Omnibus Deep-Sea Coral Amendment

DRAFT: November 4, 2016

<u>Sections that are substantially complete and may be of interest include:</u>

Prepared by the
New England Fishery Management Council

COVER IMAGES, CLOCKWISE FROM UPPER RIGHT:

A large black coral and two Paramuricea *corals in Oceanographer Canyon. Image courtesy of NOAA Okeanos Explorer Program, 2013 Northeast U.S. Canyons Expedition.*

Close-up of a sea pen colony at 2,023 meters depth on Retriever Seamount. Sea pens are octocorals and the characteristic eight pinnate tentacles are plainly visible in this image. The dark line running down below the tentacles of each polyp is the pharynx, connecting the mouth to the bag-like digestive cavity. A mysid shrimp ("possum shrimp") is swimming by the colony. Image courtesy of NOAA Okeanos Explorer Program, Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts.

Cup corals and a sea star a mile underwater in Heezen Canyon. Image courtesy of NOAA Okeanos Explorer Program, 2013 Northeast U.S. Canyons Expedition.

A Paramuricea *coral in Nygren Canyon which 165 nautical miles southeast of Cape Cod, Massachusetts. Image courtesy of NOAA Okeanos Explorer Program, 2013 Northeast U.S. Canyons Expedition.*

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2 Background and purpose

2.1 What are deep-sea corals?

Worldwide, deep corals can build reef-like structures or occur as thickets, isolated colonies, or solitary individuals, and often are significant components of deep-sea ecosystems, providing habitat (substrate, refugia) for a diversity of other organisms, including many economically important fish and invertebrate species. They are suspension feeders, but unlike most tropical and subtropical corals, do not require sunlight and do not have symbiotic algae (zooxanthellae) to meet their energy needs. Deep corals can be found from near the surface to 6000 m depth, but most commonly occur between 50-1000 m on hard substrate (Puglise and Brock 2003), hence their "deep-sea" appellation.

A diversity of coral species live in the northeast region (see section 5.2 for details). The characteristics of these corals vary in terms of their size, shape, and flexibility, growth rates and reproductive strategies, preferred depth range, and habitat associations. Some are relatively common, whereas other types are rare. All coral are vulnerable to fishing gear impacts, but the degrees of susceptibility and the rates of recovery vary, depending both on coral biology and on spatial overlap between corals and fishing grounds, which influences the likelihood of gear interactions. In general, coral species richness is greater at deeper depths (Cairns 2007), but there are concentrations of corals at depths where fishing routinely occurs, for example in the Gulf of Maine.

2.2 Need and purpose for action

This action is needed to reduce potential impacts to corals from fishing activity, as allowed under the Council's discretionary authority. The purpose of this action is to consider area-based management measures for deep-sea corals occurring in the New England region.

The following problem statement was adopted by the Council for this action in April, 2016:

> "The Council is utilizing its discretionary authority under section 303(b) in MSA to identify and implement measures that reduce, to the extent practicable, impacts of fishing gear on deep-sea corals in New England. This amendment contains alternatives that aim to identify and protect concentrations of corals in select areas and restrict the expansion of fishing effort into areas where corals are likely to be present.
>
> Deep-sea corals are fragile, slow-growing organisms that play an important role in the marine ecosystem and are vulnerable to various types of disturbance of the seafloor. At the same time, the importance and value of commercial fisheries that operate in or near areas of deep-sea coral habitat is recognized by the Council. As such, measures in this amendment will be considered in light of their benefit to corals as well as their costs to commercial fisheries."

2.3 Management background and authority

There are multiple provisions in the Magnuson Stevens Fishery Conservation and Management Act (MSA) that can be used to justify coral protection. One is the Essential Fish Habitat (EFH) authority, where corals are considered a component of essential fish habitat, and fishing restrictions are enacted in the context of minimizing, to the extent practicable, the effects of fishing on EFH (see section 305(b)). In the Northeast region, this authority was used in Monkfish FMP Amendment 2 to protect deep-sea corals and associated habitat features in two offshore canyons, Lydonia and Oceanographer, from fishing activity occurring under a monkfish day at sea. Options for minimizing the adverse effects of fishing on EFH include fishing equipment restrictions, time/area closures, and harvest limits (in this case, direct harvest of corals).

