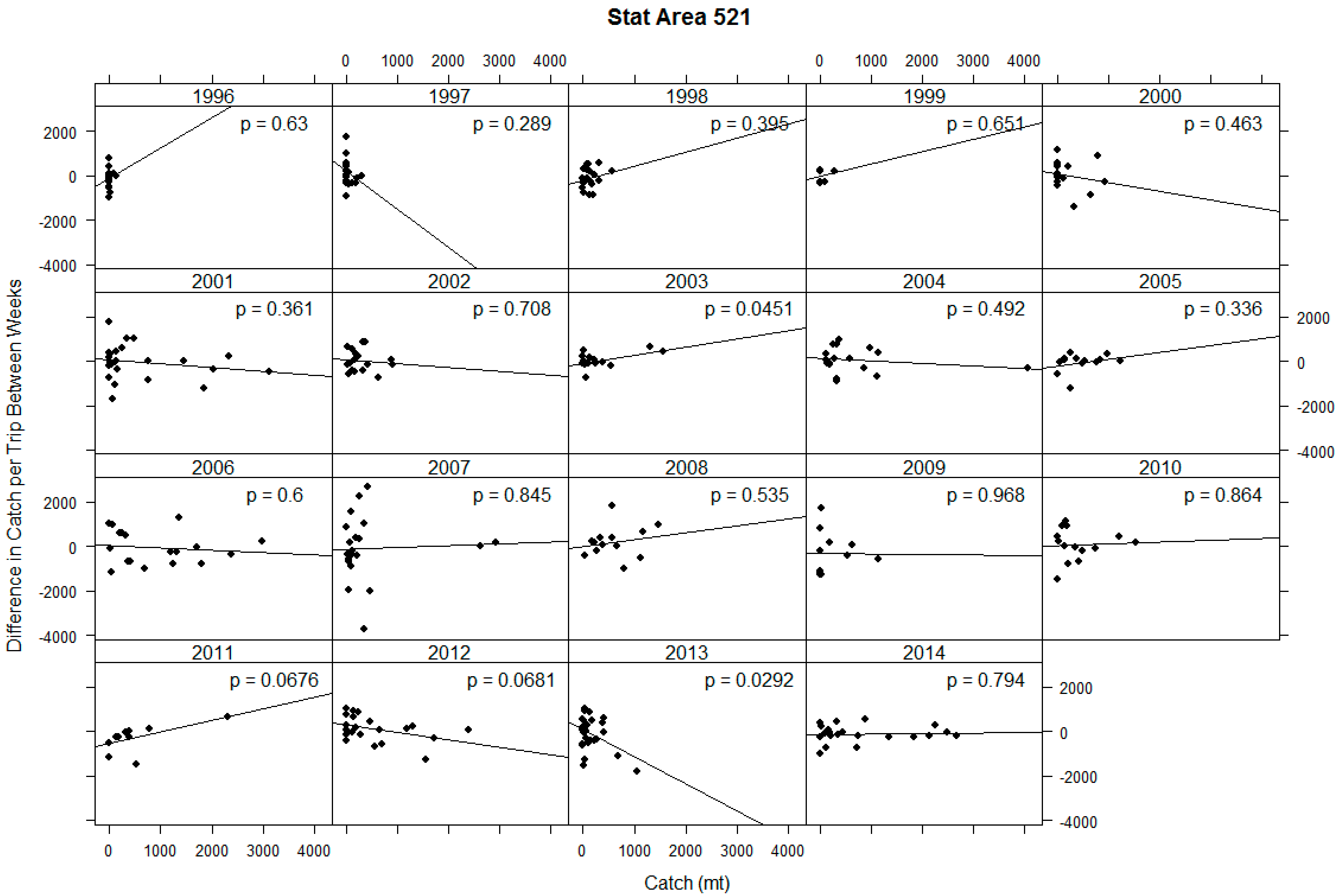


Figure 21 - Predator catches two weeks apart, Statistical Area 521 (Area 3)

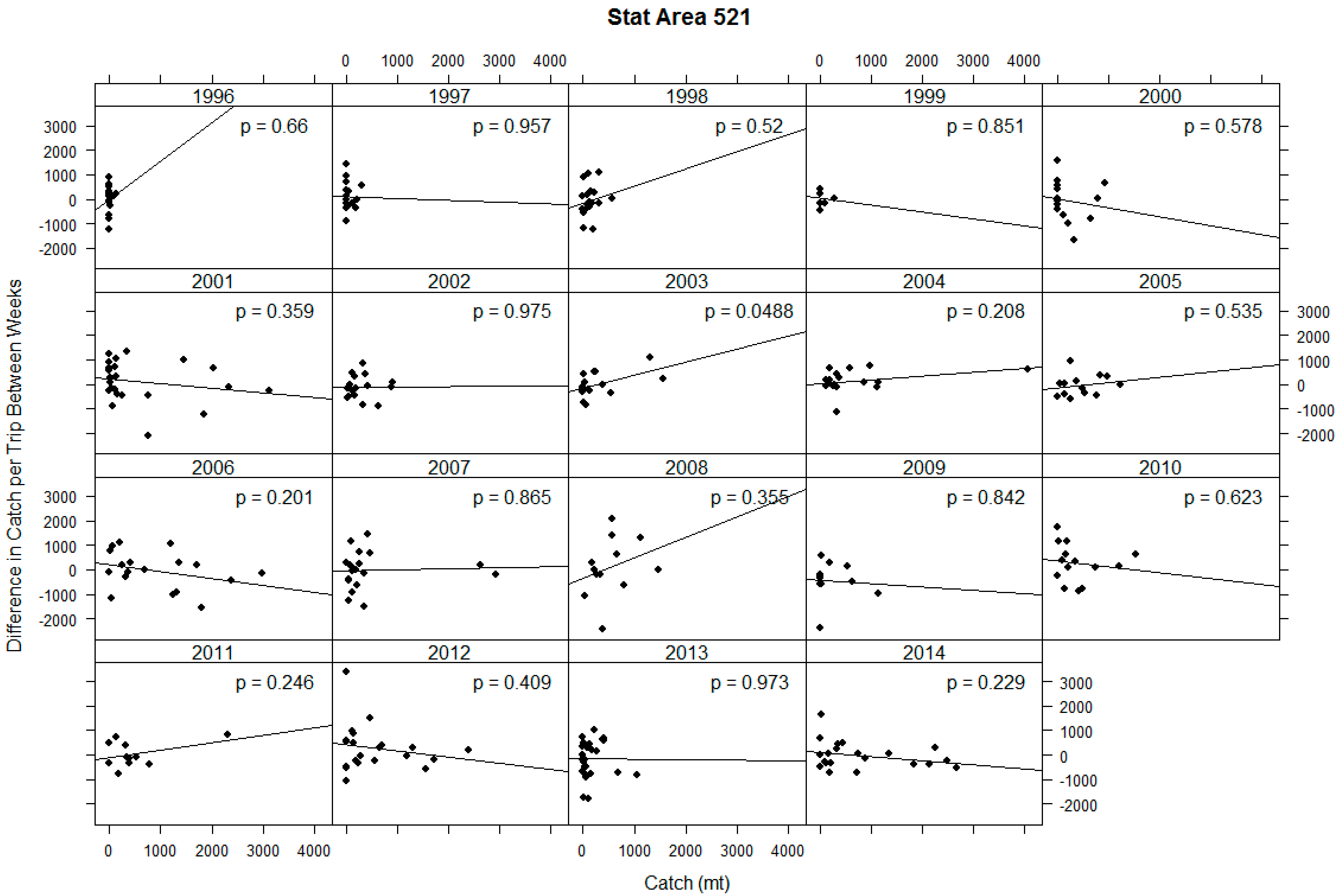


Figure 22 - Predator catches in sequential weeks, Statistical Area 537 (Area 2)

