Executive Office of Energy and Environmental Affairs
Massachusetts Office of Coastal Zone Management

Fisheries
Work Group Report

2020 Massachusetts Ocean Management Plan Review

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1. Work Group Members

Kathryn Ford (Chair), MA DMF Habitat Program, kathryn.ford@mass.gov
Tom Shields, MA DMF Shellfish, thomas.shields@mass.gov
Robert Glenn, MA DMF Survey and Assessment Program, robert.glenn@mass.gov
Tracy Pugh, MA DMF Invertebrate Fisheries Project, tracy.pugh@mass.gov
Story Reed, MA DMF Statistics, story.reed@mass.gov
Greg DeCelles, MA DMF Groundfish, gregory.decelles@mass.gov
Chris Schillaci, MA DMF Shellfish, christopher.schillaci@mass.gov
Jon Hare, NOAA NEFSC Science Director, jon.hare@noaa.gov
Alison Verkade, NOAA GARFO, alison.verkade@noaa.gov
David Stevenson, NOAA GARFO, david.stevenson@noaa.gov
Steve Cadrin, SMAST Dept Fisheries Oceanography, scadrin@umassd.edu
Chris McGuire, TNC Federal Fisheries, cmcguire@tnc.org
Emily Shumchenia, NROC Northeast Ocean Data Portal, emily.shumchenia@gmail.com
Nick Napoli, NROC Northeast Ocean Data Portal, nicknapoli01@gmail.com
Samantha Coccia-Schillo, CZM GIS Specialist, samantha.coccia-schillo@mass.gov
Prassede Vella, CZM Ocean Planning Lead, prassede.vella@mass.gov

Recreational Fishing Advisory Committee Members
Kevin Blinkoff, Executive Editor, On The Water Media
Kalil Boghdan, Down River Charters
Tim Brady, Tim Brady & Sons Charters
Raymond Kane, Massachusetts Fisheries Advisory Commission Chairman
Mike Pierdinock, CPF Charters

2. Overview

On November 18, 2019, the Massachusetts Division of Marine Fisheries convened a Fisheries Work Group to discuss if and how to update three maps in the Massachusetts Ocean Management Plan: important fish resource areas, high commercial fishing effort and value, and concentrated recreational fisheries activity. The Work Group also discussed the need for additional layers and how to include aquaculture. The assessments recommended by the Work Group were discussed by CZM staff and the Science Advisory Council on January 29, 2020. Work Group discussions were held via email from March to July 2020 and separate virtual meetings to discuss the concentrated recreational fisheries layer and the commercial fisheries effort and value layer were held on July 7 and August 27 2020, respectively. In September 2020 the Work Group results were discussed by the Science Advisory Council and the Ocean Advisory Commission. Additional work on the commercial fisheries effort and value layer was completed by a subgroup of DMF and CZM staff from November 2020 to January 2021. This report represents the Work Group recommendations for SSU and existing use layers in the 2020 Ocean Plan Update. Drafts of this report were improved by the comments identified in the advisory and public meetings. The primary changes recommended by the Fisheries Work Group are as follows:

- High commercial fishing effort and value – update with more recent data, use last 10 years of data.
- Concentrated recreational fishing – no change, add new survey to science priorities.

- Important fish resource areas – use a vulnerability approach and include the cod spawning area for separate important fish resource SSU layers for cables, pipelines, and sand mining. Develop an important fish resource areas for renewable energy in a future iteration.
- Fixed fishing facilities – update this layer and include as an area of Water Dependent Use.

3. Introduction

The primary charge of the Fisheries Work Group (as well as the other five work groups) was to identify changes to the Special, Sensitive, and Unique (SSU) resource areas and existing water dependent use (WDU) maps that were developed in 2014 for the 2015 Ocean Plan (EEA 2014). The charge to the Work Group includes other priorities, such as updating the baseline assessment and discussing the science framework, that are being addressed outside of the scope of this report. There is one SSU resource, important fish resource areas, and two existing WDU maps, high commercial fisheries effort and value and concentrated recreational fisheries, that the Work Group mapped in 2009 and 2014 and reassessed this year for the 2020 Ocean Plan Update. Additionally, the Work Group discussed how the Ocean Plan should address fixed water dependent facilities including fish weirs and aquaculture. This report describes the reassessment work done for each of these topics.

4. High commercial fishing by effort and value

4.1 Methods

For this Ocean Plan Update, the Fisheries Work Group conducted several analyses. The first was the 1988-2018 time series analysis using a fixed price model for assessing value. This analysis most closely resembles the analyses used in the high commercial fishing effort and value maps in the 2009 and 2015 Ocean Plans.

The Fisheries Work Group also recommended developing maps that used the truncated time series of 2010-2019 since the past decade of fishing activity best reflects existing uses in the ocean planning area. A subgroup of the Fisheries Work Group analyzed the truncated time series with both the fixed price model used in previous Ocean Plans and an adjusted price model using prices reported by year as using a single year's price could result in misleading patterns. This time series was also modeled with and without the lobster fishery.

The two time-series' use different end points due to the length of time it took to complete this work. Since the Work Group recommended moving forward with the truncated time series (which was originally done with 2010-2018 data), the more complicated 1988-2018 model was not updated to include 2019.

4.1.1 Non-shellfish

The 1988-2018 time-series analysis used the same methods as described in previous Fisheries Work Group reports to map non-shellfish commercial effort and value. This analysis required combining multiple harvester catch reporting systems and dealer reports to generate a map that represented regions where both high effort and high value fisheries occurred. The full description of the method used to combine multiple types of catch reporting systems is available in the previous Fisheries Work Group reports (EEA 2009, EEA 2014).

The 2010-2019 time-series analysis relied on the trip-level reporting data from the comprehensive mandatory trip-level reporting program that DMF implemented in 2010 for all fisheries. The trip-level reporting program eliminates known data gaps in pre-2010 DMF catch report data and minimizes duplication between federal and state data collection programs. Since the NMFS VTR program collects the same type of data at the trip-level from federal permit holders, those individuals were exempt from reporting to DMF and DMF collected those data from NMFS VTRs. To integrate the DMF and NMFS trip-reports, a spatial routine was run to translate the latitude and longitude coordinates provided on the NMFS VTR to DMF Statistical Reporting Areas (SRA) (Figure 1). These data were combined with the DMF trip-level reports creating the final dataset used in this analysis.

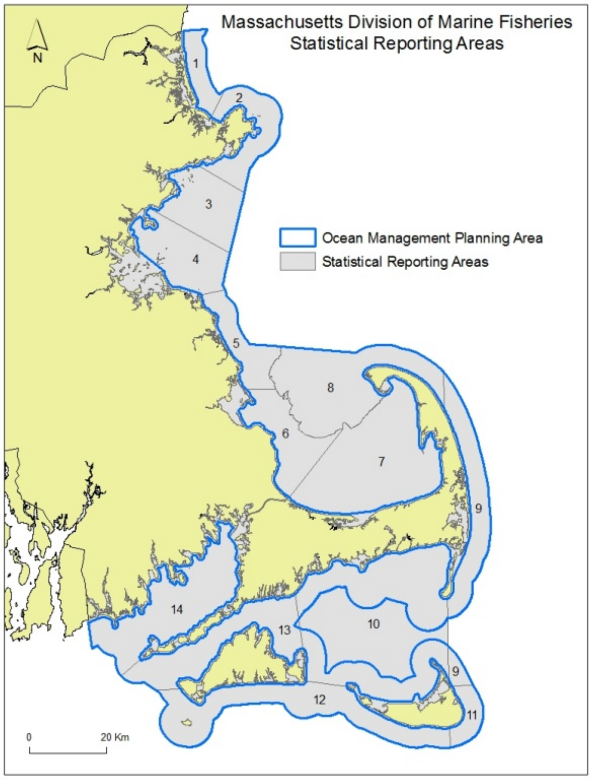


Figure 1. DMF Non-Shellfish Statistical Reporting Areas. Ocean Planning area is blue boundary line.

For the assessment of effort, trips were calculated in a manner consistent with the method used for the DMF fishery-specific catch reports (1988-2009) in previous reports. This was done because trip-level data can accommodate multiple areas *per trip,* thus simply summing trips by SRA from trip-level data could potentially inflate the number of *actual* trips. Landings were converted to live pounds (whole animal, shell on) based on the grade and market reported by the harvester. The dataset was then truncated to only include data from State Waters (SRA<15).

For the assessment of value, live pounds for all non-shellfish species reported on harvester catch reports were converted to values by multiplying them by the Massachusetts state-wide landings-weighted average price per live pound, using 2018 average price for the 1988-2018 analysis and 2019 average price for the 2010-2019 analysis. This "fixed price" model was similar to the analysis done for the 2009 and 2015 Ocean Plans, which used 2007 and 2012 average prices, respectively (Appendix A).

The Fisheries Work Group recommended updating the method for incorporating price information since any changes in price between the iterations at the individual species level could impact the value and subsequent relative weighting of commercial importance in this analysis. For example, a species with constant landings between 1988 and 2012 that experiences a major price increase in 2012 relative to 2007 would have had more importance in the 2015 Ocean Plan. Therefore, to limit the impact of this type of value assessment in this Ocean Plan Update, an "adjusted-price" analysis was used for the 2010-2019 time series, whereby live pounds were converted to values by multiplying them by the landings weighted average price per live pound reported in each year. The adjusted price model does not incorporate estimates of inflation, but provides true values associated with each species each year.

For both time series (1988-2018 and 2010-2019), value and effort information were then aggregated by SRA and year. These annual totals by SRA were then averaged across the time-series and divided by the square kilometers of their corresponding SRA to arrive at a measure of fishing effort and value per unit of area. These estimates were used for the non-shellfish component of 2019 Ocean Plan Update commercial fisheries analysis.

Finally, the 2010-2019 fixed and adjusted-price datasets were analyzed without lobster landings to examine spatial patterns driven by other fisheries that may be overwhelmed by the dominant lobster fishery.

4.1.2 Shellfish

The shellfish component of the analysis used Massachusetts dealer reported shellfish transactions from the Standard Atlantic Fisheries Information System (SAFIS) for both time series, 1988-2018 and 2010-2019. Each transaction, e.g., each trip/DSGA combination, was considered to represent one fisherman trip. Total number of trips and landings value were tallied by Designated Shellfish Growing Area (DSGA; Figure 2) and averaged over the available years. When no price or value information was provided by the dealer, values were derived by multiplying the live pound landings by the state-wide landings-weighted average price per live pound in accordance with each price model. In the fixed-price, 2010-2019 model, the 2019 average was applied to all years whereas in the 1988-2018 model, the 2018 average was applied to all years; in the adjusted price model, averages from the year in question were applied to that year. Records missing a DSGA were removed in all analyses. The values were then divided by the square kilometers of each DSGA to obtain average trips and landings value per square kilometer.

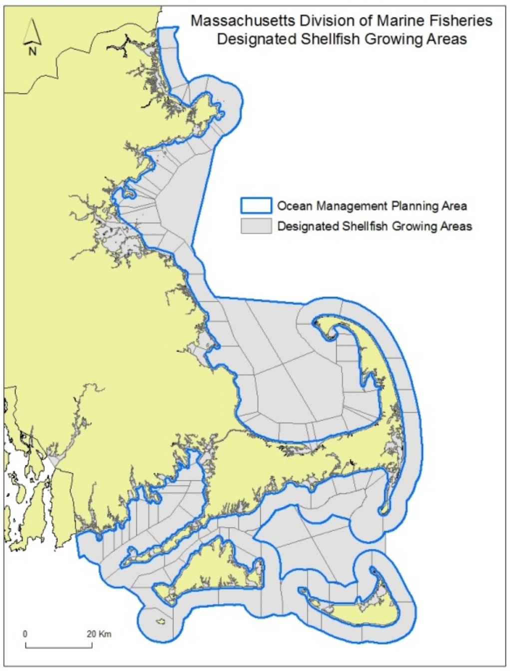


Figure 2. Designated Shellfish Growing Areas updated 1/10/2014. Ocean Planning area is blue boundary line.

4.1.3 Geoprocessing

Spatial analysis utilized ArcGIS Pro 2.X software for all geoprocessing. All geoprocessing analysis steps remained consistent with the analyses done for the 2009 and 2015 Ocean Plans and are outlined in Appendix B.

All sources of commercial fishing effort and landings value data were converted to a 250 m^2 raster grid and condensed into two layers representing the combined fishing effort across all commercial fisheries, and the combined value of landings generated by those fisheries for the shellfish and non-shellfish components (DSGA and SRA, respectively). The raster grid was then clipped to the ocean management plan boundary. To prevent the scale of commercial fisheries in one part of the state overshadowing the importance of those in other parts of the state, the planning area was broken into two regions: north of Cape Cod and south of Cape Cod (Figure 3). The two raster layers (combined fishing effort and total landings value) were then re-classified into 10-percentile bins, within each of those regions. With the two layers now on the same relative scale, they were added together (i.e. given equal weight). The resulting combination was re-classified into high (top 25%), medium (middle 50%)

and low (bottom 25%) categories within each region. These geoprocessing steps were applied to both time-series (1988-2018 and 2010-2019).

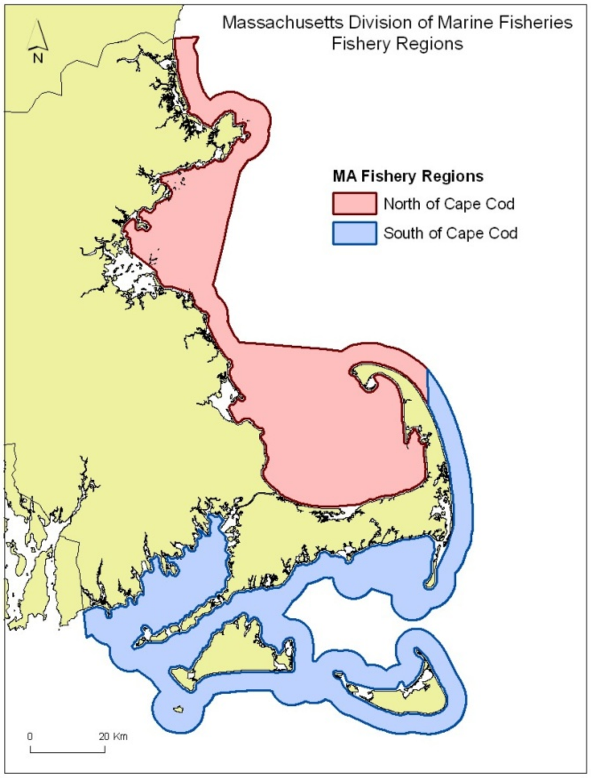


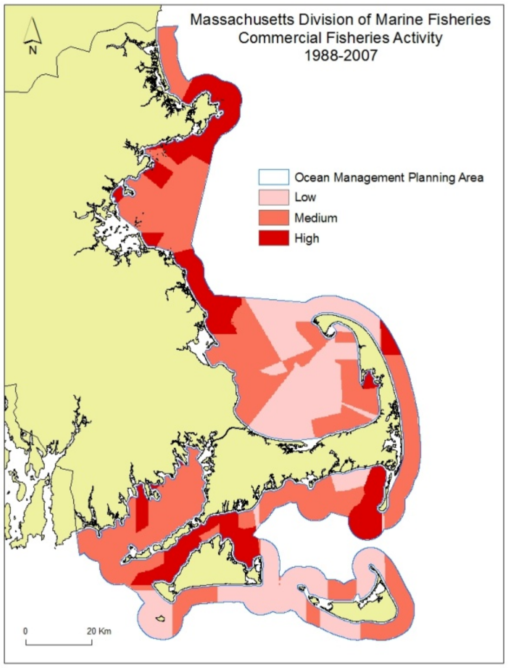
Figure 3. Regions used in commercial fishing analyses.