In the Northeast Region, coral distributions extend well beyond the bounds of designated EFH. The Section 303(b) discretionary provisions found in the 2007 reauthorization of the MSA (below) provide a second and more flexible mechanism by which Councils may protect deep-sea corals from the effects of fishing.

> Any fishery management plan which is prepared by any Council, or by the Secretary, with respect to any fishery, may—
>
> (A) designate zones where, and periods when, fishing shall be limited, or shall not be permitted, or shall be permitted only by specified types of fishing vessels or with specified types and quantities of fishing gear;
>
> (B) designate such zones in areas where deep sea corals are identified under section 408 (this section describes the deep-sea coral research and technology program), to protect deep sea corals from physical damage from fishing gear or to prevent loss or damage to such fishing gear from interactions with deep sea corals, after considering long-term sustainable uses of fishery resources in such areas; and
>
> (C) with respect to any closure of an area under this Act that prohibits all fishing, ensure that such closure—
>
> (i) is based on the best scientific information available;
>
> (ii) includes criteria to assess the conservation benefit of the closed area;
>
> (iii) establishes a timetable for review of the closed area's performance that is consistent with the purposes of the closed area; and
>
> (iv) is based on an assessment of the benefits and impacts of the closure, including its size, in relation to other management measures (either alone or in combination with such measures), including the benefits and impacts of limiting access to: users of the area, overall fishing activity, fishery science, and fishery and marine conservation;

In May 2010, the Council received guidance from NMFS NERO regarding implementation of the discretionary provisions. This guidance was updated by the NMFS Office of Habitat Conservation and distributed to all eight regional fishery management councils in June 2014. Both the 2010 and 2014 guidance documents refer to the deep-sea coral research and technology program as a conduit for providing information about coral distributions to the Councils. According to the 2014 guidance, when designating deep-sea coral zones, the following parameters and considerations apply:

1. The authority may only be used for deep-sea coral areas identified by the DSCRTP.
2. Deep-sea coral zones may only be designated within the U.S. Exclusive Economic Zone (EEZ) and within the geographical range of a fishery managed under an FMP. A Council may develop protective measures for such zones that apply to any fishing, not just that managed under the applicable FMP. Thus, measures may apply to fishing that is managed under a different federal FMP or to state-regulated fishing that is authorized in the EEZ.[1]
3. A Council should coordinate with potentially affected Councils, state commissions, and states to ensure that it has sufficient information to support the need for its action and to analyze impacts of the action on other fisheries.
4. Long-term sustainable uses of fishery resources in the deep-sea coral areas must be considered. This consideration informs but does not limit the scope of protective measures that a Council may adopt.
5. Deep-sea coral zones and protective measures may be adopted even if there are no vessels currently fishing at or near the areas or there is no indication that current fishing activities are causing physical damage to deep-sea corals.
6. To ensure the effectiveness of protective measures, deep-sea coral zones may include, as necessary, additional areas beyond the exact locations of the deep-sea corals.

The 2014 guidance suggests the following criteria for identification of coral zones. The NOAA Strategic Plan for Deep-Sea Coral and Sponge Ecosystems (NOAA 2010b) provides similar guidance on selection of coral conservation measures.

- The size of the reef or coral aggregation, or density of structure-forming deep-sea corals;
- The occurrence of rare species;
- The importance of the ecological function provided by the deep-sea corals as habitat;
- The extent to which the area is sensitive to human-induced environmental degradation;
- The likelihood of occurrence of deep-sea corals in unsurveyed areas based on the results of coral habitat suitability models or similar methods.