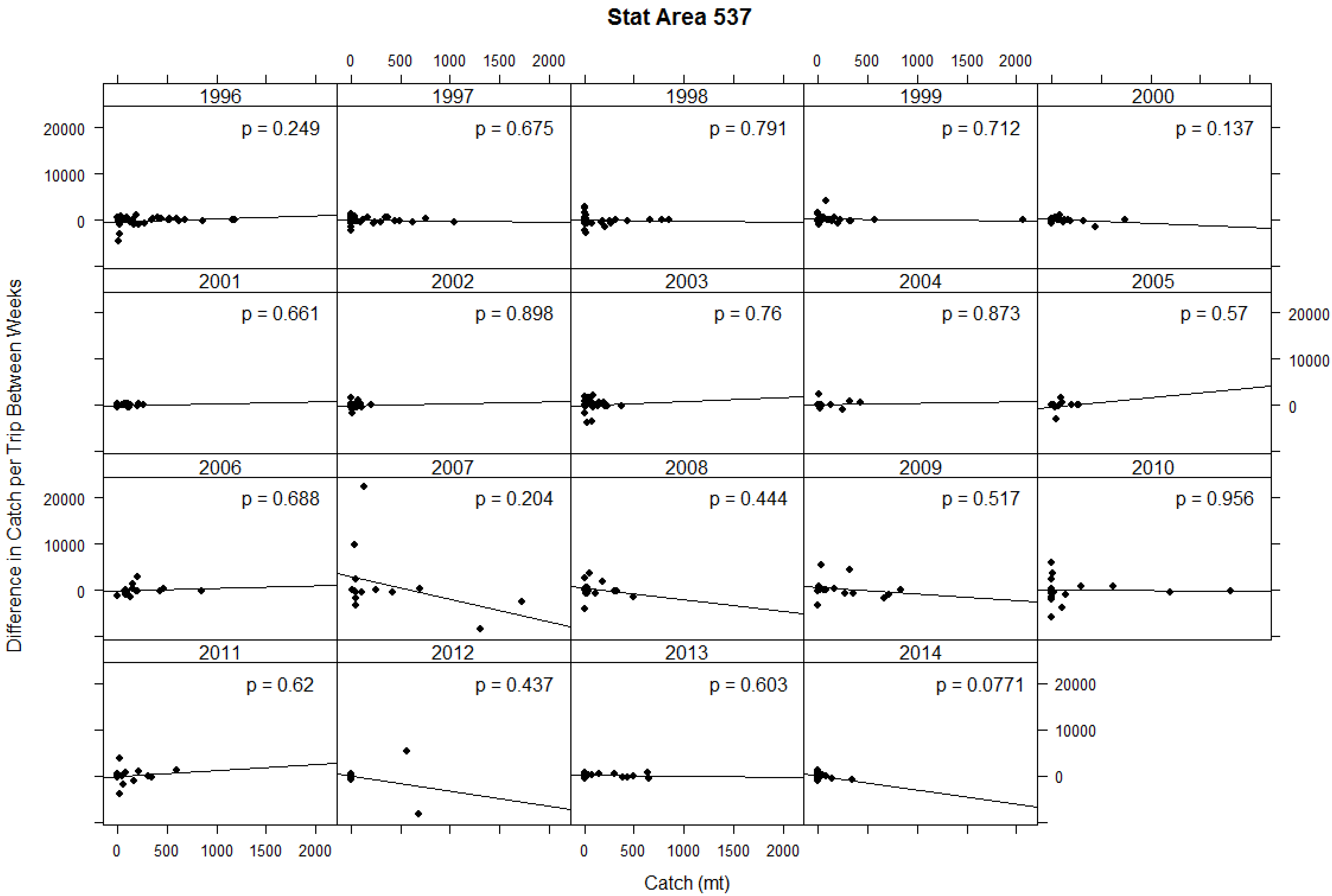
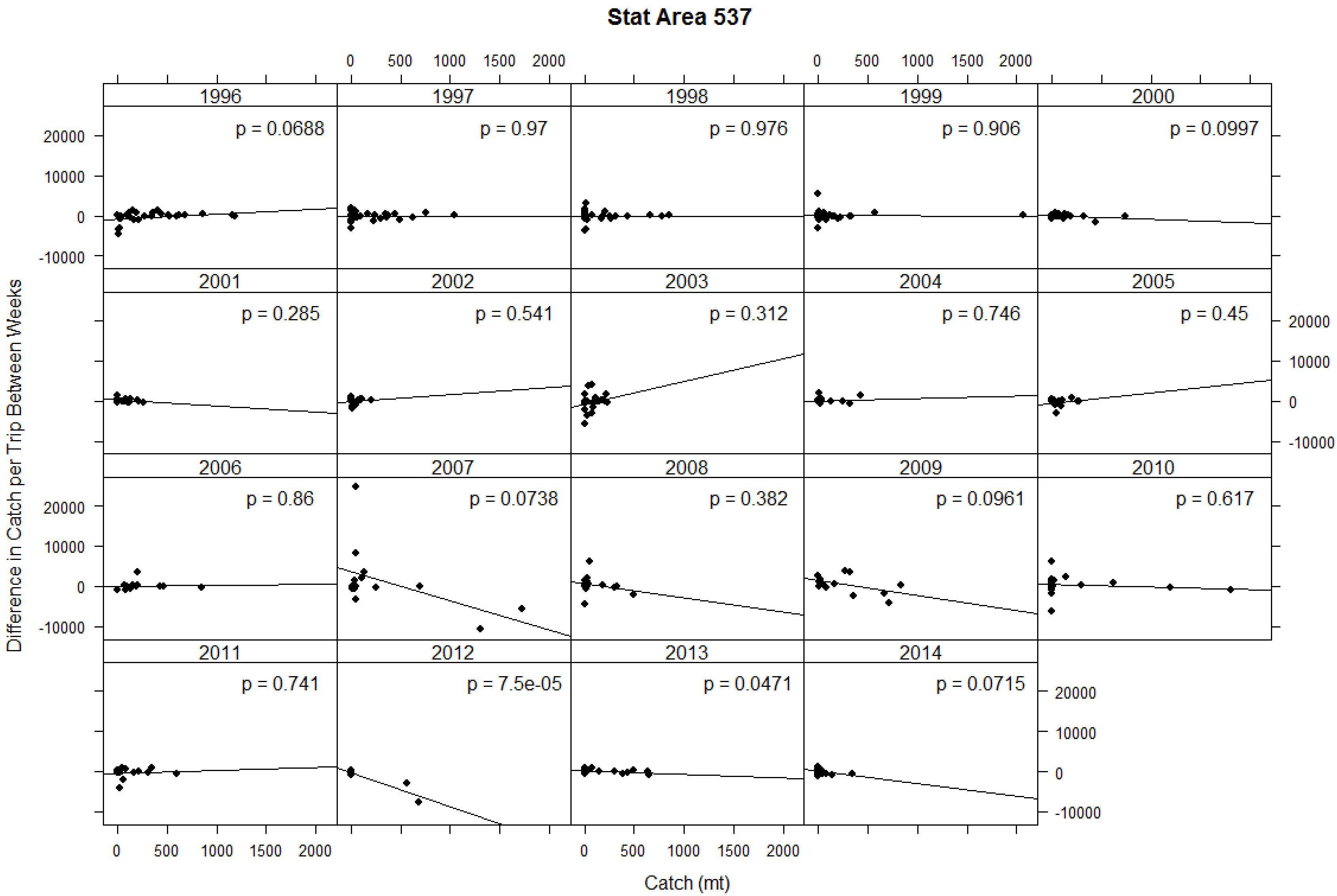


Figure 23 - Predator catches two weeks apart, Statistical Area 537 (Area 2)



<u>TASK #4: Potential midwater trawl closures</u>

> *Examine potential impacts (biological, economic, social) to different fisheries (herring, tuna, striped bass, etc.) of closing the following 30-minute squares to midwater trawl gear year-round: 99, 100, 114, 115, and 123. Calculate the percent of the total Atlantic herring stock area that these 30-minute squares comprise.*

Each 30 minute square comprises <1% of the total Atlantic herring stock area. Within each herring management area, the squares of interest here (99, 100, 114, 115, and 123) comprise <2%, with the exception of Area 1B (Map 15, Table 1, Table 2). These area calculations were done in ArcGIS using the UTM19N projection. Sliver portions of the squares were excluded where there were landmass intersections or artifacts from geoprocessing. The areas excluded were exceptionally small in relation to the overall areas and did not influence the percentages.

Map 15 - Atlantic herring management areas and 30 minutes squares

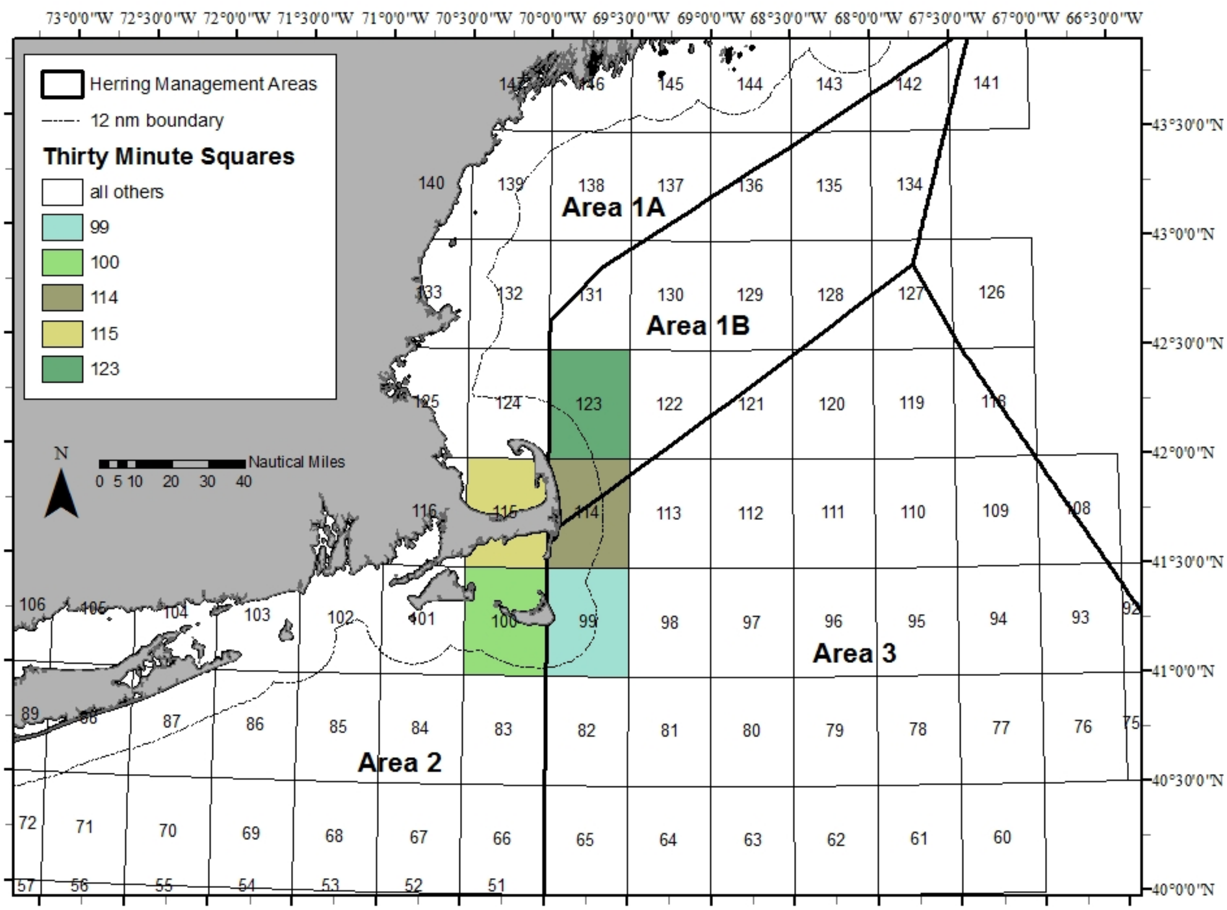


Table 1 - Percent of the Atlantic herring management areas specific 30-minute squares comprise