4.2 Results

4.2.1 1988-2018

The most direct comparison with previous Ocean Plans is the 1988-2018 time series map (Figure 4).

A



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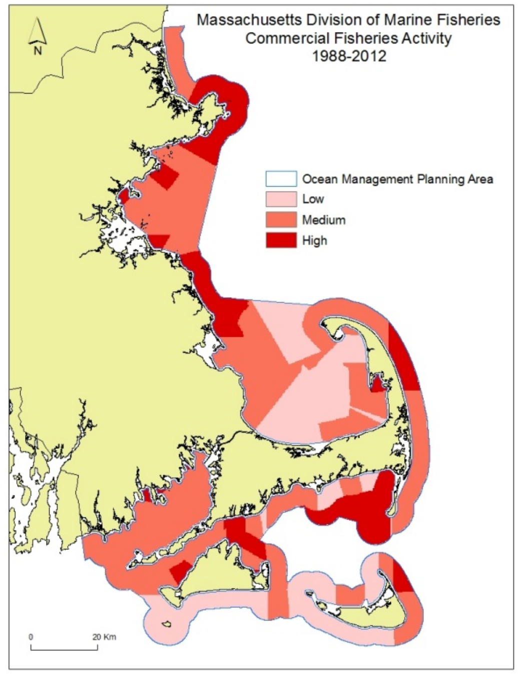

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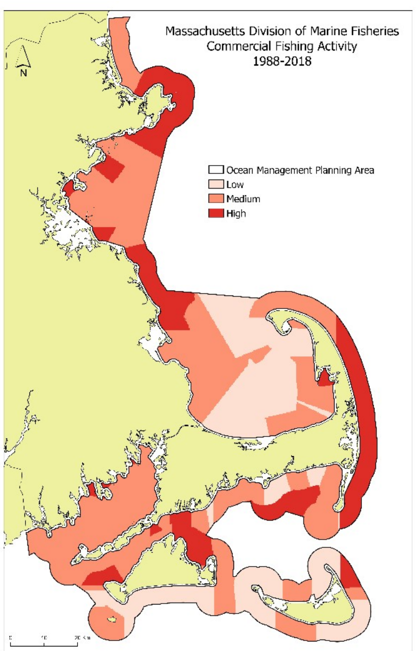

Figure 4. Commercial Fisheries Activity raster maps. (A) 2009 Ocean Plan using 1988-2007 data (top left), (B) 2014 Ocean Plan Update using 1988-2012 data (top right), and (C) 2019 Ocean Plan using 1988-2018 data (bottom left). High, medium, and low values are scaled and relative to each region, north and south of Cape Cod.

4.2.2 2010-2019

For this time series, there are four maps: the effort and value using 2019 prices, the effort and value using adjusted prices, and both maps without lobster (Figure 5).

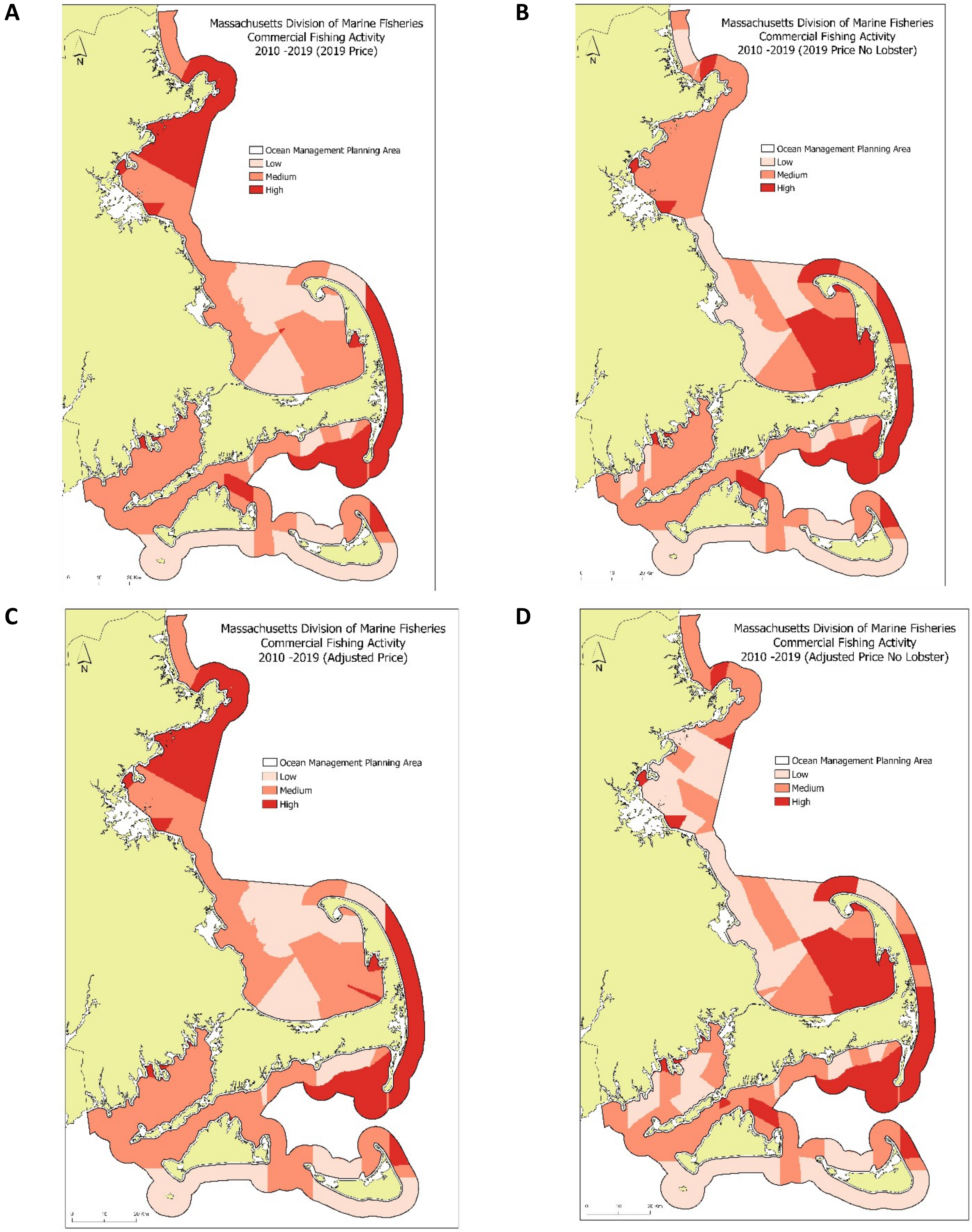

Figure 5. Commercial Fisheries Activity raster maps. (A) 2010-2019 data with 2019 price (top left), (B) 2010-2019 data with 2019 price and no lobster (top right), (C) 2010-2019 data with adjusted prices (bottom left), and (D) 2010-2019 data with adjusted prices and no lobster (bottom right). High, medium, and low values are scaled and relative to each region, north and south of Cape Cod.

The Fisheries Work Group recommends using the values with adjusted prices in the truncated time-series (2010-2019) commercial fisheries activity raster map (red polygons in Figure 5C) as the updated "High Commercial Fishing by Effort and Value" map in the 2019 Ocean Plan Update.

4.3 Discussion

In previous ocean plan updates, using all the relevant data was deemed important to get a sense of longer-term patterns. In the 1988-2018 time series, which can be compared to past ocean plan maps, the subtle changes between the different time series (Figure 4) are hard to interpret since the spatial patterns of fishing activity change over time in response to market forces, management actions, abundance, etc. However, the stability of high effort and value areas in the northern region is noteworthy. This is likely driven by the relative stability of the influence of the Gulf of Maine lobster industry.

The Fisheries Work Group concluded that more recent patterns are most relevant to use for ocean planning purposes. Furthermore, the consistency of the dataset from the implementation of trip-level reporting across the fisheries limits risk of error. Therefore, the high commercial fishing by effort and value map was updated using the 2010-2019 time series. Additionally, the analysis is more accurate with annual price adjustments over the time series. To determine how impactful the change from the fixed price model to the adjusted price model was, the two were compared (Figure 5). Differences were found to be minimal, so using the improved model does not introduce noteworthy changes.

It is important to remember that the final maps convey relative importance of fisheries activity in two regions: north of the Cape and south of the Cape (Figure 3). Therefore, the absolute values reflected in an area with "high" effort and value may be quite different. In general, due to the influence of American lobster and oyster aquaculture landings, effort and value absolute values are higher in the region north of the Cape than south of the Cape. Spatial scales also play a critical role when interpreting these results. The areal units used to report and aggregate these data are coarse. Concentrated commercial fisheries can occur in locations that exist at finer spatial scales than can be accurately detected by these data. Conversely, concentrated fishing in an isolated portion of an areal unit will influence the value for the entire areal unit, which is potentially misleading for locations within that unit where no commercial fishing occurs. Other jurisdictions are addressing this issue through Vessel Monitoring Systems (VMS), which provide a much finer resolution spatial data. However, many of the Massachusetts fisheries are not covered by VMS due to size or activity in fisheries that are not federally managed (Appendix C), which is the primary reason the Work Group did not recommend focusing on VMS data.

The accuracy of these data depends upon commercial harvesters and dealers accurately and completely reporting their data, especially the area information. The shellfish component of the analysis depends on dealers assigning the correct DSGA to shellfish transactions. Though this is a required field, compliance is a challenge. If a dealer fails to correctly assign a DSGA to a shellfish transaction, that transaction would either be omitted (if no DSGA indicated; averaging less than 0.3% of all transactions each year) or mis-represented (if the incorrect DSGA was reported). This may be why some ports show unexpected high activity. In some cases, transactions may be legitimately reported without a DSGA because a species was harvested from offshore waters outside MA State Waters, or dealers may not realize they need to provide a DSGA for species. If the DSGA from legitimate State Waters shellfish harvest is not provided, especially when concentrated within a specific species, there is the potential to underrepresent that species in this analysis. Lastly, if any inshore shellfish data are missing from the dealer dataset altogether, they will not be represented in this dataset. There are several known caveats for this in earlier years of the dataset, particularly in the Falmouth and Chatham regions. However, the affected DSGAs are primarily excluded from this analysis due to the ocean plan boundary. In recent years, improving the legitimacy of DSGA reporting for inshore shellfish has been prioritized; therefore, DSGA activity from 2017 forward is considered validated whereas earlier years carry more of the stated caveats.

Much of the trends seen in previous Ocean Plans and in the 2010-2019 analysis are driven by American lobster landings. State water lobster landings and value were more than double that of any other species in most years and is well documented within the last decade (DMF 2011-2019). In the last 10 years, the lobster fishery primarily occurred north of Cape Cod with a reduction in activity south of Cape Cod. This drives the stability of the northern region seen in all models. When lobster effort and value were removed, the most notable changes occurred north of Cape Cod, particularly off of Cape Ann and in Cape Cod Bay (Figure 5). The southern region remained more stable with and without lobster because the fishery makes up a far less percentage of the landings and value as compared to the north region. Other species driving some of the high effort and value are likely a mix of shellfish, inverts, and finfish. For example, whelk is a prominent fishery in Nantucket sound. The outer cape has a mix of lobster and finfish, with some shellfish as well. Cape Ann is driven by a mix of inshore shellfish species when excluding lobster.

A notable commercial fisheries trend in the past decade that is not evident in the mapping is the greater than 300% increase in oyster effort and value between 2010 and 2019 (DMF 2019). This is due to a boom in aquaculture beginning in 2012 that has resulted in oyster becoming the second highest valued state waters species trailing only lobster. In value, oyster is consistently close to double the next highest species in the more recent years of the time series[1]. The ocean plan boundary does not include a lot of the inshore areas throughout Massachusetts, and this is where much of the oyster aquaculture activity occurs. A few DSGAs that do have oyster activity are highlighted in Figure 5, primarily in Cape Cod Bay, and more specifically Wellfleet and the high activity spot in the eastern part of the bay. Other areas with very high effort and value include areas outside of the ocean management planning area, such as Duxbury and Plymouth.

Consistent with the conclusion reached in the 2014 Ocean Plan Update, the Fisheries Work Group sees great value in better spatial assessment of the individual fisheries and fishing practices for both screening purposes and the determination of potential impacts from a given project. The impacts of construction projects on commercial fisheries will vary for fixed and mobile gear fisheries and the mobility of the species being targeted (e.g. surf clams compared to finfish). Additionally, providing more information on the ranked areas, such as what fisheries are occurring and some absolute values of effort and landings within some of the highlighted areas may help better inform decision making efforts. The various stages of construction projects all have unique potential impacts and timing can heavily influence the amount of impact anticipated.

5. Concentrated recreational fishing

5.1 Background

For the 2009 and 2015 Ocean Plans, a survey was sent to expert fishermen (including charter boat captains and Division of Marine Fisheries employees) with maps of four different regions of the state. Both surveys provided maps of the state and requested information regarding concentrations of recreational fishing activity (where fishermen fish). Seventeen fishermen in 2009 and twenty-eight fishermen in 2015 responded by drawing polygons on the maps; their maps were georeferenced and digitized. The individual survey results were gridded into 250m^2 cells. In 2009, all survey results were used to identify areas of concentrated recreational fishing (Figure 6A). In 2015, a heat map was

[1] In 2019 state-wide, oyster was estimated at $30 mil and the next species is haddock at $18 mil. In 2018 state wide, oyster was estimated at $28 mil and surf clam was next at $17 mil (surf clam is primarily offshore).

generated identifying degree of overlap in the 2015 survey results (Figure 6B), and any area with a survey response was used to identify areas of concentrated recreational fishing.

A **B**

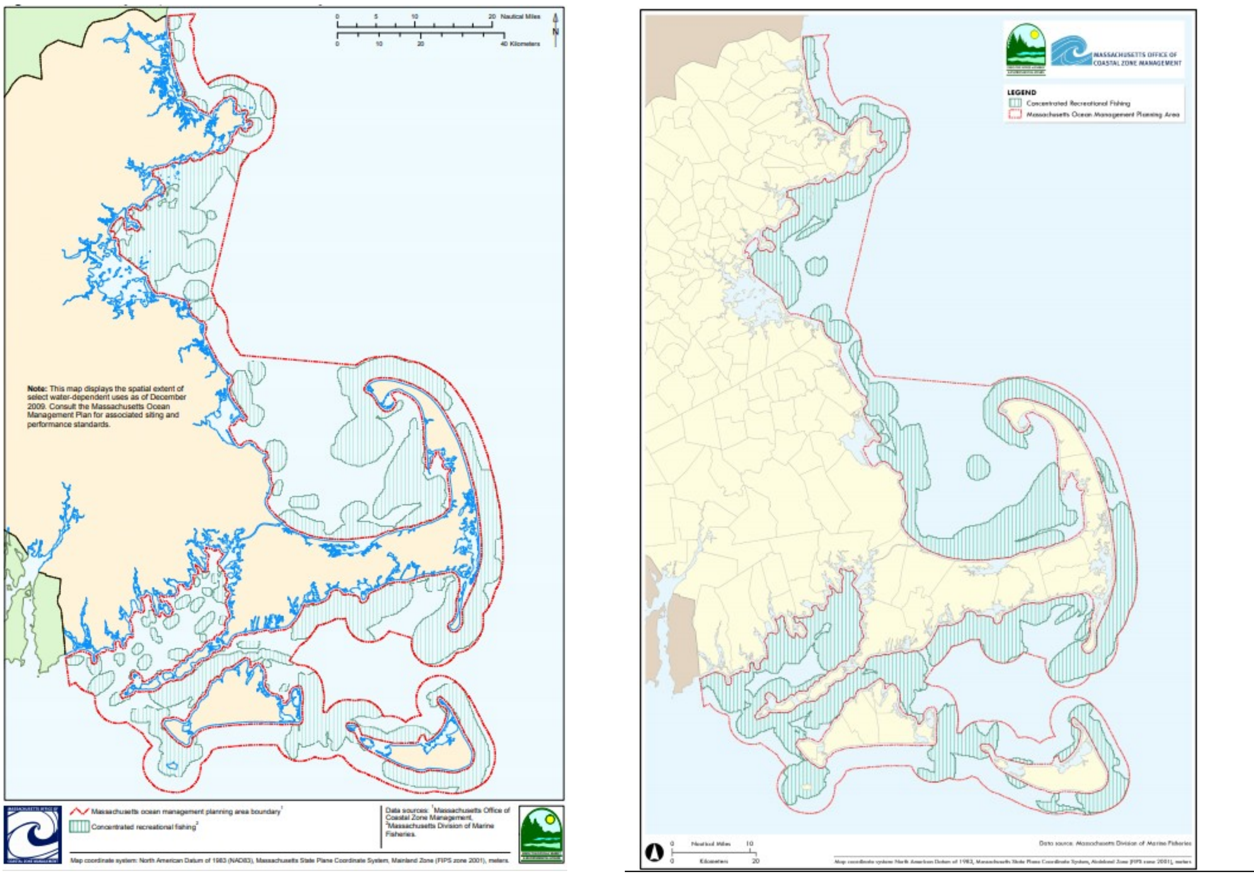

Figure 6. (A) 2009 Massachusetts Ocean Plan Concentrated Recreational Fishing map (Figure 2-15 from the MOP). Any cell with a survey response was used to identify concentrated recreational fishing in the 2009 ocean plan map. (B) 2015 Massachusetts Ocean Plan Concentrated Recreational Fishing map (Figure 17 from the MOP). Any cell with a survey response was used to identify concentrated recreational fishing in the 2015 ocean plan map.