Finally, the 2014 guidance suggests that options for protecting corals from fishing gear damage include but are not limited to:

[1] This is different from the 2010 guidance from NERO, which indicated that for coral management provisions to apply to fisheries managed under the Atlantic Coastal Cooperative Fisheries Management Act (ACA), either the ASMFC must take complementary action in their FMP, or there must be a Council FMP for the same resource. The relevant example in our region is the offshore component of the American lobster fishery, which is managed by ASMFC.

1. Restrictions on the location where fishing may occur. If a closure to all fishing is being considered, it must comply with requirements at MSA section 303(b)(2)(C),14 which include establishing a timetable for review of the closed area's performance. This review should be conducted in consultation with the DSCRTP. Given the additional requirements and process, a Council may want to consider whether targeted gear restrictions, as opposed to a full fishing closure, would provide sufficient protection.
2. Restrictions on fishing by specified types of vessels or vessels with specified types and quantities of gear. These could include, for example, limits on the use of specified fishing-related equipment, required equipment modifications to minimize interactions with deep-sea coral communities, prohibitions on the use of explosives and chemicals, prohibitions on anchoring or setting equipment, and prohibitions on fishing activities that cause damage to deep-sea corals.
3. Proactive protection by freezing the footprint of current fishing activities of specified types of vessels or vessels with specified types and quantities of gear to protect known or expected locations of deep-sea corals.
4. Limits on the harvest or bycatch of species of deep-sea coral that provide structural habitat for other species, assemblages, or communities.

As noted in the 2014 Office of Habitat Conservation guidance and the NOAA Strategic Plan for Deep-Sea Coral and Sponge Ecosystems, other sections of the MSA may also apply to the protection of deep-sea corals and associated ecosystems:

- MSA section 303(a)(7) requires that an FMP describe and identify EFH for the fishery, minimize to the extent practicable adverse effects caused by fishing, and identify other actions to encourage the conservation and enhancement of the EFH. Federal action agencies must consult with NOAA on activities that may adversely affect EFH, and NOAA provides non-binding conservation recommendations to the agencies through that process. If a deep-sea coral area is EFH (e.g., essential for spawning, breeding, feeding or growth to maturity of fish managed under an FMP), then it must be identified as such and the above requirements apply.
- Section 301(a)(9) requires Councils to include conservation and management measures that, to the extent practicable, minimize bycatch.
- Section 303(b)(12), authorizes Councils to include management measures in FMPs to conserve target and non-target species and habitats.

2.4 Amendment development process

The coral protection zones included in this amendment were initially developed during 2010 and 2011 as part of the Council's Omnibus Essential Fish Habitat Amendment 2 (OHA2). The Council approved a specific range of alternatives for analysis in April 2012. In September 2012, the Council split the coral protection zones areas and associated management measures out of OHA2 into a separate omnibus amendment. The canyon and seamount Habitat Area of Particular Concern designations, which do not restrict fishing activities but rather serve as a focus for future management efforts as well as EFH consultations, were retained within OHA2. The OHA2 HAPC designations and the coral zones in this action have overlapping but not identical locations and boundaries.

The Council took final action on OHA2 in June 2015, including approval of the canyon and seamount HAPCs. OHA2 and its associated Environmental Impact Statement are currently undergoing final development and review, with implementation expected in 2017.

Because Mid-Atlantic and New England-managed fisheries overlap spatially along the shelf break, the two Councils have been coordinating their coral management efforts for years through technical work groups (NEFMC Habitat PDT, MAFMC Coral FMAT) and via the NEFMC Habitat Committee, which currently includes two MAFMC representatives. In June 2013, the New England, Mid-Atlantic, and South Atlantic Fishery Management Councils formalized this coordination via a memorandum of understanding (http://s3.amazonaws.com/nefmc.org/June-2013-Final-DSC-MOU.pdf). Specifically, the purposes of this Memorandum of Understanding (MOU) are:

- To establish a framework for coordination and cooperation toward the protection of deep sea coral ecosystems; and
- To clarify and explain each Council's role and geographic areas of authority and responsibility with regard to deep-sea coral management.