Area	30-Minute Square				
	99	**100**	**114**	**115**	**123**
Herring Area 1A				3.2%	
Herring Area 1B			3.9%		10.6%
Herring Area 2		0.6%		0.2%	
Herring Area 3	1.7%		1.0%		
Source: GARFO GIS Database					

Table 2 - Percent of the Atlantic herring stock area specific 30-minute squares comprise

30-Minute Square	Percent Herring Stock Area
99	0.4%
100	0.4%
114	0.4%
115*	0.3%
123	0.4%
Source: GARFO GIS Database *115 is smaller because a large portion of the 30-minute square is overlaps Cape Cod, which was not included in the area calculation.	

No analysis was done to quantify landings from these 30 minute squares. The PDT feels that the model used to generate the "heat maps" presented earlier (starting p. 5) would be the most appropriate method to do so, and can be done.

The size of a square relative to a stock or management area has little relevance to a discussion of potential biological, economic, and social impacts of closing a particular square year round, since both fish and fishing effort are not evenly distributed throughout the stock area. The PDT is uncertain the degree to which an accurate assessment of future impacts can be made regarding area closures, as future changes in environmental conditions, and fish distribution, and fisheries would factor in.

For bluefin tuna, portions of the 30-minute squares in question have been important foraging grounds. However, much of the Bluefin fishery catches in recent years have been further north, and in some cases east, of these squares. If herring biomass increases in an area, bluefin could be attracted. However, the areas in question are known to be a migratory corridor for herring, so they only remain there for limited time periods. Foraging and spawning requirements move herring outside these areas.

TASK #5: Cod and herring in Ipswich Bay

Examine predator/prey relationships between cod and herring in Ipswich Bay.

The NMFS food habits database is sizeable, but only a small portion of the data is from Ipswich Bay. The sources for the data are the spring and fall bottom trawl surveys. Cod are known to be omnivorous, and around 10% of their diet is herring.

TASK #6: Analytical ideas from public scoping

Examine ideas for analysis identified in the public scoping comments for Amendment 8.

Using the thematic coding that the PDT previously conducted to summarize scoping comments (NEFMC 2015b), the topics listed below were identified. Some of the topics are explored or explained within this memo, some are the subject of current research, while others could be tasked to the PDT in the future.

- Stock assessment/modeling
  - Determine why there is a retrospective pattern in the stock assessment.
  - Revise modeling based on closer to real-time data (not 2-3 year lag).
- Formally explain and/or determine how much herring is used by predators.
  - Consider differences in age/size/nutritional value for different predators.
  - What other species also serve as prey to fish that eat herring? Is there a difference in their ability to fulfill prey role?
  - Role of herring in the ecosystem.
  - What is required to measure/account for scientific uncertainty?
- Look at the effects of inshore closures waters to herring fishing (Area 1A, Canada)
- Where are MWTs allowed world-wide; where is it banned? What has been the effect?
- Consider socio-economic impacts on businesses and communities of changes in herring regulations, considering economic value of other businesses that depend on herring (tuna, whale watch, recreational fishing).
- Devise tools to analyze localized depletion.
- Has abundance of herring declined inshore (e.g., off Nantucket)?
- Reconstruct the history of environmental factors such as ocean temperatures, salinity, shifts in oceanic and climatic regimes (here and elsewhere) to determine impacts on pelagic species.
- Better understand herring schooling behavior.
- Are the effects of herring seining different from midwater trawling? Why/How?

Summary and next steps

The PDT has focused here on characterizing the spatial and temporal footprint of the herring fishery and predator fisheries and businesses as time and data have allowed. Additional work could occur on finer scale resolutions and other fisheries or gear types not reported here (e.g., small mesh bottom trawl). Several overlaps were identified. Even if correlations are found between herring removals and a signal in a predator fishery or business (i.e., whale watching) that may suggest that localized depletion is occurring, the PDT expects it will be difficult to identify a causal link, using just the data available. It is not a trivial undertaking.

The PDT has not yet examined the Study Fleet data relative to the current tasking, but the data may be useful for estimating catch rates on a given trip, though only a subset of the fishery participates in Study Fleet. It would need to be determined how many herring trips that have participated in Study Fleet have occurred within the area of interest (e.g., 12 nm). Within 12 miles, there is very little trawl fishing for herring, except on the back side of the Cape, around Block Island, and in Area 1A (fall only). Herring fishing on the back side of the Cape is primarily done in the spring and fall and is episodic. The fishery around Block Island is primarily prosecuted in the winter, and is unlikely to have much interaction with other fisheries (e.g., tunas are only present from about May-September, primarily in the Gulf of Maine and Georges Bank).

AUGUST 9, 2016 PDT MEMO

Method to identify herring fishery locations at sea

As described on p. 5, the best approach to identifying the locations of Atlantic herring fishing is to use the method that combines Vessel Trip Report and observer data developed by DePiper (2014). The following is an abbreviated description of the method. First, VTR data are matched to observer data. Second, a statistical model is estimated to explain the distance between hauls and the corresponding VTR coordinate. Days absent and gear used are major explanatory factors. Third, the results are used to expand the VTR coordinate to a circular region. Fourth, portions of circular regions that cannot be fished (such as land or areas closed to fishing) are removed and landings or fishing time from the VTR data are assigned to the remaining region. Finally, the individual trips are aggregated to the appropriate level.

This approach has been used in Tasks #1-3 below. Note that the model output is the location of herring landings rather than catch. Thus, landings are reported here where catch was requested. However, for the Atlantic herring fishery, landings generally approximate catch, as Atlantic herring discards represent a very small fraction of total Atlantic herring catch (generally <0.3%). Because the landings data are model outputs, the data should be considered estimates. Further, the PDT was cautious to ensure there are no data confidentiality issues with the data presented.

TASK #1: Mapping herring fishery

> *Make zoomed in heat maps of herring effort overlaid with all current and proposed spatial regulations to better identify the importance of areas to the fishery and potential impacts of measures developed through Amendment 8, such as: groundfish closed areas (with 15 mi move along), distances 12, 30, 50 mi from shore, stat areas/30-min squares, herring management areas, bathymetry (100 fathom or 200 m depth), ASMFC spatial regulations (spawning closed areas), RH/S bycatch cap areas, and haddock AM areas.*

The Greater Atlantic Regional Fisheries Office (GARFO) has created an online "story map" describing current management areas for the scallop fishery, and a similar interactive map product has been developed for the Atlantic herring fishery, particularly in support of Amendment 8. The interactive map of the Atlantic herring fishery is available at: http://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=5d3a684fe2844eedb6beacf1169ca854

Herring fishery locations are mapped using the method that combines Vessel Trip Report and observer data developed by DePiper (2014). Many caveats are needed to understand the maps. For example, fishery locations and intensity should not be confused as measures of abundance (or depletion) given the numerous regulations constraining a fishery (e.g., catch limits, time/area closures).

Some aspects of the map are still underdevelopment. For example, GIS layers of herring catch by month will be uploaded soon, and the PDT is developing communication tools to explain the various spatial/temporal regulations that have influenced where fishing has occurred. It is possible to create interactive maps, using this approach, for other federal fisheries for species that are predators of herring (e.g., groundfish). Please send feedback or questions to Rachel Feeney (rfeeney@nefmc.org).

TASK #2: Herring fishing within specific 30-minute squares

> I*dentify herring catch from the following 30-minute squares, by season or month back to 2000: 99, 100, 114, 115, and 123. Calculate the percent of the total Atlantic herring stock area that these 30-minute squares comprise.*

Methods

Landings by 30-minute square were estimated using the VTR-observer method developed by DePiper (2014). After aggregating the model output at the monthly level, landings from each of the relevant 30-minute squares were extracted. As noted above, landings are reported here rather than catch.

ArcGIS (with the UTM19N projection) was used to calculate the percent of an Atlantic herring stock area that these 30-minute squares comprise. The PDT went a step further, to also calculate the size of the squares relative to the Atlantic herring management areas. Sliver portions of the squares were excluded where there were landmass intersections or artifacts from geoprocessing, though the areas excluded were exceptionally small in relation to the overall areas and did not influence the outcomes.