5.2 Methods and Results

For the 2020 Ocean Plan, the original methods were revisited first by the Fisheries Work Group and then by a subcommittee of the Marine Fisheries Advisory Commission (MFAC) with expertise in recreational fishing.

No additional datasets were identified that could improve the mapping resolution of the 2014 map and the map captures major areas of fishing activity. The MFAC subcommittee recommended redoing the survey but it should attempt to get feedback from 2,000 fishermen. Since resources were not available to conduct the survey, it is recommended as a science priority. Lacking a new survey, the subcommittee recommended keeping the 2015 map as the Concentrated Recreational Fishing map.

5.3 Discussion

The recreational fishery is surveyed using the Marine Recreational Information Program (MRIP) survey, which is a state-regional-federal partnership that collects data about how often anglers fish and what they catch. A pilot study in 2013 added a voluntary fishing location question to the survey. The question was ultimately removed since the change to the survey methodology was not approved by all

MRIP states as required for survey standardization. Adding this information to the survey is not seen as a high priority or likely for MRIP.

Since the existing MRIP survey cannot be used to assess location of recreational fishing, the subcommittee recommended conducting another survey similar to the efforts in 2008 and 2015. To improve the accuracy of the survey, the subcommittee recommended that the state could use the 150,000 person angler database generated from the recreational fishing license to send out the survey, and that a new survey effort should consider other survey methodologies such as utilizing cell phones or vessel GPS devices. Also of interest for future discussion is including recreational lobster. The reporting standard for recreational lobster changed in 2011 and may provide useful information for ocean planning. The majority of this activity is thought to be outside of the ocean planning area, so it wasn't prioritized this year. Shellfishing was also recognized as an important recreational fishing activity that occurs primarily outside of the ocean planning area. Neither the Work Group or subcommittee identified a source of information that could be used to better understand the spatial distribution of recreational shellfishing; it is thought that a town-by-town approach will be needed.

6. Important fish resource areas

6.1 Methods

A primary goal of the ocean planning process is to create layers with statewide extent for the purpose of site selection screening for wind power and other ocean uses. In 2009, 2014, and 2020, the important fish resource area assessment relied exclusively on fisheries-independent otter trawl survey data collected by DMF each year in September and May since this dataset has the most reliable, consistent statewide extent for fish species composition, biomass, and abundance. All trawl survey stations are located within the ocean management plan boundary. The trawl survey purpose is to measure changes in the relative abundance of commercially and recreationally important groundfish over time. The survey has 23 strata, stratified according to depth and region. Over time, the survey has collected 181 species. The top 10 species by biomass and abundance from 2008-2018 are listed in Table 1. The species on both lists are scup, butterfish, winter flounder, silver hake, and red hake.

Table 1. Total abundance and biomass, Massachusetts spring and fall trawl surveys 2008-2018.

Species	Abundance	Species	Biomass, kg
SCUP	1,918,417	SPINY_DOGFISH	51,644
BUTTERFISH	544,004	SCUP	18,034
BAY_ANCHOVY	447,527	LITTLE_SKATE	13,900
LONGFIN_SQUID	322,629	WINTER_FLOUNDER	8,257
BLACK_SEA_BASS	115,533	WINTER_SKATE	8,175
NORTHERN_SAND_LANCE	70,521	AMERICAN_LOBSTER	7,701
WINTER_FLOUNDER	47,880	BUTTERFISH	5,427
SILVER_HAKE	37,700	SMOOTH_DOGFISH	4,305
ATLANTIC_ROCK_CRAB	35,440	SILVER_HAKE	3,860
RED_HAKE	33,783	RED_HAKE	3,696

The trawl survey results were compiled for these analyses according to the survey strata since that is the appropriate scale of analysis based on the survey design. However, since some strata are not spatially contiguous due to the need to have enough area in which to randomly assign multiple tows (Figure 7), other spatial distribution errors can be introduced. Also, the trawl survey samples less in areas with large amounts of fixed gear and hard bottom.

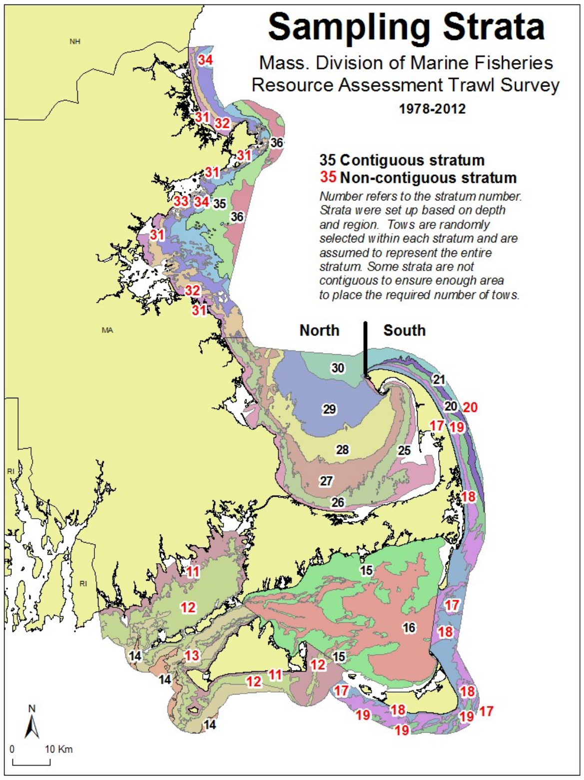

Figure 7. Contiguous and non-contiguous sampling strata. North-south break indicated by black line.

For the 2020 Ocean Plan Update, two analyses were conducted. The first analysis used the same analysis done for the 2009 Ocean Plan and the 2015 Ocean Plan Update. This method is described below as the "composite method." The second analysis, the "vulnerability method," reflects on how the ocean plan is being used to inform and screen specific types of construction activities and focuses on species that are potentially vulnerable to those activities.

6.1.1 Time period

The composite assessment was done using multiple time periods. Based on the Fisheries Work Group recommendation, the survey years 1978-2018 were used to compare to analyses done in 2009 and 2015. For the 2020 update, the Fisheries Work Group recommended comparing the full dataset (1978-2018) to a truncated dataset (2008-2018). The truncated dataset better reflects current areas of high biomass. The vulnerability assessment used data from the 2008-2018 time period.

6.1.2 Species Selection

In the composite analysis, the same species that were analyzed in 2009 and 2015 were used. Twenty-two species were selected for the composite analysis based on their vulnerability to the trawl (e.g. catchability) and their commercial and recreational importance in the state (Table 2). Atlantic cod young-of-the-year and black sea bass young-of-the-year were included as separate species in the assessment. Species biomass distributions are strongly tailed with low or zero catches dominating. Therefore, specific analytical decisions were made in order to achieve the following goal: a statewide distribution identifying strata with relatively high biomass consistently over time for commercially and recreationally important species in the dataset. All statistical and classification work was conducted in R and Excel; maps were prepared in ArcGIS Pro 2.4.

Table 2. Species selected for consideration in the composite Fisheries Resource analysis (in black), the vulnerability Fisheries Resource analysis (in red), and those that overlap (in bold)

American Lobster	Scup	Sand lance
Atlantic Cod	**Sea Scallop**	Surf clams
Black Sea Bass	Silver Hake	Ocean quahogs
Channeled Whelk	**Spiny Dogfish**	Atlantic herring
Haddock	**Summer Flounder**	Dogfish
Horseshoe Crab	Tautog	
Jonah Crab	**Windowpane Flounder**	
Knobbed Whelk	**Winter Flounder**	
Little Skate	**Winter Skate**	
Loligo	**Witch Flounder**	
Red Hake	**Yellowtail Flounder**	

For the 2020 Ocean Plan Update, the Fisheries Work Group recommended creating maps specific for each use in the Mass Ocean Plan. After some discussion, the species selection process focused on species vulnerable to sand mining, cables, and pipelines. Species vulnerable to renewable energy were not discussed since renewable energy was not thought to be a priority in the coming years in state waters and since renewable energy projects may influence pelagic species which the trawl survey does not capture very well. Since different species are vulnerable to different construction activities, maps tailored to each use could better reflect where species vulnerable to that use might be and therefore, improve the protection of those areas. The uses were discussed in turn and two main distinctions were drawn between the relatively greater impacts of sand mining and pipelines and relatively lesser impacts of cable laying (Table 3). The specific species mapped and how they were mapped are in Table 4.

Table 3. Vulnerabilities by project types as discussed by the Fisheries Work Group

Vulnerable to cables	Vulnerable to sand mining & pipelines
(Impacts considered small and temporary enough to not worry about eggs in most circumstances.)	Species w/demersal eggs (e.g. whelk, herring, winter flounder, loligo squid)
Regulated closed areas/fishing protected areas for cod and winter flounder	Regulated closed areas/fishing protected areas for cod and winter flounder and species with migrations impeded by sand mining e.g. crabs, lobster, horseshoe crabs
(Impacts considered small and temporary enough to not worry about sand lance which can move.)	Species dependent on sand habitat e.g. sand lance
Species that can't move from the impact e.g. surf clams, ocean quahog, scallops, adult channeled whelk	Species that can't move from the impact e.g. surf clams, ocean quahog, scallops, adult channeled whelk
Spawning aggregations, e.g. cod, black sea bass	Spawning aggregations, e.g. cod, black sea bass
EMF sensitive species: All elasmobranchs including dogfish and skates; lobster; flounders	Species more sensitive to food removal: e.g. flounder, skates, black sea bass

Table 4. The species mapped

Species	Vulnerable to cables	Vulnerable to pipelines/sand mining	Preliminary draft recommendation for how to map	What was done
Sand lance	No	Yes	Trawl survey data not sufficient, can't be mapped	Did not map
Scallops	Yes	Yes	Trawl survey data not sufficient, consider using known commercial areas	Used trawl survey data since it's all we have and we used it last time
Surf clams	Yes	Yes	Trawl survey data not sufficient, consider using known commercial areas but might underrepresent north of Boston	Did not map
Ocean quahogs	Yes	Yes	Trawl survey data not sufficient, consider using known commercial areas but might underrepresent north of Boston	Did not map
Atlantic herring	No	Yes	Trawl survey data not sufficient, primary Atlantic herring spawning areas outside of Massachusetts waters (check south of Nantucket)	Did not map, reviewed maps from GMRI, NEFMC, and ASMFC. Atlantic herring spawning grounds are primarily outside of Massachusetts. Further consideration of protecting the area south of Nantucket during spawning season (fall) is warranted. See Appendix D for more information.
Cod spawning areas	Yes	Yes	Use regulatory areas	Merged to trawl survey data. See Appendix D for more information.
Cod YOY area	Yes	Yes	Use trawl survey data	Done (trawl survey data for cod recruitment)
Channeled whelk	Yes	Yes	Trawl survey data not sufficient, can't be mapped	Done, combined channeled and knobbed whelk (used trawl survey data since we used it for previous ocean plans)
Dogfish	Yes	No	Use trawl survey data	Done (spiny dogfish; used trawl survey data)
Horseshoe crabs	No	Yes	Use trawl survey data and available beach survey data	Done (used trawl survey data)
Black sea bass spawning areas	Yes	Yes	Use trawl survey data augmented with ventless survey data, consider adding *Crepidula* beds?	Done (used trawl survey data for black sea bass recruitment). Reviewed ventless data which was consistent with trawl

				survey data. Did not add *Crepidula* beds since known beds are in same locations identified by trawl and ventless surveys.
Crabs	No	Yes	Use trawl survey data augmented with ventless survey data	Done (used trawl survey data for Jonah crabs). Reviewed ventless data which was consistent with trawl survey data.
Lobster	Yes	Yes	Use trawl survey data augmented with ventless survey data	Done (used trawl survey data). Reviewed ventless data which led to two changes being made to the map.
Skates	Yes	Yes	Use trawl survey data	Done by combining all skates (winter, little; used trawl survey data)
Winter flounder	Yes	Yes	Use trawl survey data; make closed areas layer available	Done (used trawl survey data)
All flatfish	Yes	Yes	Use trawl survey data	Done by combining all flounders (summer, yellowtail, winter, witch, windowpane; used trawl survey data)
Loligo squid	No	Yes	Use trawl survey data	Done (used trawl survey data)

Fisheries Work Group members suggested we include all life stages of cod (e.g. adults), haddock, and pollock. Our focus is on the most vulnerable life stages of cod, so in the vulnerability assessment we included young of the year and the known spawning aggregations; adult cod and young of the year cod were included in the composite method. Pollock doesn't meet our abundance thresholds. They're found in too low of abundance and in not enough years to be included in the trimean assessment. Haddock occurs in the survey primarily in deeper strata in Mass Bay and the backside of Cape Cod (Figure D-5). Haddock spawns in a manner very similar to cod, but haddock stocks are not as threatened as cod. The primary haddock grounds are thought to be outside of Massachusetts waters. For these reasons, haddock was not included in the vulnerability assessment. See Appendix D for more information about herring, cod, and haddock.

6.1.3 Averaging Technique

For each species, the biomass (abundance for Jonah crab, Atlantic cod juveniles, and black sea bass juveniles) was averaged by survey stratum over the selected time series (1978-2018 and 2008-2018) using the trimean averaging technique ([1st quartile + 2*median+3rd quartile]/4). We selected the trimean to measure the center of the dataset because it is resistant to outlier years (years that have very high or low catches) when compared with the arithmetic mean. The trimeans were calculated in R.

We selected a stratum for inclusion for each species based on the criterion of having at least 8 years of non-zero catches within a season for the full time series (20% of the 40 year time series) and 2 years for the truncated time series (20% of the 11 year time series). This selection process allowed us to focus on strata where species were consistently caught in the time series. Sets of strata were analyzed by region (north or south of Cape Cod) since this boundary delineates different stock units of the same species for winter skate, little skate, fall cod recruitment, winter flounder, windowpane flounder, and American lobster. A third strata set was included for the backside of the Cape for spring cod recruitment.

We combined the species and season specific data by normalizing the species stratum trimean by dividing the stratum trimean by the sum of the trimeans for all included strata within a season. Normalizing the stratum trimean gives each species approximately equal influence in the model. The median of the normalized trimean values for all species/seasons was then determined for each stratum in Excel.