Under the MOU, each Council develops measures within their respective area of jurisdiction. Inter-council boundaries identifying areas of jurisdiction are specified at 50 CFR §600.105. The boundary between the Mid-Atlantic and New England regions runs diagonally across the shelf from the CT/RI/NY intersection point across Alvin Canyon to the EEZ. Thus, one important outcome of the MOU is that Mid-Atlantic region alternatives initially developed in 2010 are no longer included in the NEFMC coral amendment. Prior to and since signing the MOU, the New England and Mid-Atlantic Councils in particular have been sharing technical information and monitoring policy approaches discussed by the other Council to improve consistency in the policies proposed as well as in the use of scientific information.

In addition, the MOU includes a commitment to develop consistent management approaches when possible, and to engage potentially affected stakeholders regardless of which Council manages their fishery. The Mid-Atlantic Council took final action on their coral amendment, which is Amendment 16 to the Mackerel, Squid, and Butterfish FMP, in June 2015. Many of the coral zones selected by MAFMC were initially developed by NEFMC, although the boundaries were subsequently refined by MAFMC using new sources of data and stakeholder feedback, and some additional areas were added. The management measures (e.g. gear restrictions) selected by MAFMC generally fall within the range initially developed by NEFMC and approved for analysis in 2012. While final NMFS approval and rulemaking is pending, the preferred MAFMC approach is described below to facilitate continuity in management approaches. A proposed rule was published on September 27, 2016.

- MAFMC selected discrete zones in various individual canyons or canyon complexes, specifically Block, Ryan/McMaster, Emery/Uchupi, Jones/Babylon,

Mey-Lindenkohl Slope, Spencer, Wilmington, N. Heyes/S. Wilmington, S. Vries, Baltimore, Warr/Phoenix, Accomac/Leonard, Washington, and Norfolk.
  - The Council adopted boundaries developed during a workshop held during April 2015. The workshop included input from industry members, conservation organizations, and scientists, and participants reviewed updated bathymetric data, habitat suitability model outputs, and the locations of direct coral observations prior to and during the meeting.
- MAFMC selected a broad zone with a landward boundary between 400-500 meters extending to the EEZ.
  - The landward boundary line is comprised of straight segments, with the following constraints: minimum depth of 400 m, maximum depth of 500 m, and consistency with discrete boundaries where possible.
  - The north/south extent encompasses the entire MAFMC area of jurisdiction.
  - The discrete zone boundaries take priority in areas of overlap.
- For both broad and discrete zones, MAFMC's amendment prohibits all bottom tending-gear, with an exemption for the red crab fishery. Prohibition would not apply to the American lobster fishery managed by ASMFC. Transit would be allowed, subject to gear stowage requirements.
- Frameworkable measures would include:
  - Boundaries of coral zones,
  - Management measures within zones, including fishing restrictions, exemptions, monitoring, and anchoring,
  - New discrete coral zones, and
  - Special access programs.
- Finally, MAFMC's amendment implements a VMS requirement for all Illex squid moratorium vessels, whether they are fishing within or outside of coral zones.

3 Management alternatives

This section describes management measures to conserve deep-sea corals within the New England region. Two conceptual approaches are proposed for the development of coral zones. Both would rely on the discretionary coral protection authority provided in the 2007 MSA reauthorization.

The **'discrete areas'** approach would designate more narrowly defined coral zones based on discrete bathymetric/geological features and groupings of corals. These zones include specific locations in the Gulf of Maine, single canyons, and individual seamounts. The boundaries of the discrete coral zones are based on direct observations of corals and other animals, plus inferences about the likely spatial extent of coral habitats, based on terrain data or habitat suitability models. The discrete coral zones were developed to encompass species that attach to hard substrates, and are relatively large or have other attributes that make them more susceptible to fishing-related impact. While there is abundant soft substrate in the deep ocean, hard substrate areas are much more limited in their distribution. Becauase hard substrate areas tend to be patchy in their spatial distribution, some soft sediment areas and associated fauna would be included within the discrete zone boundaries, incidental to the primary conservation target.