Data

For the selected 30-minute squares (Map 15, p. 43), Figure 24 and Figure 25 show the share of the fishery-wide monthly landings occurring within each square during the time periods 2000-2009 and 2010-2015. For example, almost 25% of herring landings in May for the years 2010-2015 was from square 114, and under 2% was from the other squares reported here. Table 3 provides detail for just square 114.

Each 30-minute square reported here comprises under 0.5% of the total Atlantic herring stock area (Table 2, p. 44). Within each herring management area, these squares comprise <2% of the stock area they reside within, with the exception of the squares within Area 1B (Table 1, p. 44).

Table 3 - Monthly landings (mt) and share of fishery-wide landings in 30-minute square 114, 2000-2015 calendar years

	2000-2009		2010-2015	
Month	**Kept (mt)**	**Share**	**Kept (mt)**	**Share**
1	3,959	5.63%	13,089	22.65%
2	1,999	3.68%	3,510	13.34%
3	469	1.74%	1,072	5.80%
4	877	4.50%	1,168	18.53%
5	2,956	5.19%	6,331	31.20%
6	0	0.00%	125	0.28%
7	18	0.01%	530	0.75%
8	31	0.02%	2,913	3.83%
9	629	0.50%	4,606	6.94%
10	4,024	3.33%	62	0.10%
11	13,573	16.57%	C	C
12	20,564	39.74%	1,702	5.85%
C = confidential				

Discussion

Of the 30-minute squares areas reported here, 114 (to the east of Cape Cod) is the only square where over 10% of the fishery-wide landings in a given month through the time series have occurred. In 2000-2009, the landings in 114 were primarily in the early winter, about 17% (~14K mt) and 40% (~21K mt) of the fishery landings for November and December, respectively. Landings in 114 for all other months were under 6% of the total for the month. In this time range, November and December in 114 had both the highest landings and the highest share of landings.

In 2010-2015, square 114 continued to be important, but the fishery timing shifted, such that January (23%, ~13K mt) and May (31%, ~6K mt) were months with the highest shares of and actual landings. April was third highest in terms of share of landings (19%) and September was the third highest in terms of actual landings (~4.6K mt).

A few points to note:

- For a given month and square, the percent of catch coming from that area is independent of actual catch, depending rather on the total fishery-wide catch for the month.
- Square 114 is currently split almost in half by Areas 1B and Area 3 (Map 15, p. 43), and the January-April Area 1B closure became effective in 2014. Thus, most but not all of the data presented here comprise a time period when herring fishing was allowed in all of square 114. However, these data would not necessarily be representative of future time series, given this closure.
- The Atlantic herring ACL between management areas has shifted over time. The percent of catch allowed from Area 3 was about 33% through 2006, then increased, ranging from about 38-42% ever since. From Area 1B, the percent sub-ACL decreased in 2010, ranging from about 6-7% prior to 3-5% since.
- The boundary between Areas 1B, 3 and 2 shifted in 2007, increasing Area 3 shoreward.
- The size of a square relative to a stock or management area has little relevance to a discussion of potential biological, economic, and social impacts of closing a particular square year round, since both fish and fishing effort are not evenly distributed throughout the stock area.
- If the Committee is interested in closing certain areas, it is generally the case that it is difficult to accurately predict future impacts of area closures, as future changes in environmental conditions, and fish distribution, and fisheries would factor in. With an area closure, a fishery could move and concentrate in other areas, with unintended consequences.

Figure 24 - Share of monthly Atlantic herring landings (all gears) by 30-minute square, 2000-2009 calendar years

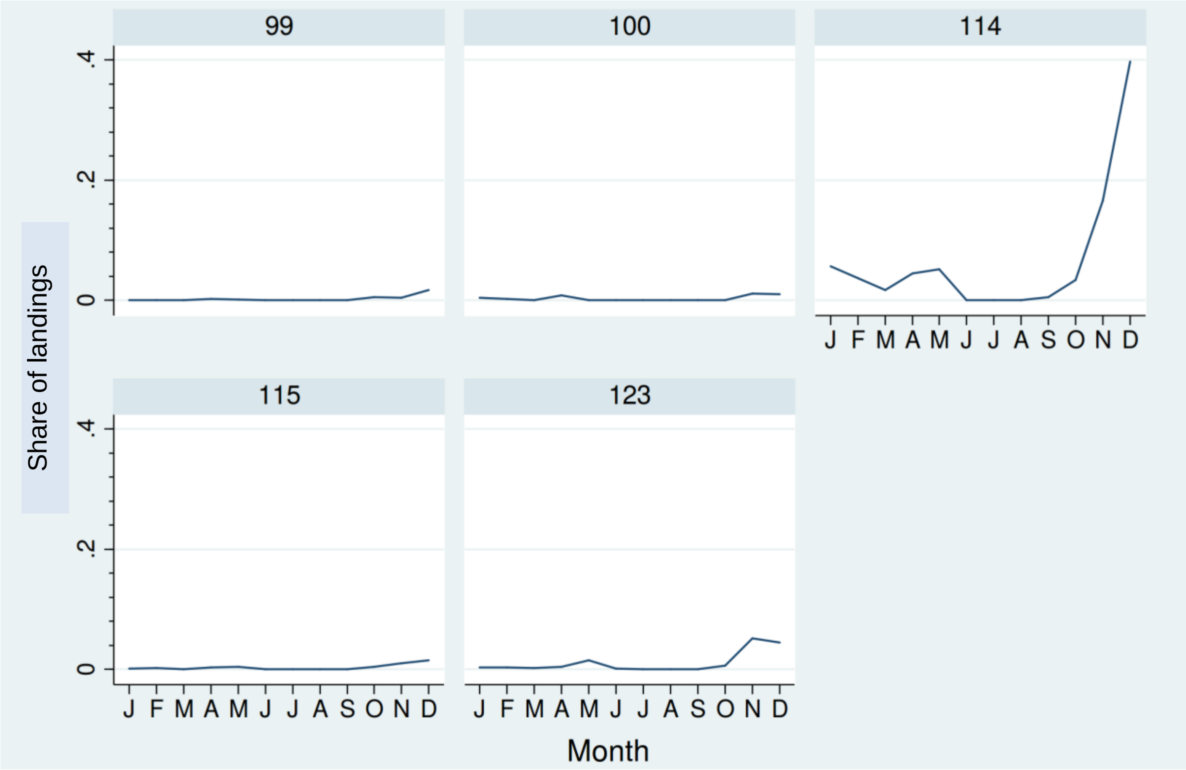
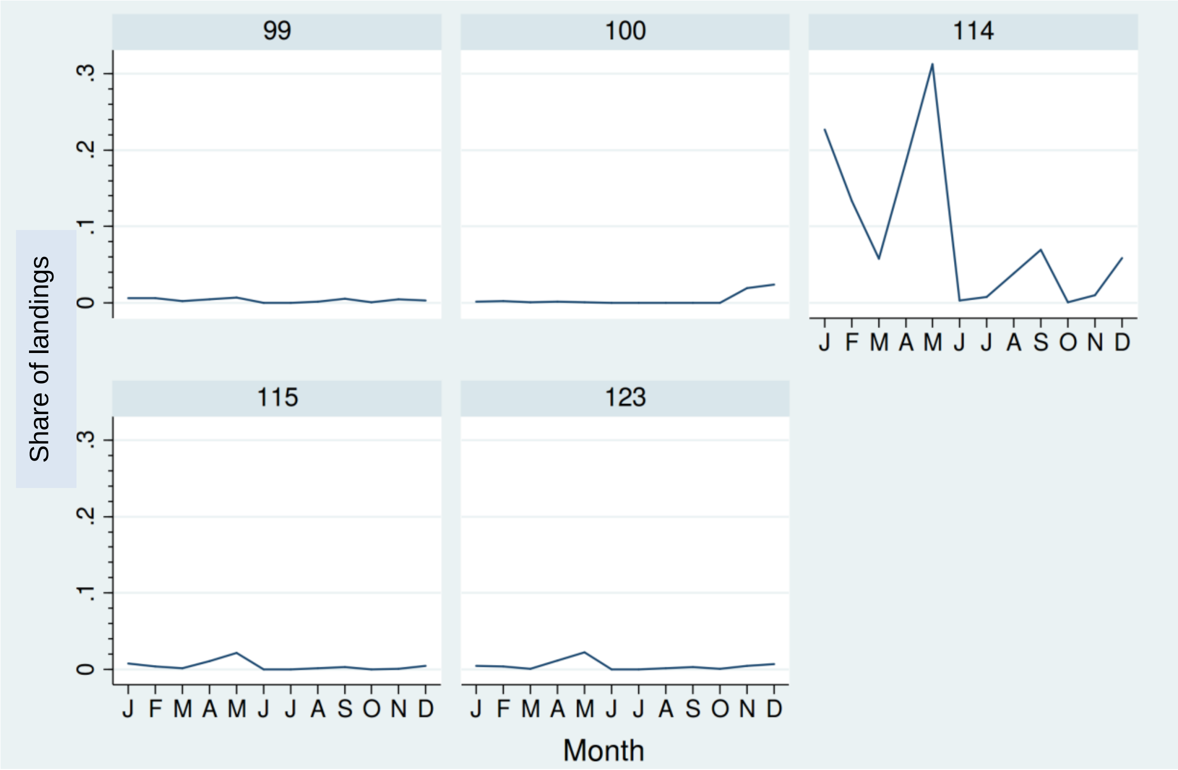


Figure 25 - Share of monthly Atlantic herring landings (all gears) by 30-minute square, 2010-2015 calendar years



TASK #3: Evaluate herring effort inshore

Within both 6 and 12 miles from shore, examine herring effort, including the amount of catch. Identify areas (e.g., Ipswich Bay, Nantucket Shoals) where herring fishing seasonally intensifies.

a. Determine and compare midwater trawl trip catches over time in each area, considering variation in tow-specific catches (accounting for tow time, number of tows, and trip duration).

b. Determine if, over the time of intensified fishing, catches could only be maintained by longer tows, more tows and/or longer trips, thereby indicating local depletion (e.g., F much higher than F set for entire stock).