In ArcGIS Pro 2.4, the normalized trimeans were joined to the stratum polygons by stratum number using the Join tool and then clipped to the ocean management plan boundary. We then classified the strata into high (top 25%), medium (middle 50%), and low categories (bottom 25%) based on quartiles of the distribution of medians of normalized stratum trimean values within regional stratasets (north and south of Cape Cod) (Figure 8).

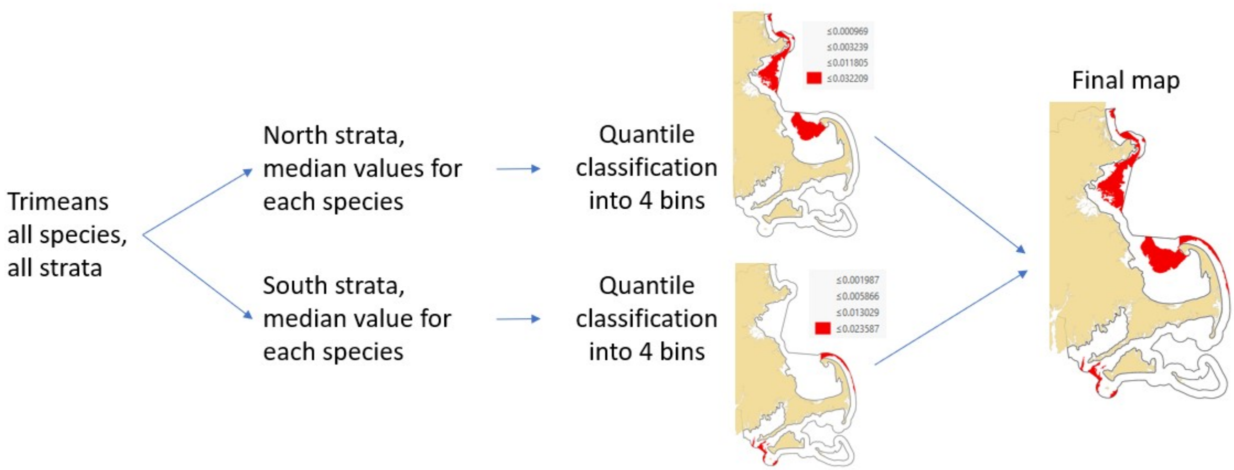

Figure 8. Illustration of classification method used for composite mapping.

6.1.4 Ranking & Indexing Techniques

For the vulnerability maps, the normalized trimeans were summed by season for each species and summed to create species groups for skates (winter and little), flounders (summer, yellowtail, winter, witch, windowpane), and whelks (channeled and knobbed). The ranks were joined to the stratum polygons by stratum number using the Join tool in ArcGIS Pro and then clipped to the ocean management plan boundary. The top 25% of strata (the top 6 of 23 strata) were then ranked from 1-6 (6 having the highest normalized trimean value for that stratum-species combination) and the top 6 were used for creating individual species/species-groups maps.

The individual species and species groups were combined to create the final vulnerability maps by creating an index to reflect both the diversity and the biomass value of the stratum. For each stratum, the count of species for which that stratum was in the top 6 as well as the sum of the stratum rank values for all species were calculated. The count and sum were then multiplied and the top six indexed strata were mapped. This way, strata biomass rank values are more heavily weighted if that stratum was ranked for more species. For cables, the species considered vulnerable and used in mapping were sea scallop, cod recruitment, skates, whelk, spiny dogfish, black sea bass recruitment, lobster, and flounders (not loligo squid, horseshoe crabs, or Jonah crabs). For pipelines and sand mining, the species considered vulnerable and used in mapping were sea scallop, cod recruitment, skates, whelk, black sea bass recruitment, lobster, skates, flounders, loligo squid, horseshoe crabs, and Jonah crabs (not spiny dogfish). An illustration of the ranking process and index development is provided in Appendix E.

6.2 Results

6.2.1 Composite Ocean Plan map

The composite map identifies areas of the state with consistently high biomass for all 22 species using the same method used in the original Ocean Plan of 2009 and the update in 2014.

The results from four separate time periods, 2009 MOP (1978-2007), 2014 MOP (1978-2012), and 2 time periods for the 2020 MOP (1978-2018 and 2008-2018), are presented in Figure 9. The full time series, 1978-2018, resulted in a larger area being designated as Important Fish Resource Area and the 2008-2018 time series results in a smaller area being designated as Important Fish Resource Area (Table 5).

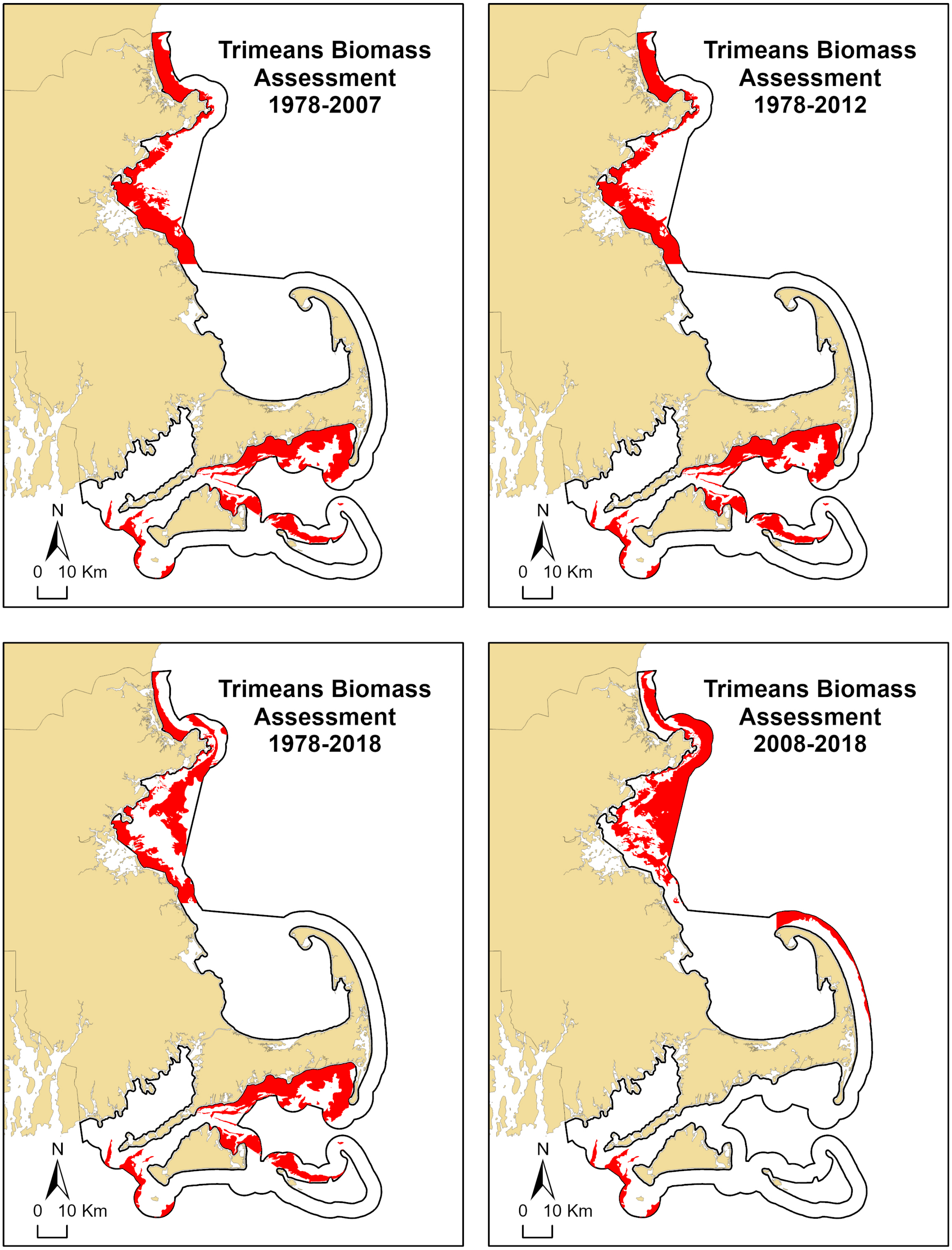

Figure 9. Highest 25% of trimean values are the important fish resource areas A) 1978-2007 (top left); B) 1978-2012 (top right); C) 1978-2018 (bottom left); and D) 2008-2018 (bottom right). Trawl data is clipped to ocean planning area boundary. Ocean planning area boundary is in black.

Table 5. Surface area of Important Fish Resource Area

	Area (acres)	% of OMP area
2009, 2015 area	253,681	18
1978-2018 area	314,694	23
2008-2018 area	185,170	13

North of Cape Cod, deeper strata are gaining in importance in the more recent time series. South of Cape Cod, we see high scup and tautog catches in stratum 11 (which includes the shoreline of Buzzards Bay, Martha's Vineyard, and shallower sections of Muskeget Channel) and notable declines in biomass in stratum 15, the shallow stratum hugging the shorelines of Nantucket Sound. South of Cape Cod, only deeper strata remain as "important" in the more recent time series.

6.2.2 Species specific maps

The ranked trimean data was used to produce maps for each species (or species group) (Figure 10). The maps were compared to the original trawl survey data and other data sources and were reviewed by experts to assess if specific changes were warranted based on known patterns or biases introduced by the trawl survey.

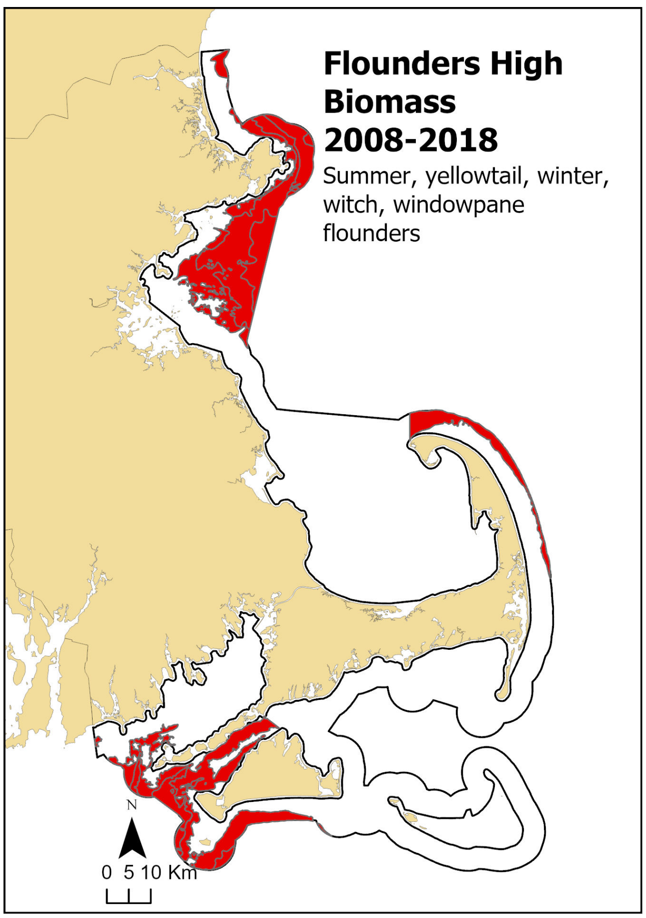

Figure 10. In this example, the normalized trimean biomass for all flounders in each season (fall and spring) were added to get a total normalized biomass for each stratum. The top 6 strata (25%) were selected as having high biomass values.

For lobster, when compared to the DMF ventless survey data (Pugh and Glenn 2020) and further reviewed by the DMF lobster biologist, Dr. Tracy Pugh, three areas stood out as particularly poorly mapped by the ranked trimean assessment: stratum 33 in Massachusetts Bays, stratum 14 at the mouth of Vineyard Sound, and stratum 17 east of Nantucket. These inaccuracies were addressed as follows:

- East of Nantucket shows up in the trimean assessment for lobster as having high biomass, but the high biomass region is in reality well to the north in Provincetown waters. Since survey stratum 17 extends from Provincetown to Nantucket, a misleading picture of this resource is created. Since stratum 14 has consistently high catches for both the trawl survey and the ventless survey, the decision was made to include stratum 14 instead of stratum 17. The average high biomass value for the top three strata south of the Cape was input as the stratum 14 biomass.
- Stratum 33 (Massachusetts Bay) has a poor tow-completion rate due to the presence of lobster gear, and therefore is thought to be underrepresented in this assessment. So stratum 33 was also manually selected as having a high value and the average high biomass value for the top three strata north of the Cape was input as the stratum 33 biomass. Stratum 31 was subsequently dropped to stay consistent with the selection of a total of 6 survey strata as the top 25%.

For black sea bass and Jonah crab, there were no inconsistencies between the DMF ventless survey data and the trawl survey data at the statewide scale, so the trawl survey data were relied upon (Pugh pers comm). The horseshoe crab map was reviewed by DMF biologists with expertise in that species and it was concluded that the sixth stratum, stratum 31 just north of Boston Harbor in shallow water, did not need to be ranked. The more important strata for horseshoe crab are adequately represented by the five strata remaining. The whelk map (a combination of knobbed and channeled whelks) was reviewed by DMF biologists with expertise in those species and it was concluded that it adequately represents the distribution of those species.

The vulnerability maps for cables (Figure 11) and pipelines/sand mining (Figure 12) are similar since the species vulnerable to each activity are almost the same. The major difference between the cable and pipeline/sand mining map is the inclusion of Nantucket Sound in the pipeline/sand mining map. Horseshoe crabs and squid are both found in high abundance in Nantucket Sound. They were not considered vulnerable to cables, but they were considered vulnerable to pipelines/sand mining. The only other difference between the two maps is the addition of stratum 20 on the back side of Cape Cod in the cable map. This stratum is on the cable map due to the prevalence of spiny dogfish, which were not considered vulnerable to pipelines but they are considered vulnerable to electric cables due to their sensitivity to electromagnetic fields.

As shown in Figures 11 and 12, the species driving the patterns by region are as follows:

- Vineyard Sound: black sea bass recruitment, cod recruitment, flounders, lobster, loligo squid, skates, spiny dogfish, whelks (not horseshoe crab, Jonah crab, or sea scallop)
- Nantucket Sound: black sea bass recruitment, horseshoe crab, loligo squid, whelks
- Backside of Cape Cod: cod recruitment, flounders, lobster, sea scallop, spiny dogfish
- Massachusetts Bay: flounders, Jonah crab, lobster, sea scallop, skates

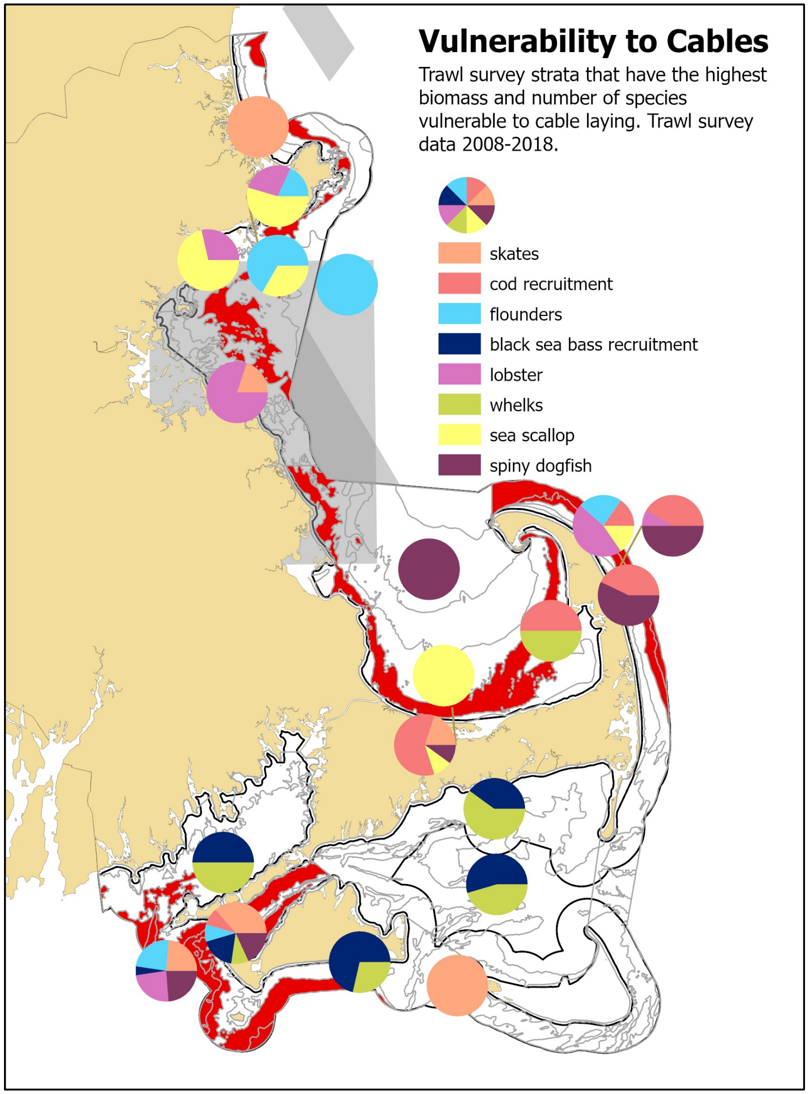

Figure 11. The vulnerability map for cables. Spawning groundfish closures are in grey.