The **'broad areas'** approach would designate a coral zone along the entire shelf-slope region between the US/Canada EEZ boundary and the New England/Mid-Atlantic Council boundary. Broad zones are generally intended to cover areas beyond the distribution of currently occurring fishing effort, and represent a precautionary approach to management that would prevent the expansion of fishing into additional deep-water habitats. They would encompass coral habitats in the canyons, on the continental slope and on the seamounts. The broad areas do not overlap the coral zones in the Gulf of Maine.

The broad zone alternatives, in addition to encompassing the canyon and seamounts themselves, include additional areas of low-relief mud habitats that harbor other species of corals, including sea pens. Specifically, the white sea pen, *Stylatula elegans*, and the common sea pen, *Pennatula aculeata* possibly have lower susceptibility to fishing disturbance, and are more widely distributed than other types of corals. Other corals fall into the category of lower susceptibility – specifically, the hard coral *Dasmosmilia lymani*. This species was noted as being relatively common, including in shallower depths, is small in size, and is possibly less susceptible to fishing gear impacts. Some larger species such as the bamboo coral *Acanella arbuscula* are also associated with these soft substrates.

Management options for restricting or modifying fishing operations within the deep-sea coral zones include restrictions on mobile bottom-tending gears, restrictions on bottom-tending gears, and authorized exemptions to these restrictions. Different restrictions may be appropriate in broad vs. discrete zones, or among the various discrete zones.

Note that broad areas and discrete areas could be implemented simultaneously. While the individual discrete zones do not overlap one another, the canyon and seamount zones overlap the broad zone alternatives. In some areas, the landward boundary of the discrete canyon zones is slightly shallower than the landward boundary of the shallowest broad zone, so combining the discrete zones with one of the broad zones would protect additional coral habitats in the heads of the canyons. A combination approach might also be appropriate if different management measures are desired in the discrete vs. broad areas.

In order to increase flexibility and allow for incorporation of new scientific information, there is an alternative that would allow new coral zones, or new fishing restrictions in designated coral zones, to be implemented via framework action.