Cautionary note/data limitations

For schooling, pelagic fish, catch per unit effort (CPUE) should not be used as an indicator of fishery impacts on abundance, particularly in a discrete geographic area, because CPUE could vary, either due to depletion, immigration, or emigration. Thus, a decline in CPUE would not necessarily indicate localized depletion. Furthermore, identifying localized depletion is very difficult, because the rate of herring removal relative to the rate of herring immigration to an area must be identified. It would be difficult to find evidence on a spatial scale that is smaller than the scale that herring can move in a day (about 15 nm/day). Because of fish movement, tow time should not be used to estimate the density of a herring school.

VTR data could be used to approximate the amount of time spent fishing in determining catch rates. The VTR data include tow-hours for midwater trawl trips and the VTR tow-hour data for the trawl fisheries are fairly reliable. However, there have been an insufficient number of MWT tows in discrete areas (e.g., in Ipswich Bay 6 or 12 miles from shore) to make robust conclusions.

Methods

Given these limitations, the Herring PDT at least identified inshore herring landings using the method of DePiper (2014). Monthly herring landings were aggregated for all gear types and by MWT gear (PTM and OTM) for five years (2010-2014). The landings within 6 nm and 12 nm were extracted.

Data

Table 4 and Table 5 include total landings of herring by all gear types and by MWT gear within 6 and 12 nm from shore, along with landings from all areas for each month of 2010-2014. For example, over 56% of the herring landings in January for the years 2010-2014 was from within 6 nm of shore and over 77% was from within 12 nm of shore.

Discussion

- A decline in CPUE would not necessarily indicate localized depletion.
- There have been an insufficient number of MWT tows in discrete areas (e.g., Ipswich Bay, 6 or 12 miles from shore) to make scientifically robust conclusions regarding CPUE.

- The nearshore fishery is particularly important between October and February. For both all gear types combined and for just MWTs, under 30% on the landings from March through September came from within 6 or 12 nm from shore.

Table 4 - Total landings of herring by <u>all gear types</u> within 6 and 12 nm from shore along with total landings from all areas, 2010-2014

Month	Within 6 nm		Within 12 nm		Kept all areas (mt)
	Kept (mt)	Share	Kept (mt)	Share	
1	27,775	56.33%	38,307	77.69%	49,304
2	7,190	30.69%	10,908	46.56%	23,425
3	1,065	7.54%	2,140	15.14%	14,131
4	732	13.37%	1,296	23.67%	5,472
5	2,007	13.17%	3,756	24.66%	15,232
6	1,755	5.17%	4,782	14.09%	33,940
7	3,208	5.42%	9,496	16.05%	59,155
8	8,368	12.83%	22,586	34.63%	65,230
9	5,407	9.21%	17,183	29.25%	58,742
10	11,475	22.99%	31,035	62.17%	49,921
11	2,845	23.42%	6,126	50.42%	12,149
12	18,315	70.46%	22,276	85.70%	25,992
TOTAL	**90,142**	**21.84%**	**169,891**	**41.17%**	**412,693**

Table 5 - Total landings of herring by <u>midwater trawl gear</u> within 6 and 12 nm from shore along with total landings from all areas, 2010-2014

Month	Within 6 nm		Within 12 nm		Kept all areas (mt)
	Kept (mt)	Share	Kept (mt)	Share	
1	20,053	52.54%	28,855	75.60%	38,169
2	5,072	26.24%	8,028	41.53%	19,331
3	448	4.06%	1,192	10.81%	11,027
4	576	12.33%	1,024	21.90%	4,676
5	1,853	12.73%	3,504	24.08%	14,556
6	83	0.37%	110	0.49%	22,518
7	227	0.59%	413	1.07%	38,516
8	991	2.83%	2,273	6.49%	35,035
9	1,830	4.70%	4,423	11.36%	38,924
10	8,310	22.99%	22,141	61.26%	36,144
11	2,258	20.50%	5,309	48.20%	11,014
12	12,967	66.83%	16,326	84.15%	19,401
TOTAL	**54,667**	**18.90%**	**93,600**	**32.35%**	**289,311**

TASK #4: Study Fleet habitat suitability model

> *Determine if the Study Fleet habitat suitability model could be useful to understanding localized depletion.*

Study Fleet overview

The Study Fleet program began in 2002, but its fully-functioning electronic logbook program (i.e., the "FLNDRS" system) began in 2010 with fishermen recording tow-by-tow data (some vessels still report at the sub-trip level rather than tow-by-tow). Herring fishery participation started with a few small-mesh bottom trawl vessels in Area 2. Then in 2013, funds from the Pacific States Marine Fisheries Commission helped expand participation that year to include eight herring midwater or pair trawl vessels and to 14 of these vessels in 2014, but participation has declined a bit since.

Study Fleet habitat suitability modeling to date

Dr. John Manderson of the NEFSC has been working with the Study Fleet data and participants to develop models of suitable habitat for Mid-Atlantic species such as mackerel and butterfish, to help understand the physical forces that affect fish habitat. Fish metabolic processes are affected by water properties, like temperature and oxygen, which have spatial and temporal variation. A number of tools in the Mid-Atlantic are contributing to improved ocean modeling including satellites, radar, gliders, and buoys. The mechanistic models are informed by real-time data, such as from the Study Fleet program. On a fine-scale, individual Study Fleet vessels have collaborated on experiments to, for example, understand movements of water fronts and their impacts on fishery catch and bycatch. There is a lot of dialogue with participants on their knowledge of the ecosystem.

The rationale for the fishing fleet's particular location is complex (e.g., weather, area management, global economics), so using the Study Fleet data has its challenges. This past winter, for example, there was no mackerel fishing until a storm in mid-January caused a cold snap that mixed water over Nantucket Shoals to allow the cold water corridor from the Gulf of Maine to form and move mackerel down to the Mid-Atlantic for the fishermen to access for a short time period. The mackerel model helped identify and understand this event.

Utility of the Study Fleet data and modeling for Amendment 8

The habitat models describe probabilities of fish occupancy in space and time, given: 1) the accuracy of the information, 2) the space-time scales at which the data were acquired, 3) the space time scales of the projections, which are a function of the biological data used to inform them, and the resolution of the ocean models and other habitat data used to project them. They do not predict absolute concentrations of animals (population size/habitat volume). In the ocean, the habitat volumes are changing shape, volume and geographic position even for demersal species and particularly when climate changes are affecting the properties of the ocean liquid.

It is possible to determine the timing and volumes of habitat overlap between species at some resolution determined again by the data informing them and the models used to project them. For high resolution, high resolution data are needed describing habitat partitioning amongst species. Studying fine scales of habitat partitioning are possible by working with the Study Fleet in a way that is really not possible with offshore research cruises that would require a tremendous amount of funding.

Species vary in terms of how important bottom temperature is to their distribution. This work has been pioneered for mackerel. Cold blooded animals, generally are fairly responsive to temperature in setting the metabolic rates. Having this prediction tool would be helpful for herring management (e.g., in developing river herring catch caps), but it has yet to be developed for herring, the bycatch species in the fishery, or for herring's predators. The oceanographic model that the mackerel model is built on is now being expanded to the Scotian Shelf. The model for each species is different and would take some effort and funding to develop.

Identifying fields of preferred herring temperature habitats would inform analysis of localized depletion, but the fishery may not necessarily mirror where the habitat is, though the industry could using it to better target the resource. The PDT cautioned that improving fishery efficiency is not a goal that has been the identified for Amendment 8, and that the Committee should remain focused on what is most relevant for Amendment 8. A more direct approach to understanding where the fisheries operate would be to use the fishery data rather than models of temperature suitability. It may be useful in estimating where the fishery could go if they were closed out of an area. For the different predators, whether and how they may be impacted by the localized depletion of herring would depend, in part, on their reliance on herring, and their degree of tolerance for different thermal environments.

The Study Fleet data may be useful for estimating catch rates on a given trip, though only a subset of the fishery participates in Study Fleet. Most of Study Fleet trips by herring vessels have been in Herring Management Area 2, but in 2015 there were a fair number of trips in Area 3. Providing data at the 10-minute square level would be the finest scale possible without breaching confidentiality restrictions. *It* would need to be determined how many herring trips that have participated in Study Fleet have occurred within the area of interest (e.g., 12 nm). Within 12 miles of shore, there is very little trawl fishing for herring, except on the back side of the Cape, around Block Island, and in Area 1A (fall only). Herring fishing on the back side of the Cape is primarily done in the spring and fall and is episodic. The fishery around Block Island is primarily prosecuted in the winter, and is unlikely to have much interaction with other fisheries (e.g., tunas are only present from about May-September, primarily in the Gulf of Maine and Georges Bank).