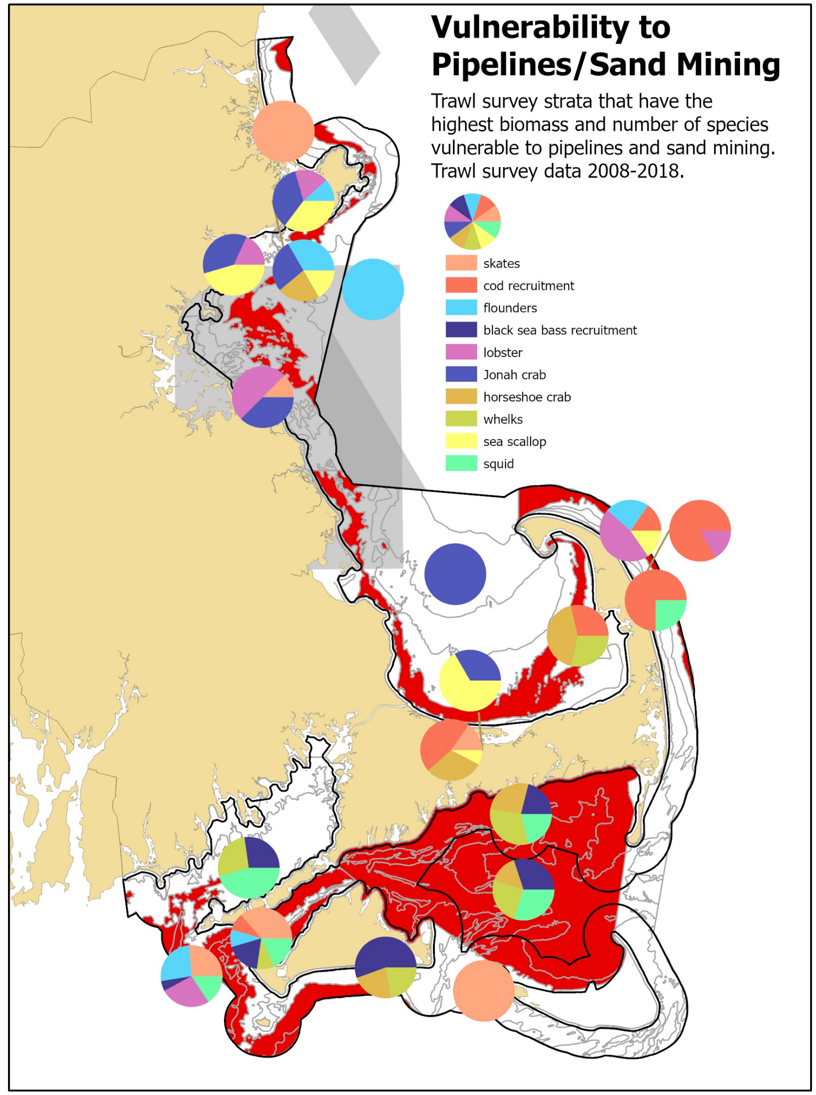

Figure 12. The vulnerability map for pipelines/sand mining. Spawning groundfish closures are in grey.

6.2.3 Habitat closure maps

To inform the review process for construction projects, maps identifying areas protected from fisheries that DMF regulates are provided. They are:

- The Winter and Spring Massachusetts Bay Cod Spawning Protection Areas for the protection of aggregations of spawning cod from recreational fishing (Figure 13)
- The Winter and Spring Massachusetts Bay Cod Conservation Zones for the protection of aggregations of spawning cod from commercial fishing (Figure 13)
- The Winter Flounder Spawning Area Closure for the protection of spawning winter flounder from commercial fishing (Figure 14)
- Inshore Restricted Waters for the protection of spawning winter flounder and to reduce user conflict from commercial fishing (Figure 14)

The Winter Cod Conservation Zone prohibits any taking of cod by any means from November 15-January 31 (322 CMR 8.07 (1)) and the Winter Massachusetts Bay Spawning Protection Area prohibits recreational fishing for cod by any gear except for pelagic hook and line gear from November 1-January 31. The Spring Cod Conservation Zone prohibits any landing of cod from April 16-July 21 (322 CMR 8.07 (2)) and the Spring Massachusetts Bay Spawning Protection Area requires charter and party boats to have a letter of authorization to fish from April 15-April 30. (https://www.fisheries.noaa.gov/bulletin/northeast-multispecies-groundfish-fishing-year-2019-recreational-rules)

The Winter Flounder Spawning Area Closure is closed to the commercial fishing for any finfish (except for sea herring and line trawling for cod) from February 1 to May 31 (322 CMR 8.04) to protect spawning winter flounder and winter flounder eggs. Net fishing is managed on a year-round basis to reduce conflicts between different fisheries and users and to identify and regulate all inshore net fisheries for purposes of resource conservation and management (322 CMR 4.02). Fishing with all but cast nets and small bait nets (as described in 322 CMR 4.02 (5)) requires a special regulated fishery permit endorsement issued by the Director of DMF. These areas are known as Inshore Restricted Waters.

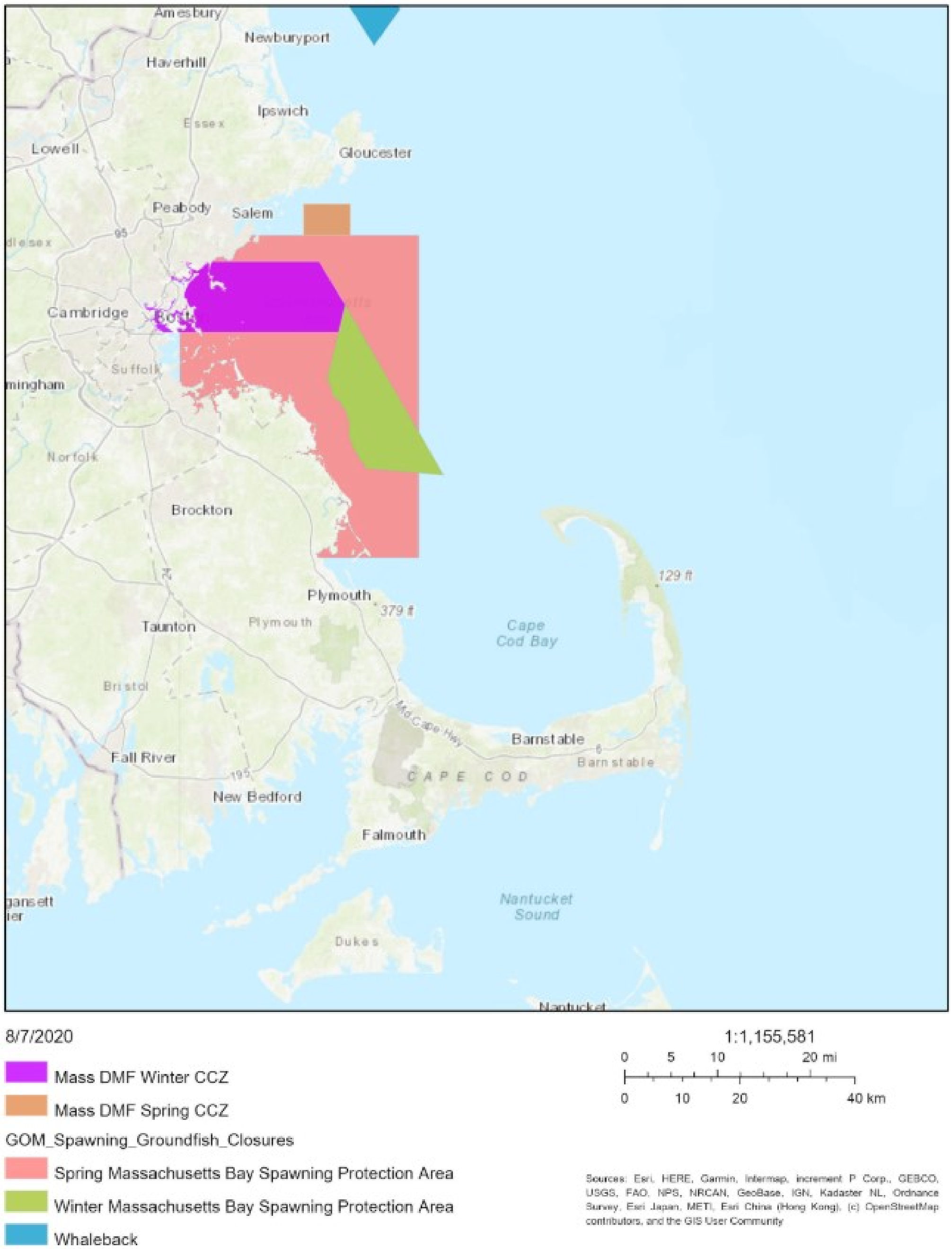

Figure 13. Fisheries regulated areas for the protection of spawning cod.

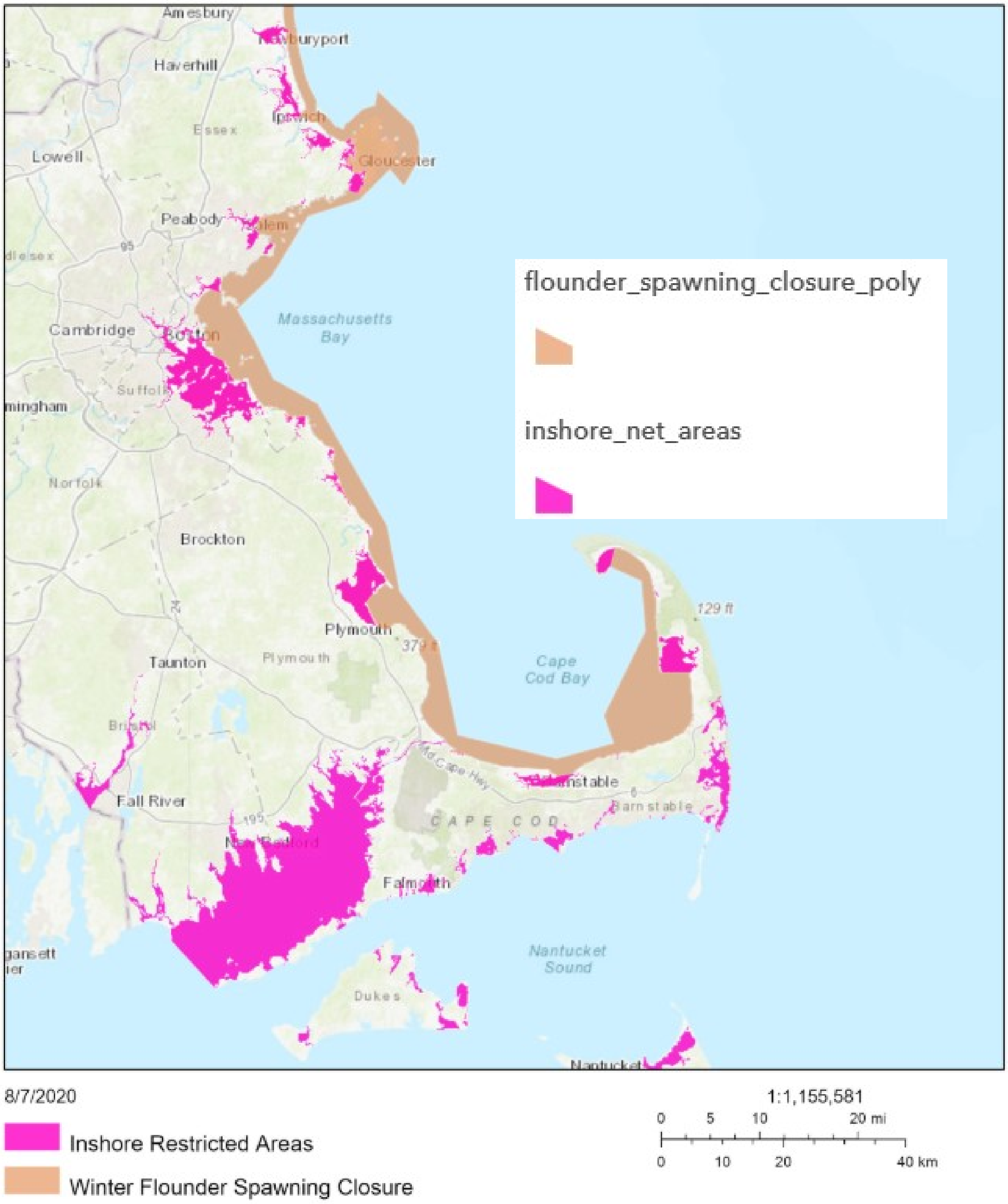

Figure 14. Fisheries regulated areas for the protection of spawning winter flounder.

6.2.4 Vulnerability + habitat closure

The Fisheries Work Group recommended including the cod spawning closure areas with the vulnerability assessment to best encompass areas vulnerable to the adverse effects of cables, pipelines, and sand mining. Within these areas, project proponents should address how they will avoid and mitigate impacts to the vulnerable resources. Two maps are proposed to amend the Massachusetts Ocean Plan and replace the important fish resource areas map:

1) Fish Resource Areas Vulnerable to Cables, which combines the cable vulnerability map with the cod spawning area, clipped to the ocean management plan boundary (Figure 15);
2) Fish Resource Areas Vulnerable to Pipelines and Sand Mining, which combines the pipeline/sand mining vulnerability map with the cod spawning area, clipped to the ocean management plan boundary (Figure 16).