3.1 No Action

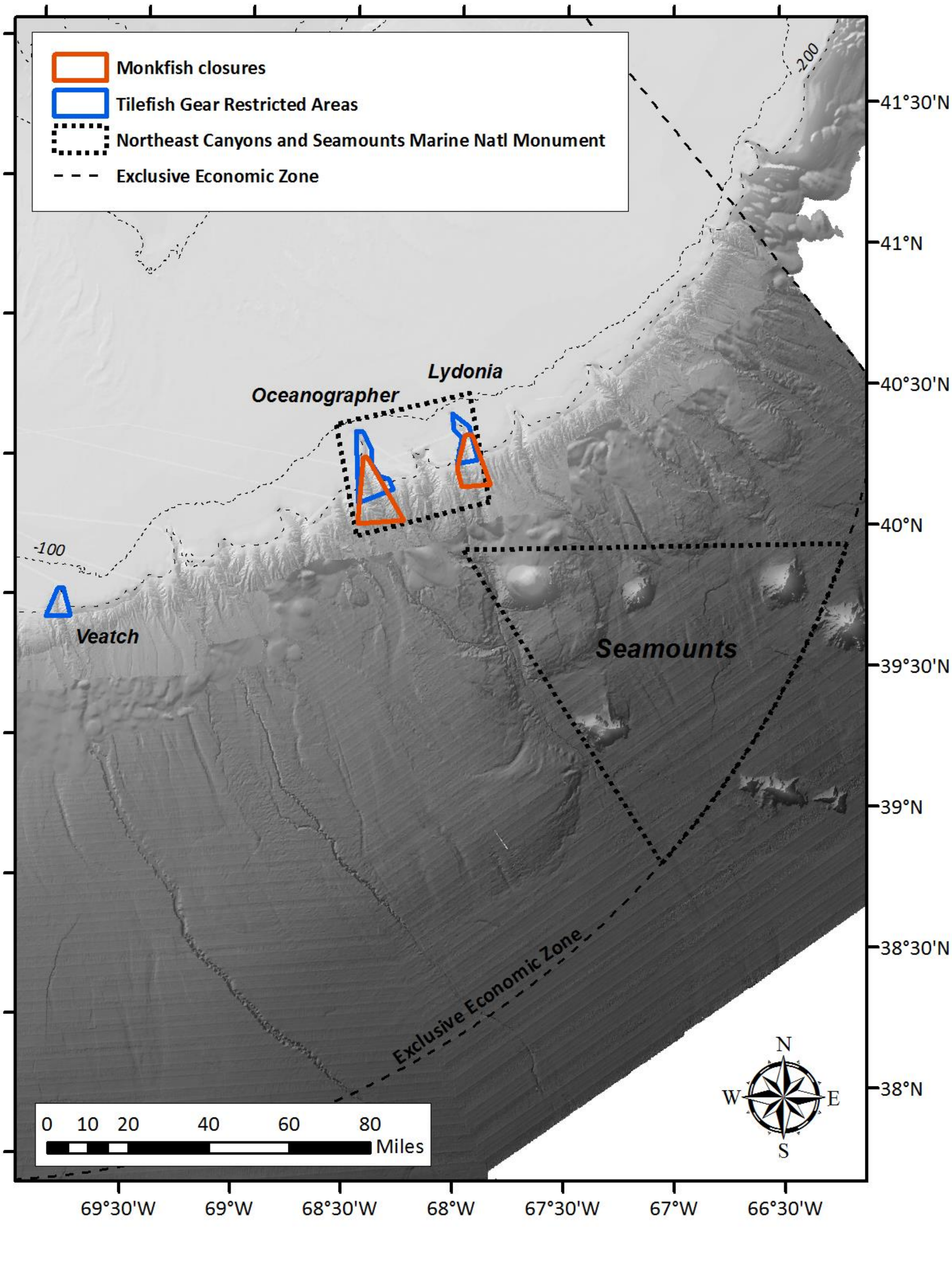
Currently there are no coral zones designated by the Council under the discretionary authority. However, some management areas currently in place offer protection to deep-sea corals in certain locations.

- **Monkfish FMP (Joint New England and Mid-Atlantic Councils)**: Monkfish Amendment 2 (2005) prohibited fishing with any gear type while on a monkfish DAS in Lydonia and Oceanographer Canyons. The rationale provided in Monkfish Amendment 2 explicitly references protection of deep-water species and habitat in canyons, including deep-sea corals. These areas were developed via the MSA EFH authority, not using the discretionary coral protection provisions. These same two areas were later adopted as mackerel, squid, and butterfish bottom trawling restricted areas via Amendment 9 to that FMP (2008). Under the MSB FMP, no permitted mackerel, squid, or butterfish vessel may fish in the areas with bottom trawl gear.
- **Tilefish FMP (Mid-Atlantic Council)**: Amendment 1 to the Tilefish FMP (2009) adopted mobile bottom-tending gear restrictions (Gear Restricted Areas, or GRAs) in Lydonia, Oceanographer, and Veatch Canyons. There is also a GRA in Norfolk Canyon, outside the New England region. These apply to any mobile bottom-tending gears regardless of fishery. Note that the Tilefish GRAs are located towards the heads of the canyons, with the boundaries based on those of the Tilefish Habitat Areas of Particular Concern (HAPC). The HAPCs were designed to protect clay outcrop habitats which occur in the heads of the canyons to roughly 300 m, although they cover deeper water areas along the axis of the canyons as well and would therefore have conservation benefits for deep-sea coral occurring deeper than 300 m. As above, these areas were developed via the MSA EFH authority, not using the discretionary coral protection provisions.
- **Northeast Canyons and Seamounts Marine National Monument:** On September 15, 2016, President Barack Obama designated the Northeast Canyons and Seamounts Marine National Monument, which has two sub-areas. The first encompasses the shelf-slope region from Oceanographer to Lydonia Canyons between approximately 100 meters and 2,000 meters, and the second encompasses all four seamounts in the EEZ. While regulations under the Magnuson-Stevens Act have not been implemented yet, sixty days from designation the monument areas will be closed to all fishing, except that