Discussion

- Such modeling tools do not yet exist for Atlantic herring. Even if funding and resources were in place, a model could not be developed within the timeline of Amendment 8 development.
- A Study Fleet-informed temperature habitat suitability model may be useful to understand the distribution of herring (or their predators), predicting where fish are likely to occur.
- However, it would not inform localized depletion questions, as it is unable to measure a response in a population to removals; it only predicts where fish are likely to occur given a habitat model (temperature).
- This type of model could inform bycatch monitoring/avoidance.

TASK #5: Marine Recreational Information Program striped bass data

> *The MRIP charter and private rental data include intercept site. Look at catch per trip for striped bass from private rental and charter intercept sites on Back side of Cape (0-3 mi from shore); compare to herring catches.*

Introduction

In January 2016, the Committee tasked the PDT with identifying the location of fisheries for herring's predators, by season and gear type. In March, the PDT reported that, although the striped bass fishery is largely recreational (60-70% of total striped bass removals in recent years), the only data for catch locations at sea are from the commercial fishery. The PDT provided data on the commercial spatial patterns of landings and CPUE within Massachusetts state waters – to the finest spatial scale possible. In New England, the only commercial fisheries for striped bass occur in Massachusetts and Rhode Island, around 8% and 1% of total commercial harvest in recent years, respectively) (ASMFC 2015). In Massachusetts, the recreational fishery is more predominant than average, accounting for about 85% of total removals (recreational and commercial striped bass fishing is prohibited in federal waters). Recreational fishery data are collected by the Marine Recreational Information Program (MRIP).

Data limitations/Methods

MRIP angler intercept data were reviewed for the possibility of identifying a response in striped bass catch rate from herring fishing in nearby waters. MRIP staff interview fishermen at "intercept sites" as fishermen complete their trip, typically at a boat ramp. On outer Cape Cod particularly, towns can be adjacent to Cape Cod Bay, Nantucket Sound, and/or the Atlantic Ocean.

MRIP does not collect catch location data, so it is not possible to identify where recreational striped bass fishing occurred at sea and then relate that to herring fishing locations. This is a very relevant point to any interpretation of a comparing herring catches and striped bass CPUE from the MRIP database, particularly for outer Cape Cod. MRIP only collects the category of location (bay, sound, river, etc). It is assumed here that when a fisherman says something other than bay/river/sound, they were fishing on the "backside" of Cape Cod. However, they could have easily launched from Provincetown or Chatham and fished elsewhere (e.g., Stellwagen Bank, Nantucket Sound). The primary boat ramps for the Outer Cape in particular (e.g., towns of Chatham and Provincetown) could be access points to go to many fishing locations.

In an effort to infer striped bass fishing locations from MRIP interview data, relevant trips were assumed to occur on the "back side" or east of Cape Cod if:

1. The intercept occurred in one of the outer Cape Cod towns (Provincetown, Truro, Eastham, Wellfleet, Orleans, Chatham);
2. Fishing did not occur in a river, bay or sound; and
3. Striped bass was the target fishery.

There were 360 recreational fishing trips targeting striped bass met these criteria between 2008 and 2014 (Figure 26, Table 6); 76% of the trips occurred in June to August. However, given the above assumption, the number of trips actually occurred to the east of Cape Cod may be lower.

To narrow the herring fishery data, an "area of interest" was defined as the area out to about 12 nm from shore within the 30-minute square 114, which is to the east of Cape Cod (Figure 13).

VTR data was used to identify the directed commercial Atlantic herring trips (landing 6,600+ pounds of Atlantic herring per trip) that reported landings from within the area of interest. Over the same time period (2008-2014), the directed commercial fishery for Atlantic herring took 139 fishing trips from the ‘area of inquiry’ (Table 7); 10% of the trips occurred in June to August.

To identify the relative co-occurrence of striped bass and herring trips more finely, of the 360 recreational striped bass trips, there were 67 that occurred within +/- one week of just nine of the 139 commercial herring trips (Table 8). Of those nine herring trips, just one had striped bass trips occur both prior to (n=1) and following (n=2) the herring trip.

To correlate a change in striped bass CPUE with herring removals, there would need to be sufficient MRIP data from before and after multiple herring trips. Unfortunately, these data do not exist; there are no herring trips with enough associated MRIP striped bass trips to characterize a change in CPUE. Again, the number of striped bass trips reported here as occurring to the east of Cape Cod are likely an over estimate.

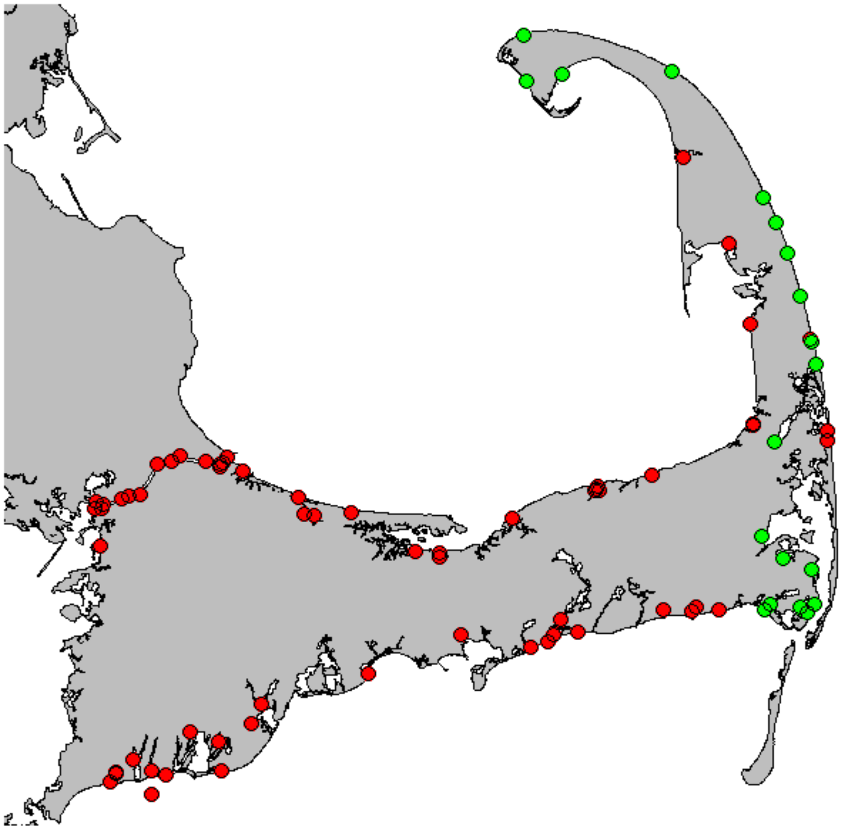
Discussion

Multi-year telemetry studies have shown that striped bass are typically present in Massachusetts waters between May and October (Kneebone et al. 2014b). As such, even if paired observations of herring removals (from federal waters) and MRIP CPUE (from state waters) were available, it would be difficult to attribute a change in striped bass catch rate to herring depletion, given the fluctuating seasonal pattern of the striped bass fishery and the fact that the fisheries occur in separate areas, state and federal waters. It is possible that a substantial portion of the striped bass population occurs in adjacent federal waters (i.e., beyond three miles from shore) where much of the herring fishing occurs. Striped bass tagged with acoustic transmitters have been shown to frequently cross this state/federal jurisdictional boundary (Kneebone et al. 2014a). However, since fishing for striped bass in federal waters is prohibited, there are no fishery dependent data to address the potential interaction with the herring fishery beyond three miles from shore.

For the area directly seaward of Cape Cod out to about 12 nm (Figure 13, p. 27), Atlantic herring landings generally occur early in spring or very late in the fall to early winter. Overall, landings are episodic (Figure 27), and rarely occur more than two weeks in a row. Given that most of the landings occur during the spring and fall herring migration, it is likely that the fishery exploits herring while they are passing through the area, and that schools of herring move too quickly through the area for sustained catches to occur; unlike the summer-time in the Gulf of Maine when the herring are more resident. The periodic/migratory nature of the herring fishery in this area, combined with the lack of spatial information for the striped bass fishery, makes it difficult to draw conclusions about the effects of localized depletion in this case.

- There are and insufficient number of striped bass trips with the MRIP data and commercial herring trips likely co-occurring to the east of Cape Cod to make scientifically robust conclusions about correlations.
- During 2008-2014, there is some overlap between these fisheries, but relatively few herring trips have occurred in June-August (10%), when the striped bass trips most common (76%).

Figure 26 - MRIP sites that had interviews with fishermen that targeted striped bass in Barnstable County (2008-2014)



Note: Green circles indicate sites in the towns of outer Cape Cod (Provincetown, Truro, Wellfleet, Eastham, Orleans, and Chatham) that had fishermen who reported they did not fish in a river, bay or sound (therefore assumed to have fished to the east of Cape Cod, though this is likely an overestimate).

Table 6 - Number of MRIP angler interviews where fishing likely occurred to the east of Cape Cod and striped bass was the target species (green circles from Figure 26)

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	0	0	0	0	4	5	6	11	8	1	1	0	36
2009	0	0	0	0	0	13	9	16	2	7	0	0	47
2010	0	0	0	0	3	9	15	25	2	0	0	0	54
2011	0	0	0	0	14	18	13	14	12	4	0	0	75
2012	0	0	0	7	2	24	12	4	9	4	0	0	62
2013	0	0	0	0	3	32	9	20	0	0	0	0	64
2014	0	0	0	0	0	2	7	9	2	2	0	0	22
Total	**0**	**0**	**0**	**7**	**26**	**103**	**71**	**99**	**35**	**18**	**1**	**0**	**360**
Note: Number of MRIP trips may be an overestimate.													