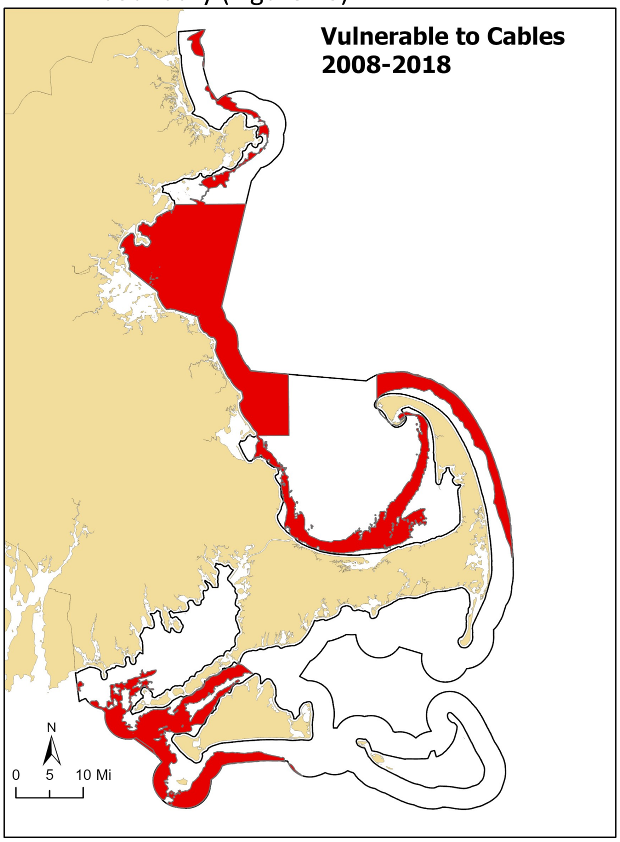

Figure 15. Areas with marine fisheries resources that are vulnerable to cable laying.

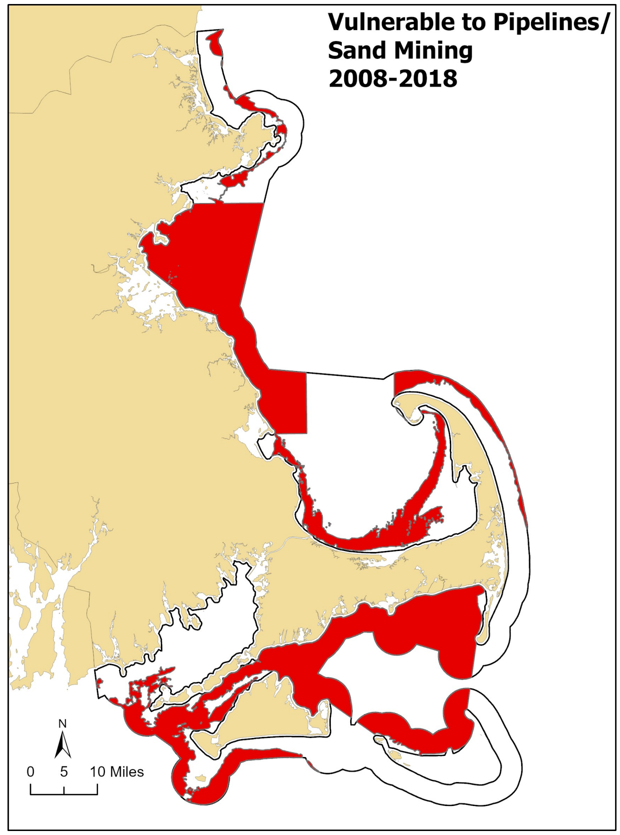

Figure 16. Areas with marine fisheries resources that are vulnerable to pipelines and sand mining.

These both represent an increase of area designated as Important Fish Resource Area in the previous Ocean Plan (Table 6).

Table 6. Surface area of areas vulnerable to cables and pipelines/sand mining.

	Area (acres)	% of OMP area	% increase from previous OMP
2020 Cables	402,562	29	11
2020 Pipelines	592,371	43	25

6.3 Discussion

The Fisheries Work Group and the Science Advisory Council have discussed in some detail specifically how to define and map important fish resource areas. The composite mapping method used for the important fish resource area map is a robust method to identify areas that have consistently high biomass over time since it is resistant to outliers. However, the composite map may not accurately reflect shorter-term changes in spatial patterns of biomass and it does not focus on species that are vulnerable to construction. The more recent data identifies deeper waters as having higher average biomass over ten years in contrast to the identification of shallower waters with higher average biomass over thirty-four years (Figure 9). Because the sample size is considerably reduced when smaller time series are examined, differences in the distribution of areas considered "important" may reflect random variation rather than actual change in relative importance of strata. Spatial-temporal variability in distribution of fish may be a function of sample size, of changes in population size, or as response to changes in abiotic environment such as temperature.

In 2014, efforts to identify "biomass hotspots" in Massachusetts found inconsistent patterns in location of high biomass over the years and that the biomass hotspots were driven by different species in different years (EEA 2014). That work also concluded that being able to explore the underlying data and better understand why certain areas might be considered of "high importance" was a critical component of working with this dataset.

Between 2014 and 2019, a subworkgroup explored various tools that could be optimized to allow for deeper exploration of this dataset and provide the much-needed context for interpreting fisheries data through the lens of ocean planning. The subworkgroup produced several maps and continued to determine methods to best represent areas of importance to fisheries by using different mapping methods and by examining how to group species. This work influenced the development of the vulnerability approach to mapping fisheries resources.

In 2020, the Fisheries Work Group discussed what types of construction projects should be required to use the important fish resource area map. In the 2009 and 2014 MOPs, the important fish resource area layer is listed as an SSU for pipelines, sand mining, and renewable energy, but not for cables since few of the 22 species mapped had notable vulnerabilities to cables. The Fisheries Work Group concluded that if species vulnerable to cables were mapped in a vulnerability analysis, then there should be an SSU for cables as well. This recommendation was influenced by the experience of Work Group members who reviewed the Atlantic Link cable project. The developers were unaware of the cod spawning activity in the Massachusetts Bay region in part because the project was not required to screen the project site with the important fish resource area layer. The Work Group views the vulnerability approach as an improvement over the composite ocean plan maps.

Some drawbacks of the current approach are as follows. The trawl survey uses a statistical design that is not efficient for determining spatial distribution and may miss specific activities that may be vulnerable to other ocean uses. Another key drawback is that several species are vulnerable that we haven't mapped (e.g. surf clam, ocean quahog, sand lance). Also, the trawl survey data are limited to May and September and may not reflect times of year when vulnerable resources may be present. The trimean method is robust, and efforts were used to ensure that regional patterns were represented. For example, cod has three stocks in Massachusetts waters: south of Cape Cod, the backside of Cape Cod, and north of Cape Cod. In each of these regions, the trimeans were normalized to identify the highest relative catches of young of the year cod in that region. These were then ranked, resulting in some isolated catches in a few strata south of Cape Cod and on the backside of Cape Cod outranking the very high catches over more strata in Massachusetts Bay. An assessment of the implications of the regional normalization process (done for winter skate, little skate, fall cod recruitment, winter flounder, windowpane flounder, and American lobster) on the ranked vulnerability maps, should be done. Also, the ranking method selected the top 6 strata, representing 25% of the strata. Another assessment looking at the top 25% of the ranked values should be done for comparison.

In the 2009 Ocean Plan development process, emphasis was placed on a creating a single map that represented areas of importance to fish resources. Since that time, the Fisheries Work Group has recognized the drawbacks of consolidating so much information into a single map layer. Other species groups have been handled as single species or as groups that share ecological niches and/or behaviors, for example “Colonial waterbirds.” In the 2015 Ocean Plan Update, maps for individual species were provided in the Fisheries Work Group report (Appendix E in EEA 2014). These maps allowed a better understanding of what species might be driving the determination of a given area as “Important.” However, since they lacked a clear connection to the uses being managed, were hard to access, and were unwieldy in their format, they were not used in for siting or informing environmental review. Therefore, the Fisheries Work Group recommends developing a digital product whereby a developer or regulator can select the project area and understand what species are driving the vulnerability of that area and what best management practices can avoid or minimize impacts to those species.

7. Aquaculture

In the Oceans Act, the legislation that established the Ocean Plan, one of the goals outlined was to “identify appropriate locations and performance standards for activities, uses and facilities allowed under the Ocean Sanctuaries Act, including but not limited to renewable energy facilities, aquaculture, sand mining for beach nourishment, cables, and pipelines” (Massachusetts 2008). Municipalities have jurisdiction for the siting of aquaculture activities with the approval of DMF. In 2014, the Fisheries Work Group proposed addressing new offshore aquaculture in a similar manner as sand mining, cables, and pipelines. This was outside the scope of work, so an aquaculture working group was established to determine how the state could best address aquaculture in the Ocean Plan.

Coincidentally, several other shellfish initiatives were underway, including the Massachusetts Shellfish Initiative (MSI) and the Massachusetts Aquaculture Permitting Plan (MAPP). The MAPP project, assisted by ocean planning leadership and momentum, drew together multiple agencies to clarify the environmental permitting process for aquaculture in Massachusetts, resulting in a website outlining the permitting process and identifying important standards (www.massaquaculturepermitting.org). Next steps of the MAPP project include determining best practices to minimize impacts and laying out a framework to assess cumulative impacts.

It is the recommendation of the Fisheries Work Group to continue to develop the MAPP and rely on MSI to address issues relevant to aquaculture and the Massachusetts Ocean Plan. The MAPP should seek to identify performance standards for aquaculture that could be considered in the next ocean plan review period. The Fisheries Work Group also recommends the inclusion of an updated fixed fishing facilities map as an area of water dependent use (WDU) in the Massachusetts Ocean Plan.

7.1 Fixed fishing facilities

In the 2015 Ocean Plan Update the fixed fishing facilities map was prepared for informational purposes. It has been updated and is now recommended as a WDU in the Ocean Plan. The fixed fishing facilities map includes existing aquaculture license sites that overlap with the ocean planning area and all fish weirs (Figure 17).

Each license includes the coordinates of the site corner markers. These were used to create a GIS layer that was cross-checked in the field to verify coordinates. All of the existing aquaculture license sites within the ocean management plan boundary are for shellfish aquaculture. There are 94 active aquaculture license sites occupying 227 acres within the ocean management plan boundary in the towns of Chilmark, Eastham, Edgartown, Fairhaven, Orleans, Provincetown, Truro, Wellfleet. All but the sites in Chilmark and Westport are inshore licenses that extend more than 1,500 ft from shore so they overlap into the ocean planning area. One offshore site in Cape Cod Bay is linked to an inshore license holder, but it is not currently producing shellfish. In total, there are 628 aquaculture license sites held by 424 permittees in Massachusetts. The sites occupy 1,332 acres.

There are three Aquaculture Development Areas (ADA) in the ocean planning area in Provincetown, Truro, and Westport. An ADA is an area a municipality has selected for aquaculture, and can be an aquaculture license held by the municipality or simply a planning area. The ADA is subdivided into smaller individual license sites available for growers to apply to the municipality for. Individual licensees still need to apply to DMF for a state permit for their aquaculture operations. An ADA may not have active aquaculture activity over the whole licensed area and so are not mapped.

Fish weirs are fish traps that are located in a single location over the fishing season and so are permitted for specific sites. The fish weir permit applications include the starting point of the fish weir, the length of the weir, and the direction in which the weir is oriented. There are 30 weir sites permitted to 5 companies that have permits that are current as of January 2021. The length of a weir varies between 300 ft to 3,600 ft and averages 2,100 ft. Other weir sites were permitted in the past, but the permits have expired; those sites were not mapped. Currently, only the starting points have been mapped. If this layer becomes a WDU, the area of the weir site will be generated using the starting point, weir length, weir direction, and a standard width of 500' to create a surface area for each weir.

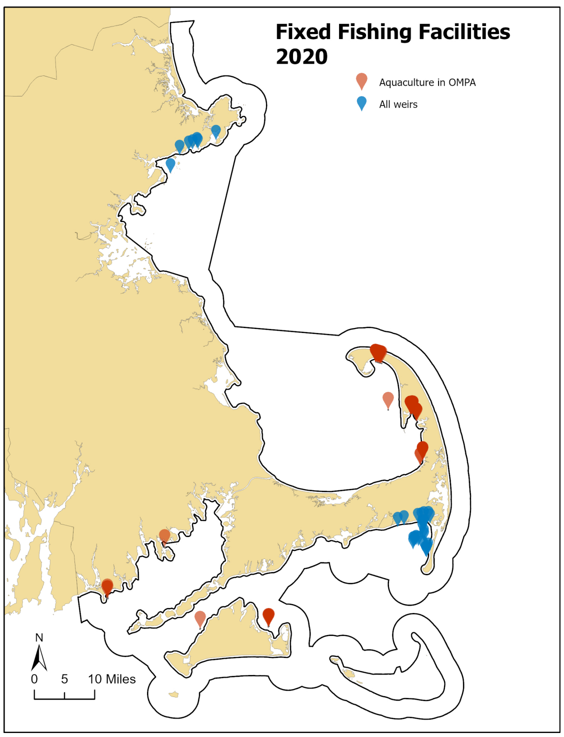

Figure 17. Fish weirs and aquaculture sites within the ocean planning area. Red markers are aquaculture sites within the planning area, blue markers are all fish weirs.

8. Stakeholder Perception Survey

As part of the review of the ocean plan, CZM conducted a survey of stakeholders and sought recommendations for changes to the ocean plan. Two changes that were recommended that are relevant to the Fisheries Work Group are: adding shellfish maps and adding a great white shark map.

8.1 Adding shellfish maps

Responses from the ocean plan survey conducted in early 2019 indicated an interest in examining the possibility of including shellfish maps in the ocean plan. The state has a series of maps called the Shellfish Suitability Maps. These maps are based on surveys of local shellfish experts and they are currently used in state permitting to identify Land Containing Shellfish, a habitat protected by DEP regulations. The Fisheries Work Group confirmed the vulnerability of shellfish species to construction activities. However, including the Shellfish Suitability Maps as SSU layers was deemed to be of limited value, particularly offshore in the ocean management planning area, due to the nature of those maps being based on expert judgment instead of stock assessment or spatial distribution surveys.

There are several ways to improve shellfish mapping, but they are time intensive and are outdated very quickly. Comparing shellfish suitability layers and commercial fishing data might be interesting. The state should consider "2nd tier" recommendations for impact sites. For example, if a project can't avoid shellfish, a survey should establish the basis for mitigation or some other action.

8.2 Great White Shark map

Responses from the ocean plan survey conducted in early 2019 indicated an interest in examining the possibility of including great white sharks in the ocean plan. Cape Cod is the only known white shark aggregation site in the North Atlantic. Given that white sharks are the only natural predator of a growing pinniped population in the Northwest Atlantic and the unique predator-prey relationship that occurs off the Outer Cape, this area was recommended for identification as an SSU. The DMF white shark biologist, Dr. Greg Skomal, also recommended that an SSU for white shark should include the eastern shoreline of Nantucket, which has similar attributes to the Outer Cape. To confirm the latter, additional acoustic monitoring of tagged white sharks is warranted in that area. The Fisheries Work Group recommended drafting a map and discussing with the Science Advisory Council (Figure 18).

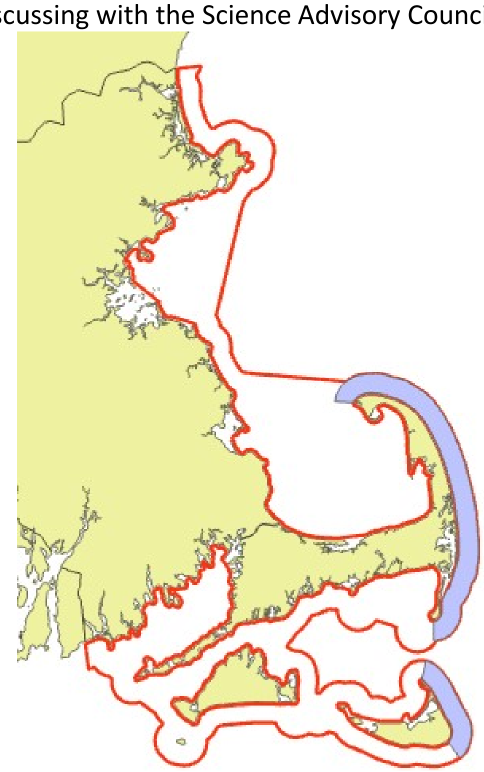

Figure 18. Draft potential Great White Shark SSU.

The Science Advisory Council concluded that the available data was not representative enough of the whole state, and the need for an SSU for Great White sharks not evident enough, to support inclusion as an SSU.

9. Proposed Science Priorities

- Complete new recreational fisheries survey.
- Provide decision-makers with more access to species-specific and temporal information underlying the important fish resource area layer and providing best management practices to avoid and minimize impact to those species.
- Continue to support the development of products that assess the cumulative impact of aquaculture and determine siting and performance criteria for new aquaculture facilities in the ocean planning management area.

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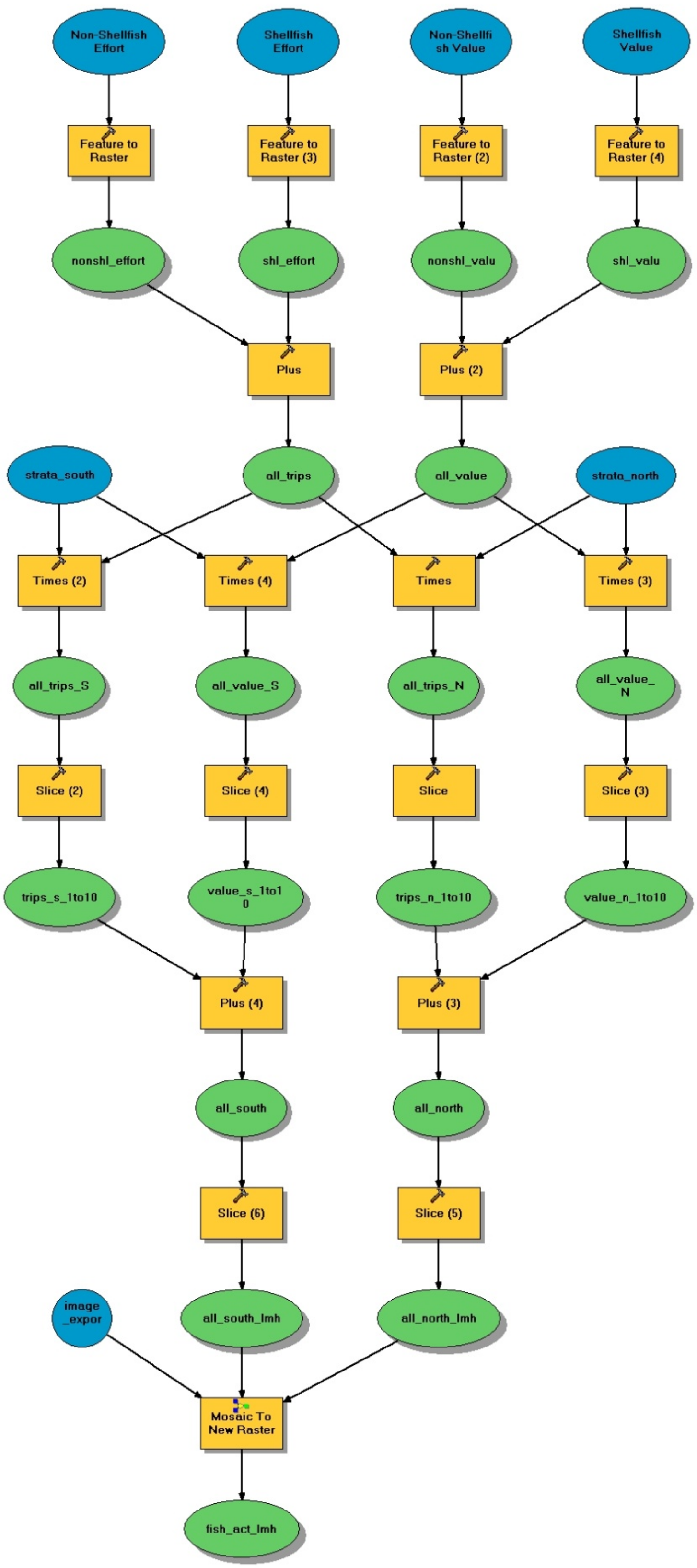
Appendices

Appendix A – Massachusetts 2007, 2012, and 2019 Landings-Weighted State-Wide Average Price per Live Pound[1] by Non-Shellfish Species

Species	2007	2012	2019	Species	2007	2012	2019
BLUEFISH	$0.51	$0.78	$1.72	JOHN DORY	$0.53	$0.81	$0.79
BONITO,ATLANTIC	$2.29	$3.82	$3.71	KING WHITING	$1.12	$1.20	$1.28
BUTTERFISH	$0.64	$0.48	$1.01	LANCE, AMERICAN SAND	$4.28	$5.37	$7.00
COD,ATLANTIC	$1.59	$2.07	$2.20	LOBSTER,AMERICAN	$5.05	$3.68	$5.60
CRAB,ATLANTIC ROCK	$0.50	$0.56	$0.80	MACKEREL,ATLANTIC	$0.10	$0.16	$0.31
CRAB,GREEN	$0.38	$0.30	$0.62	MENHADEN	$0.09	$0.08	$0.17
CRAB,HORSESHOE	$0.78	$1.08	$0.99	PERCH,OCEAN(REDFISH)	$0.55	$0.65	$0.53
CRAB,JONAH	$0.58	$0.74	$0.83	POLLOCK,ATLANTIC	$0.45	$0.85	$0.78
CRAB,RED AT	$0.91	-	$1.00	SCUP	$0.93	$0.68	$0.80
CRAB,UNC	$0.55	-	-	SEA BASS,BLACK	$2.48	$3.20	$3.08
CUNNER	-	$1.05	$3.94	SEA TROUT,GRAY(WEAKFISH)	-	$1.76	$2.53
CUSK	$0.70	$0.76	$0.53	SEA URCHINS	-	$1.38	$1.54
DOGFISH,SPINY	$0.23	$0.22	$0.23	SHARK,MAKO UNC	$1.15	-	-
DOLPHINFISH	$2.04	$2.86	$3.38	SHARK,PORBEAGLE	$0.62	$0.74	-
EEL,AMERICAN	$1.74	-	$3.33	SHARK,SHORTFIN MAKO	-	$1.72	$1.10
EEL,CONGER	$0.56	$0.93	$0.84	SHRIMP,PANDALID	-	$0.93	-
ESCOLAR	-	$2.03	$1.16	SKATE,LITTLE	-	$0.12	$0.15
FISH,UNC	$0.14	-	-	SKATE,WINTER	$0.22	$0.21	$0.27
FLOUNDER, PLAICE, AMERICAN	$1.61	$1.54	$1.94	SKATES	$0.24	$0.26	$0.26
FLOUNDER,WINDOWPANE	$0.40	-	$2.26	SQUID,LONG FINNED (LOLIGO)	$0.86	$1.20	$1.57
FLOUNDER,SUMMER (FLUKE)	$2.41	$2.61	$3.51	SQUID,SHORT FINNED (ILLEX)	-	$1.05	$0.40
FLOUNDER,WINTER	$2.12	$1.97	$2.76	STRIPED BASS	$2.64	$2.88	$5.35
FLOUNDER,WITCH (GRAY SOLE)	$2.46	$1.88	$1.73	SWORDFISH	$3.00	$3.17	$2.92
FLOUNDER,YELLOWTAIL	$1.86	$1.34	$0.99	TAUTOG	$2.17	$3.13	$4.65
GOOSEFISH	$1.06	$1.17	$0.53	TILEFISH (GOLDEN TILEFISH)	$1.42	$2.17	$1.47
HADDOCK	$1.54	$1.80	$0.97	TRIGGERFISHES	$0.68	$1.19	$1.19
HAKE, ATLANTIC, RED	$0.30	$0.44	$0.49	TUNA,ALBACORE	$1.19	$1.05	$0.76
HAKE, ATLANTIC, RED & WHITE	$0.66	$1.19	$1.94	TUNA,BIGEYE	$3.41	$5.50	$4.36
HAKE, ATLANTIC, WHITE	$1.27	$1.10	$1.00	TUNA,BLUEFIN	$7.74	$9.31	$4.38
HAKE,SILVER (WHITING)	$0.53	$0.61	$0.92	TUNA,YELLOWFIN	$2.66	$4.16	$2.75
HALIBUT,ATLANTIC	$4.61	$6.78	$5.80	WAHOO	$2.30	$3.20	$2.92
HERRING, ATLANTIC, SEA	$0.09	$0.11	$0.27	WOLFFISH,ATLANTIC	$0.66	-	-
Source: SAFIS Dealer Reports [1]Live Pound: whole animal, shell on							

Appendix B – ArcGIS Model – Commercial Fisheries Activity



Appendix C – Fisheries not covered by the Vessel Monitoring System in Massachusetts

Fisheries that occur in Mass waters	VMS data in state waters?
Sea herring	Federal vessels only
Ocean quahog, surfclam	Federal vessels only
Scallops (dredge and diving)	Federal vessels only
Monkfish	Federal vessels only
Northeast multispecies/coastal access permit (large mesh groundfish; includes trawls, gillnets, hook and line)	Federal vessels only
Highly migratory species (tuna, sharks, swordfish; hook and line and purse seines)	Federal vessels only
Small mesh multispecies	Federal vessels only
Fish weir	Locations are known
Aquaculture	Locations are known
American eel	No VMS (river codes reported)
Pots (conch, lobster, black sea bass)	No VMS
Atlantic mackerel, squid, butterfish	No VMS
Summer flounder, scup, black sea bass	No VMS
Northern shrimp	No VMS*
White perch	No VMS
Smelt	No VMS
Bay scallop	No VMS
Other shellfish (razor clams, oysters, seaworms)	No VMS
Atlantic bluefish	No VMS
Horseshoe crab	No VMS
Inshore net	No VMS
Striped bass	No VMS
Surface gillnet	No VMS
Green crabs	No VMS
Sea urchin (dredge and diving)	No VMS
Menhaden	No VMS
Sand eels	No VMS
Skate	No VMS*
Cusk	No VMS*
Spiny dogfish	No VMS*
Tautog	No VMS
Recreational fishing	No VMS

** A vessel that has a federal permit in a fishery that requires VMS (e.g. Monkfish, northeast multispecies, scallop) can also have state endorsements for other fisheries. In such a case, the vessel reports to the VMS system even when it is fishing under the state endorsement. However, it would be difficult or impossible to discern from the VMS data which fishery the individual was participating in other than what was declared on the VMS as required for the federal permit (the declaration codes can only accommodate the fisheries required to report under VMS). Federally permitted vessels fishing in state waters must comply with their federal permit and/or more restrictive state regulations. The fisheries that this is most problematic for (cusk, skate, dogfish, and shrimp) are indicated with an asterisk. There is also a directed spiny dogfish fishery in state waters in October & November that federal groundfish boats don't participate in. Since fishermen also report VTRs with their catches, theoretically VMS tracks could be linked up to catch information. Since the VTR contains landings from an entire trip, when that trip spans multiple areas, including state and federal waters, it would be impossible to pinpoint where in the VMS track the landings actually occurred. Tilefish excluded since fishery occurs outside of state waters; salmon, river herring, shad excluded since they are not commercial fisheries at this time.*

Appendix D

Atlantic Herring

Atlantic herring are fully marine and migrate to coastal and offshore spawning grounds. In late summer and early fall, Atlantic herring aggregate into massive schools and move into coastal waters at various locations on Georges Bank and in the Gulf of Maine to spawn (Figures E-1 & E-2). Spawning times vary for different populations of Atlantic herring. In the Gulf of Maine, spawning progresses from north to south, commencing in the Bay of Fundy and eastern Maine waters in late July or early August and as late as November and even December on Georges Bank. Spawning takes place in relatively warm (approximately 10-15°C), salty water (Figure E-2).

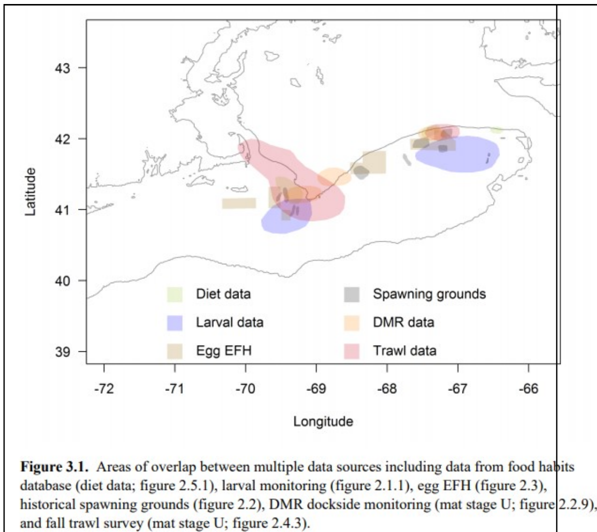


Figure D-1. Atlantic herring Georges Bank spawning locations. Source: NEFMC review document on Georges Bank herring spawning (https://s3.amazonaws.com/nefmc.org/3.-Draft-discussion-document-on-GB-spawning.pdf).

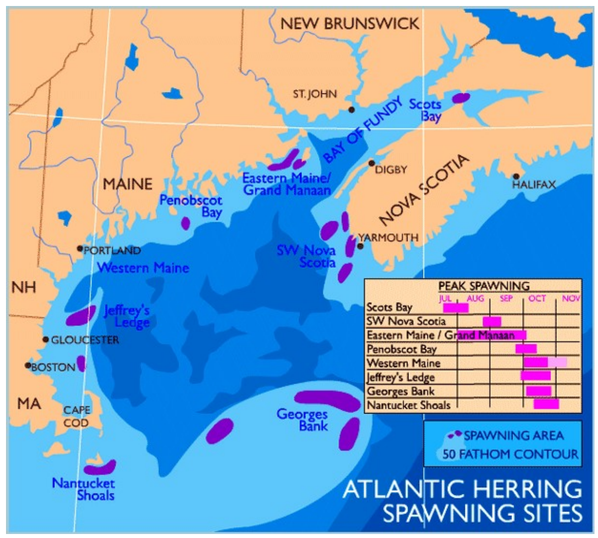


Figure D-2. Atlantic herring spawning sites and timing. Source: Gulf of Maine Research Institute. http://www.gma.org/herring/research/spawning_research/default.asp

Herring use external fertilization to produce masses of adhesive benthic (bottom-oriented) eggs that develop on the ocean floor. The eggs form dense carpets that can be several centimeters thick. In one square meter there can be as many seven million eggs. Fertilized eggs hatch into larvae in 7-10 days depending on the water temperature and then metamorphose into planktonic larvae.

In the Gulf of Maine, herring spawn in coastal waters at depths above 100 meters and over a fairly level bottom. Egg beds have been observed in water as shallow as 20 meters. The substrate may be composed of rocks, cobble, gravel, pebbles, beds of seaweed, or fragments of shells. Lobstermen often find herring eggs attached to their lobster traps.

Atlantic herring are not overfished and are not subject to overfishing. Sources: 2018 stock assessment; Gulf of Maine Research Institute; and NOAA.

Cod

In addition to the spawning areas known in Massachusetts Bays, information about the offshore spawning grounds for cod are provided below:

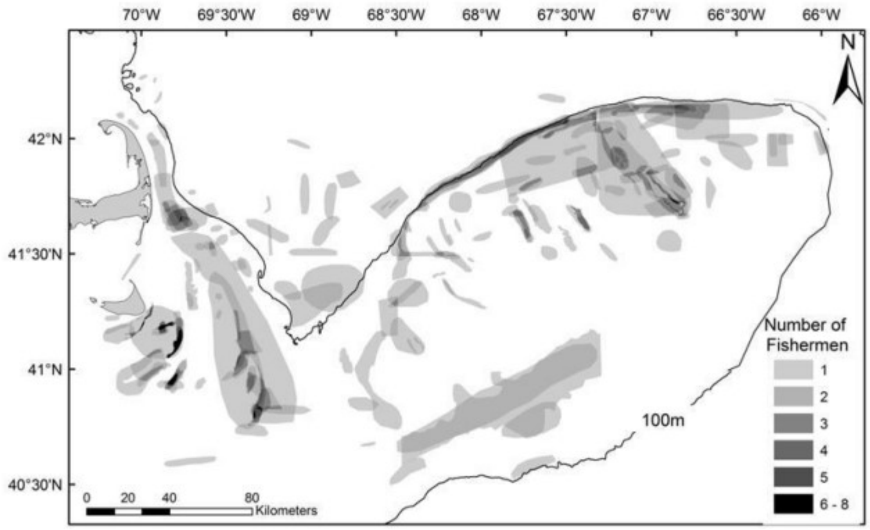


Figure 13 - Cod spawning grounds that were identified by fishermen. Each polygon represents a spawning ground that was identified by a single fisherman. The shading is used to identify areas where cod spawning activity was identified independently by multiple fishermen.