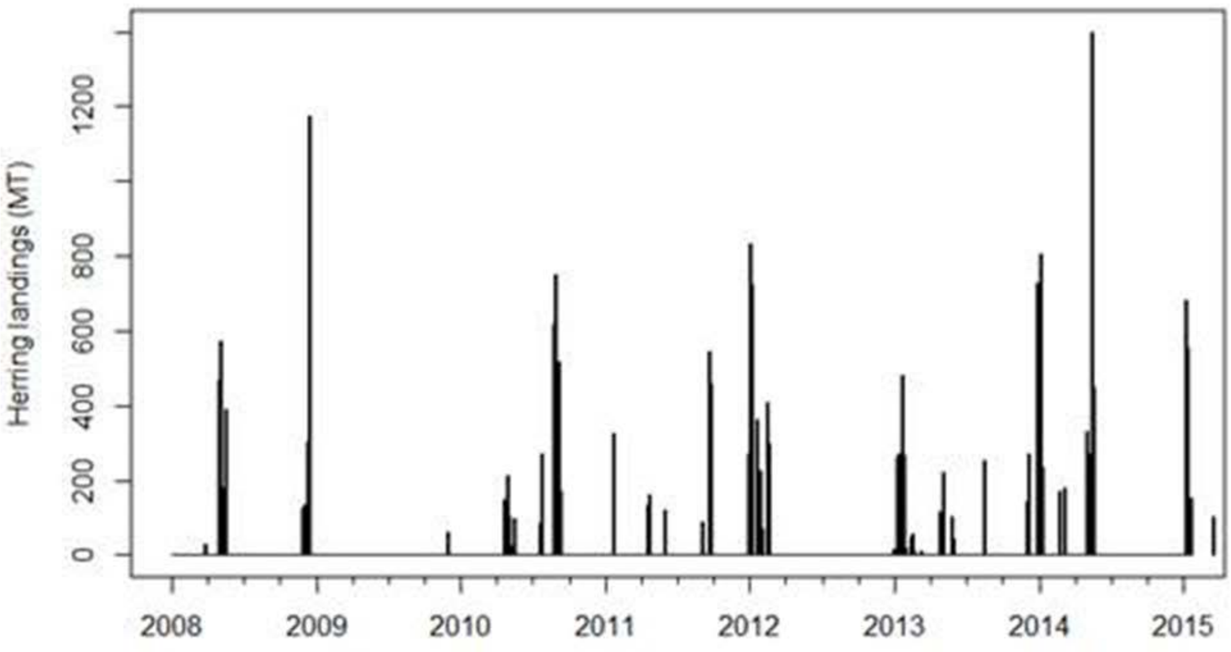
Table 7 - Number of commercial fishing trips that landed 6,600+ pounds of Atlantic herring from within 12 miles of shore in 30-minute square 114

YEAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	0	0	1	2	8	0	0	0	0	0	1	9	21
2009	0	0	0	0	0	0	0	0	0	0	1	0	1
2010	0	0	0	3	5	0	4	8	12	0	0	0	32
2011	2	0	0	4	0	1	0	0	11	0	0	2	20
2012	11	6	0	0	0	0	0	0	0	0	0	0	17
2013	12	4	1	1	5	0	0	1	0	0	0	5	29
2014	4	1	1	0	13	0	0	0	0	0	0	0	19
Total	**29**	**11**	**3**	**10**	**31**	**1**	**4**	**9**	**23**	**0**	**2**	**16**	**139**

Table 8 - MRIP sampled trips targeting striped bass (n=67) that occurred within +/- one week of commercial fishing trips that landed 6,600+ pounds of herring from the area within 12 nm east of Cape Cod (n=9)

	MRIP trips		
Herring trip date	**Week before**	**Same day**	**Week after**
5/19/2008	0	4	0
5/19/2010	1	0	2
7/25/2010	0	0	6
6/2/2011	0	0	14
9/4/2011	0	0	1
9/25/2011	11	0	0
5/26/2013	3	0	0
5/30/2013	0	0	14
8/16/2013	0	0	11
Total	**15**	**4**	**48**
Note: Number of MRIP trips may be an overestimate.			

Figure 27 – Atlantic herring landings by week for vessels catching >6,600 lbs of Atlantic herring from the area within 12 nautical miles east of Cape Cod, 2008-2014



TASK #6: Tuna fishery catch per unit effort

Describe catch per unit effort in the tuna fishery over time.

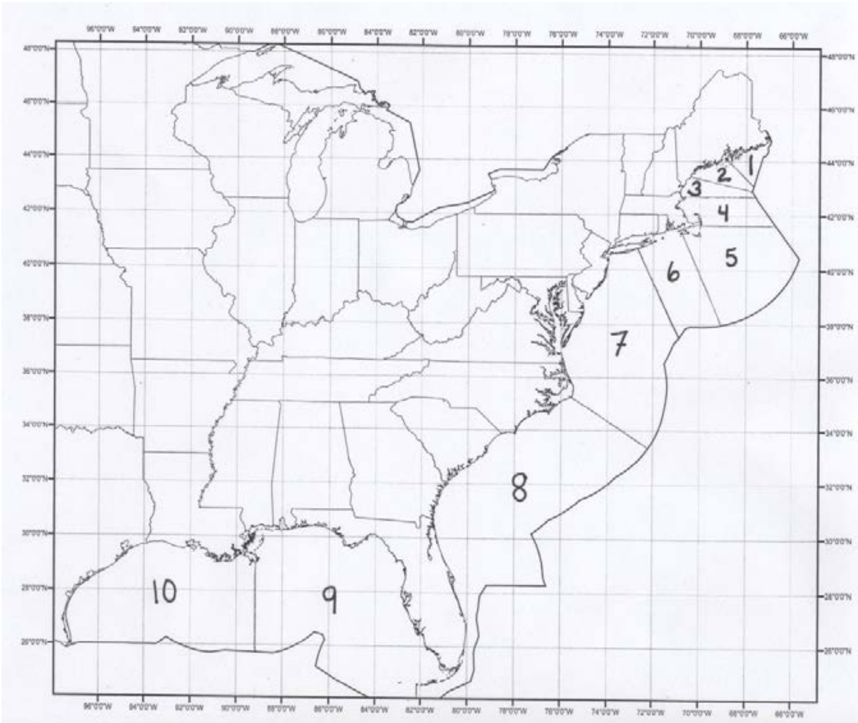
Bluefin tuna fishery overview

The bluefin tuna fishery consists of a variety of permits (Table 9) and gear types, with many management measures specific to the permit or gear (e.g., area closures, trip limits). Although the majority of permits issued are recreational, the majority of landings in 2015 were from the commercial fishery, particularly the handgear and charter/headboat fisheries. Of the commercial landings in 2015, about 90% are attributed to the Northeast reporting areas (Figure 28, Areas 1-6),

Table 9 - Bluefin tuna fishery

<table>
<tr><th>Permit category</th><th>Permits issued in 2016 (#)</th><th>2015 landings (mt)</th></tr>
<tr><td>Commercial</td><td></td><td></td></tr>
<tr><td>Longline/Trap</td><td>275/5</td><td>71.4/0</td></tr>
<tr><td>Harpoon</td><td>17</td><td>43.8</td></tr>
<tr><td>Purse seine</td><td>5</td><td>33.9</td></tr>
<tr><td>General category (rod & reel, handline, harpoon)</td><td>3,100</td><td rowspan="2">614.8</td></tr>
<tr><td>Charter/Headboat</td><td>3,600</td></tr>
<tr><td>Recreational</td><td></td><td></td></tr>
<tr><td>Angling</td><td>21,000</td><td>113.1</td></tr>
<tr><td colspan="3">Source: NMFS HMS office</td></tr>
</table>

Figure 28 – Highly Migratory Species reporting areas



Source: NMFS HMS office

Commercial data limitations

It is not currently possible to calculate catch per unit effort (CPUE) for the U.S. commercial bluefin tuna handgear fishery. The effort data for the commercial fishery are insufficient; most bluefin tuna fishermen are not required to report tuna trips with no landings, which can be quite common as there are many trips with no landings in this fishery. Vessels with Highly Migratory Species (HMS) permits are not required to submit Vessel Trip Reports (VTRs); there is no harvester reporting requirement unless the vessel holds a permit that requires a VTR be submitted (VTRs are for all species). There is some overlap between the VTR data and tuna trips, but it is a subset of the tuna trips. The only commercial bluefin tuna vessels required to report trip data (and have a Vessel Monitoring System) are the pelagic longliners (with log books). Purse seine vessels must also have VMS. Since 2015, the handgear fishermen are required to report catch (landings and discards), but there is no requirement to report trips with no catch.

In consultation with the HMS office at GARFO, the PDT examined how the number of zero trips might be identified for the commercial bluefin fishery, but concluded that a robust estimate is not possible under current reporting requirements. The NEFSC observer program does not observe the tuna fishery (i.e., no observer coverage for handgear fishermen), apart from when a trip is fishing under an Experimental Fishing Permit. The longline fishery (pelagic and bottom) is observed by the Southeast Fisheries Science Center (SEFSC) pelagic observer program.

Even if commercial CPUE could be calculated, there are limitations as to what could be concluded, particularly relative to localized depletion. Commercial bluefin tuna landings have been sensitive to the bag limit, which has varied over time.