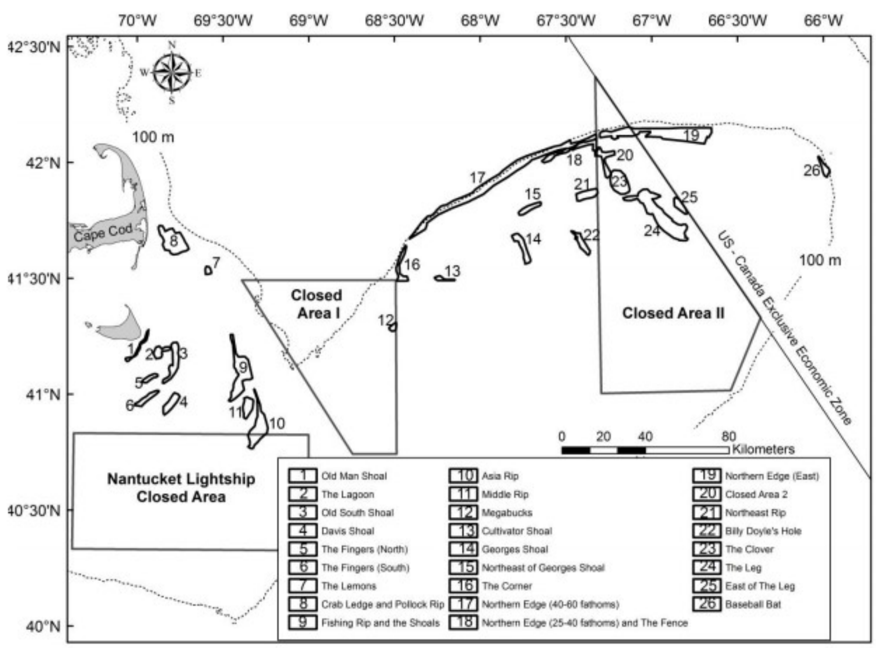


Figure 14 - Consensus spawning grounds that were identified independently by at least three fishermen.

Figure D-3. Atlantic cod Georges Bank spawning locations. Source: NEFMC report on Georges Bank cod spawning http://s3.amazonaws.com/nefmc.org/7_Cadrin-GB-cod-final-report.pdf

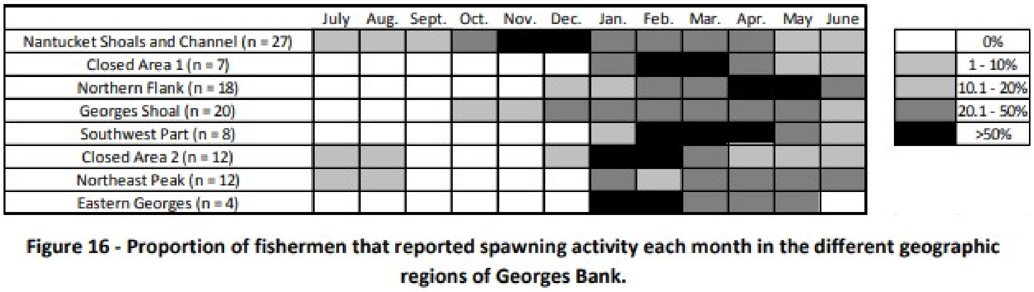


Figure D-4. Cod spawning timing as reported in NEFMC report on Georges Bank cod spawning.
http://s3.amazonaws.com/nefmc.org/7_Cadrin-GB-cod-final-report.pdf

Haddock

In the Northwest Atlantic haddock can be found as far south as Cape May, NJ to the Strait of Belle Isle, Canada in the north. They are most common in the Gulf of Maine and across Georges Bank. Generally, haddock live in deeper waters ranging between 130 to 450 feet, with juveniles generally distributed in the shallower depths. Spawning occurs from January to July varying latitudinally and controlled by temperature (later in colder autumn/winter; Page and Frank, 1989; Cargnelli et al., 1999; Klein-MacPhee, 2002; Brodziak, 2005). Eggs hatch within a month (about 15 days at typical Georges Bank temperatures; Page and Frank, 1989; Klein-MacPhee, 2002). Georges Bank has the largest aggregation of spawning haddock, which breed starting in January continuing through June. Haddock spawn in the water column, away from the bottom, typically at 100-600 feet. Females release their eggs in batches near the ocean floor, where a courting male fertilizes them. The eggs float, drifting along in the currents for 15 days until they hatch, then the larvae continue to drift near the surface for about three months before settling to the ocean floor. Sources: MA DMF; NOAA (1); NOAA (2)

Haddock are more abundant in Massachusetts waters now than they have been in 40 years. According to the 2017 stock assessment, the Georges Bank haddock stock is not overfished and is not subject to overfishing. Sources: MA DMF; NOAA (3)

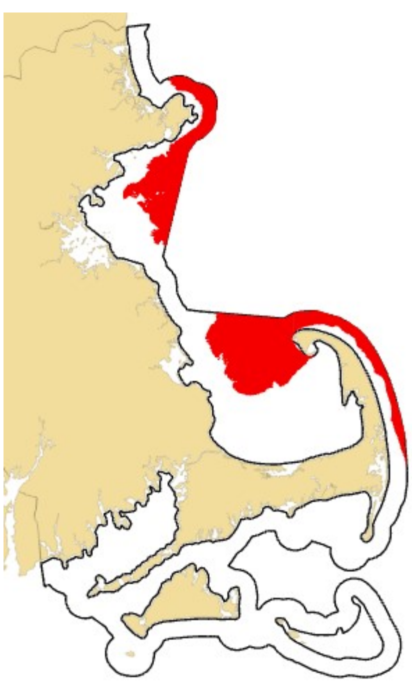


Figure D-5. Trimean assessment for haddock using trawl data, top quartile, 2008-2018 data.

Appendix E – Illustrations of ranking and indexing processes

Normalized trimean data from composite method, seasons combined

stratum	spiny_dogfish_fall_biomass	spiny_dogfish_spring_biomass
11	NA	0.006
12	NA	0.007
13	NA	0.102
14	NA	0.522
15	NA	NA
16	NA	NA
17	0.001	NA
18	0.017	NA
19	0.181	NA
20	0.704	NA
21	0.015	0.038
25	NA	NA
26	0.030	0.069
27	0.014	0.051
28	0.008	0.050
29	0.013	0.100
30	0.007	0.056
31	NA	NA
32	0.001	NA
33	NA	NA
34	0.002	NA
35	0.003	NA
36	0.004	NA

Add together

stratum	spiny_dogfish_fall_biomass	spiny_dogfish_spring_biomass	spiny_dogfish_combined
11	NA	0.006	0.006
12	NA	0.007	0.007
13	NA	0.102	0.102
14	NA	0.522	0.522
15	NA	NA	0.000
16	NA	NA	0.000
17	0.001	NA	0.001
18	0.017	NA	0.017
19	0.181	NA	0.181
20	0.704	NA	0.704
21	0.015	0.038	0.053
25	NA	NA	0.000
26	0.030	0.069	0.099
27	0.014	0.051	0.065
28	0.008	0.050	0.058
29	0.013	0.100	0.113
30	0.007	0.056	0.063
31	NA	NA	0.000
32	0.001	NA	0.001
33	NA	NA	0.000
34	0.002	NA	0.002
35	0.003	NA	0.003
36	0.004	NA	0.004

Sort

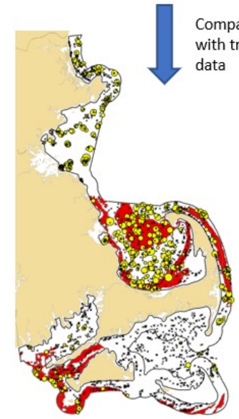
stratum	spiny_dogfish_combined
20	0.704
14	0.522
19	0.181
29	0.113
13	0.102
26	0.099
27	0.065
30	0.063
28	0.058
21	0.053
18	0.017
12	0.007
11	0.006
36	0.004
35	0.003
34	0.002
32	0.001
17	0.001
15	0.000
16	0.000
25	0.000
31	0.000
33	0.000

Rank

stratum	spiny_dogfish_ranked
20	6
14	5
19	4
29	3
13	2
26	1
27	<null>
30	<null>
28	<null>
21	<null>
18	<null>
12	<null>
11	<null>
36	<null>
35	<null>
34	<null>
32	<null>
17	<null>
15	<null>
16	<null>
25	<null>
31	<null>
33	<null>

Map top 6 strata

Compare with trawl data



Here's an example where multiple species (and seasons) were combined

stratum	winter_skate_fall_biomass	winter_skate_spring_biomass	little_skate_fall_biomass	little_skate_spring_biomass
11	0.009	0.126	0.005	0.078
12	0.005	0.120	0.020	0.087
13	0.015	0.291	0.117	0.310
14	0.054	0.196	0.257	0.246
15	0.001	0.000	0.004	0.003
16	0.016	NA	0.042	0.004
17	0.367	0.116	0.138	0.081
18	0.341	0.046	0.127	0.060
19	0.050	0.093	0.067	0.109
20	0.114	0.006	0.136	0.015
21	0.027	0.007	0.088	0.007
25	0.126	0.102	0.118	0.147
26	0.197	0.048	0.134	0.216
27	0.060	0.014	0.179	0.120
28	0.017	0.032	0.056	0.037
29	0.008	0.012	0.020	0.015
30	NA	NA	0.003	0.012
31	0.194	0.283	0.191	0.137
32	0.138	0.174	0.133	0.134
33	0.096	0.058	0.090	0.077
34	0.126	0.051	0.041	0.043
35	0.037	0.046	0.027	0.051
36	NA	0.180	0.006	0.010

Add together

stratum	winter_skate_fall_biomass	winter_skate_spring_biomass	little_skate_fall_biomass	little_skate_spring_biomass	Skates_combined
11	0.009	0.126	0.005	0.078	0.218
12	0.005	0.120	0.020	0.087	0.232
13	0.015	0.291	0.117	0.310	0.733
14	0.054	0.196	0.257	0.246	0.753
15	0.001	0.000	0.004	0.003	0.008
16	0.016	NA	0.042	0.004	0.062
17	0.367	0.116	0.138	0.081	0.702
18	0.341	0.046	0.127	0.060	0.574
19	0.050	0.093	0.067	0.109	0.318
20	0.114	0.006	0.136	0.015	0.271
21	0.027	0.007	0.088	0.007	0.129
25	0.126	0.102	0.118	0.147	0.493
26	0.197	0.048	0.134	0.216	0.596
27	0.060	0.014	0.179	0.120	0.373
28	0.017	0.032	0.056	0.037	0.141
29	0.008	0.012	0.020	0.015	0.056
30	NA	NA	0.003	0.012	0.015
31	0.194	0.283	0.191	0.137	0.806
32	0.138	0.174	0.133	0.134	0.579
33	0.096	0.058	0.090	0.077	0.322
34	0.126	0.051	0.041	0.043	0.261
35	0.037	0.046	0.027	0.051	0.162
36	NA	0.180	0.006	0.010	0.196

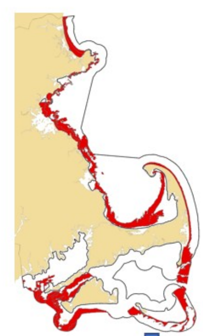
Sort

stratum	Skates_combined
31	0.806
14	0.753
13	0.733
17	0.702
26	0.596
32	0.579
18	0.574
25	0.493
27	0.373
33	0.322
19	0.318
20	0.271
34	0.261
12	0.232
11	0.218
36	0.196
35	0.162
28	0.141
21	0.129
16	0.062
29	0.056
30	0.015
15	0.008

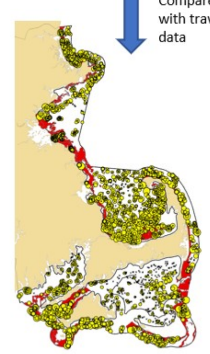
Rank

stratum	Skates_ranked
31	6
14	5
13	4
17	3
26	2
32	1
18	<null>
25	<null>
27	<null>
33	<null>
19	<null>
20	<null>
34	<null>
12	<null>
11	<null>
36	<null>
35	<null>
28	<null>
21	<null>
16	<null>
29	<null>
30	<null>
15	<null>

Map top 6 strata



Compare with trawl data



Vulnerability maps
using an index

All ranks

stratum	spiny_dogfish_combined2	skates_combined2	cod_recruitment_combined2	flounder_combined2	black_sea_bass_fall_recruitment2	lobster_combined2	Jonahcrab_combined2	horseshoecrab_combined2	whelks_combined2	sea_scallop_combined2	loligo_combined2
11					5			2	2		
12					3				3		5
13	2	4	1	1	2				1		2
14	5	5		5	1	5					3
15					4			5	6		4
16					6			3	5		6
17		3									
18											
19	4		3								1
20	6		5			1					
21			2	3		6				2	
25			4					6	4		
26	1	2	6					4		1	
27							2			4	
28											
29	3						1				
30											
31		6									
32		1				4	3				
33						2	4			5	
34				2		3	6			6	
35				6			5			3	
36				4							

Sum and count select species

Used species vulnerable to each activity

Sum, count ranks

stratum	cables_count	cables_sum	pipelines_count	pipelines_sum
11	2	7	3	9
12	2	6	3	11
13	6	11	6	11
14	5	21	5	19
15	2	10	4	19
16	2	11	4	20
17	1	3	1	3
18	0	0	0	0
19	2	7	2	4
20	3	12	2	6
21	4	13	4	13
25	2	8	3	14
26	4	10	4	13
27	1	4	2	6
28	0	0	0	0
29	1	3	1	1
30	0	0	0	0
31	1	6	1	6
32	2	5	3	8
33	2	7	3	11
34	3	11	4	17
35	2	9	3	14
36	1	4	1	4

Multiply the sum and count for each activity type

Index

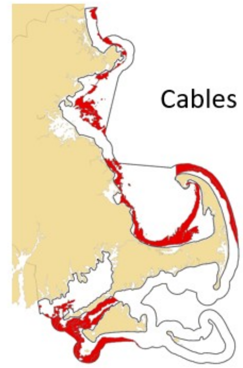
stratum	Index_cables	Index_pipelines
11	14	27
12	12	33
13	66	66
14	105	95
15	20	76
16	22	80
17	3	3
18	0	0
19	14	8
20	36	12
21	52	52
25	16	42
26	40	52
27	4	12
28	0	0
29	3	1
30	0	0
31	6	6
32	10	24
33	14	33
34	33	68
35	18	42
36	4	4

Sort (cables)

stratum	Index_cables
14	105
13	66
21	52
26	40
20	36
34	33
16	22
15	20
35	18
25	16
11	14
19	14
33	14
12	12
32	10
31	6
27	4
36	4
17	3
29	3
18	0
28	0
30	0

Map top 6 strata

Cables



Sort (pipelines)

stratum	Index_pipelines
14	95
16	80
15	76
34	68
13	66
21	52
26	52
35	42
25	42
33	33
12	33
11	27
32	24
20	12
27	12
19	8
31	6
36	4
17	3
29	1
18	0
28	0
30	0

Map top 6 strata

Pipelines