Recreational data

The Large Pelagics Survey (LPS) intercept recreational fishermen for bluefin tuna (and other large pelagics) from Maine to Virginia at boat ramps or over the telephone.[1] Here, "recreational" includes charter, private, and party boat). It is similar to the MRIP program for other recreational fisheries, and is administered by NMFS Science and Technology office at Headquarters. The LPS data are the best for characterizing the recreational bluefin tuna fishery and include catch and effort information, including data from zero landings trips. Recreational anglers are also required to report to the HMS office (online or with paper catch cards) when they land a tuna.

The SEFSC takes the lead on bluefin science for NMFS; all CPUE calculations and information that contribute to stock assessments are conducted by the SEFSC. The SEFSC uses CPUE and other fishery information to estimate relative abundance indices for three size classes of tuna (small school, large school, and large), because each size class has unique daily catch limits and fishery closures. Estimations of relative abundance include a number of factors, such as number of anglers fishing, number of lines in the water, hours fished, fishing method, fishing area, and month. Only annual CPUE calculations are made from the LPS data, not by month or other time intervals. Fishing effort is defined as hours fished

Lauretta and Brown (2015) include annual CPUE for the U.S. bluefin tuna rod and reel/handline fishery by size class. Figure 29 to Figure 31 contain the CPUE and relative abundance indices for the three size classes since 1993. Indices, particularly the negative binomial index generally fit with the CPUE, with the exception of the Large School (115-144 cm SFL) size class in recent years, likely due to the northerly shift in LPS samples to areas where these fish are likely less abundant. Large (>177 cm SFL) and Small School (66-114 cm SFL) CPUE and indices have less inter-annual change since 2003 and 2006 and are generally lower than in the years , respectively be generally lower than in the 1990s.

Discussion

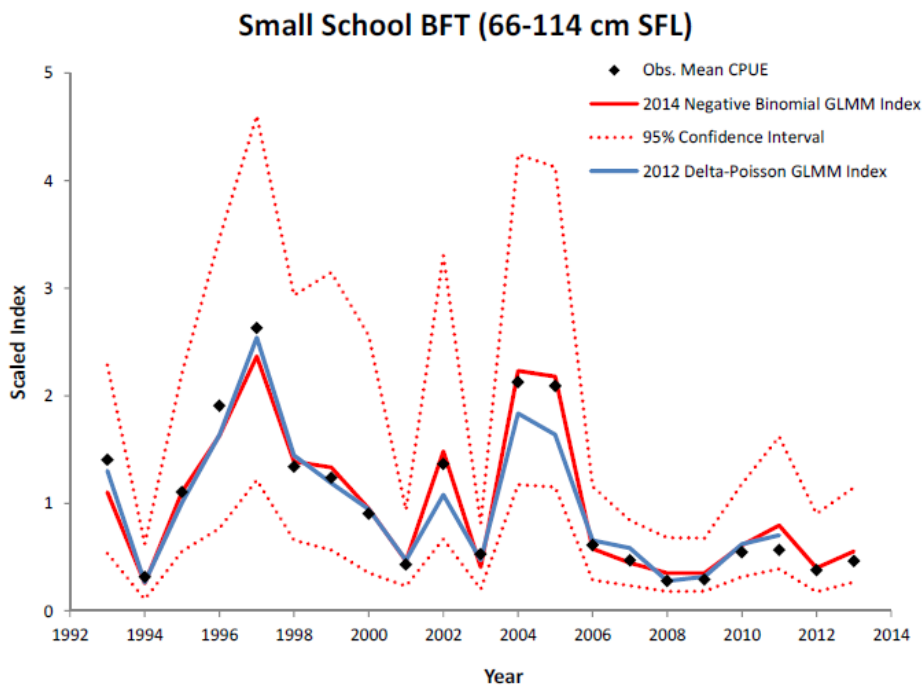
Most discussions about the rod and reel indices have focused on the divergence between the Canadian and the U.S. indices of abundance - that the Canadian indices have been increasing while the U.S. has remained relatively constant in recent years. There is no scientific consensus about what may be driving this divergence. Possible factors/hypotheses include:

- The availability/timing of tuna may have shifted to northern latitudes due to climate change and/or shifts in availability of prey.
- The U.S. handgear fishery may be hampered due to large volumes of dogfish eating bait in the rod and reel fishery.
- The LPS as a survey tool has undergone several changes in administration and survey design that may be influencing the outcomes.
- Changing regulations (e.g., trip limits, area closures) influence the ability to catch the target fishery.

These issues are a matter of ongoing discussion in the tuna science and management community. None of the data signal one hypothesis over another.

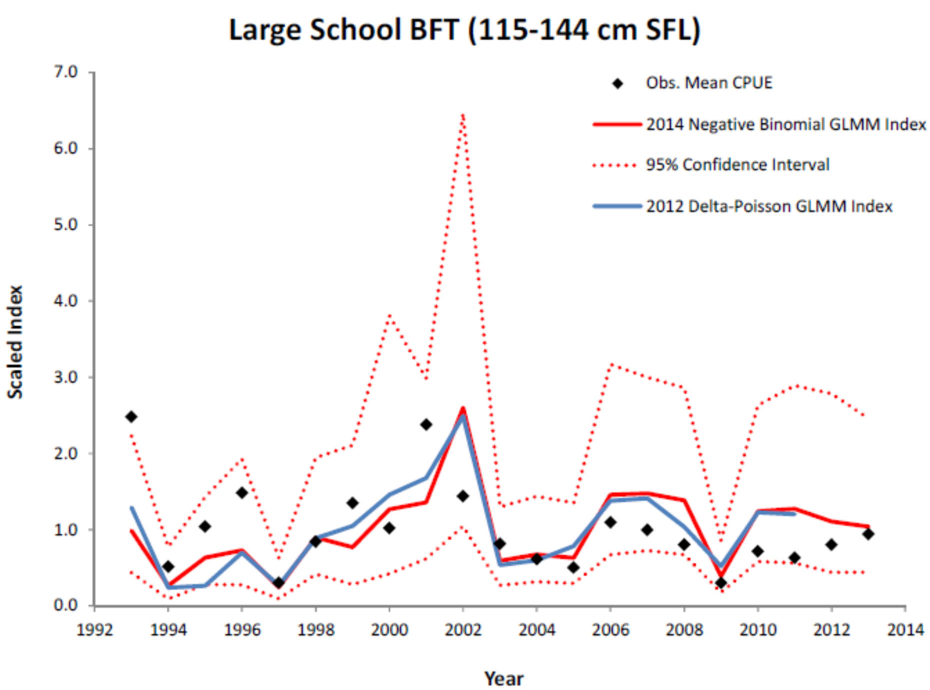
[1] http://www.st.nmfs.noaa.gov/recreational-fisheries/Surveys/survey-details

Figure 29 - Comparison of small school bluefin tuna (SMSM) standardized time series with nominal catch rate data and previous delta-Poisson model



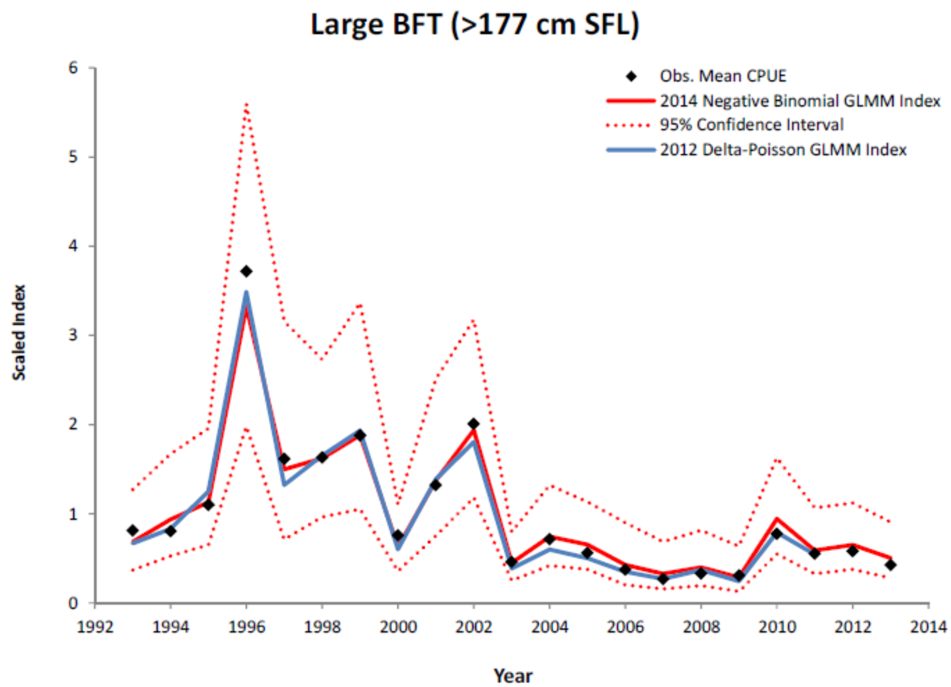
Source: Lauretta and Brown (2015).

Figure 30 - Comparison of large school bluefin tuna (LGSM) standardized time series with observed mean and previous delta-Poisson model



Source: Lauretta and Brown (2015).

Figure 31 - Comparison of large bluefin tuna (LGMD_LG) standardized time series with observed mean and previous delta-Poisson model



Source: Lauretta and Brown (2015).

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