> recreational fishing will continue to be allowed. The lobster and red crab fisheries have been granted seven years to cease operations within the monument. Energy exploration and development are also prohibited within the monument.

The Lydonia and Oceanographer Canyon monkfish and tilefish areas described above are almost entirely encompassed by the canyon section of the monument. The Veatch Canyon Tilefish GRA is fully outside the monument.

Map 1 – No Action alternative – various areas in the New England region that afford protection for deep-sea corals. Depth contours shown are in meters.



3.2 Broad deep-sea coral zone designations

These alternatives would designate a large area of the shelf-slope and abyssal plain out to the EEZ as a deep-sea coral zone. There are four overlapping and mutually exclusive broad zone alternatives under consideration, and only one may be adopted by the Council. Alternatives for fishing restrictions in these zones are described in section 3.4.

The zones have their landward boundaries along the southern flank of Georges Bank, their seaward boundary at the EEZ, and their western boundary along the New England/Mid-Atlantic intercouncil boundary line. The landward boundary options are simplified versions of 300 m, 400 m, 500 m, or 600 m depth contours, with line segments connecting waypoints with specific latitude/longitude coordinates. Map 2 shows the full spatial extent of all four broad zone alternatives. These simplified contours are shown on the maps below, are being used for analysis, and would be adopted as specific management area boundaries, should one of these areas be selected.

The original depth contours were derived from a 25 m resolution digital terrain model. In order to draw straight line approximations at the landward boundaries, a 50 m depth tolerance was allowed on either side. For example, the landward boundary of the 300 m zone has a minimum depth of 250 m and a maximum depth of 350 m. The relationship between the zone boundaries and depth contours is illustrated in Map 3, which shows what these boundaries look like along the western shoulder of Oceanographer Canyon.

The simplified boundary alternatives were derived from the raw depth contours using the simplify line tool in ArcGIS 10.2.2 for Desktop. In many locations along the continental shelf edge, a distance over ground tolerance of 0.5 km achieves the desired +/- 50 m depth tolerance, while significantly simplifying the contour. Thus, a 0.5 km distance over ground tolerance was specified when running the automated line simplify tool. In steeper locations where this tolerance resulted in boundaries outside the +/- 50 m depth tolerance, waypoints were added manually to follow the depth contour. The objective was to minimize the number of waypoints and simplify the boundary as much as possible, given the 50 m depth tolerance around each target contour. Given the shape of the contours along the edge of the shelf, the 300 m zone is a somewhat smoother boundary, with the 400-600 m zones becoming increasingly complex.

The broad zones align generally with the discrete zones at the heads of the canyons, with some of the discrete canyon zone boundaries approximating the 300 m zone, and others approximating the 400 m zone (Map 4).

Rationale: The overall objective of this type of measure would be to prevent the expansion of fishing effort into deepwater coral areas, while limiting impacts on current fishing operations. Progressively deeper broad zones encompass less and less fishing activity.

Table 1 – Size and depth of broad coral zones

Area name	Area size, km^2	Target minimum depth, m	Maximum depth, m
300 m broad zone	67,142	300	6000 m (approximate)
400 m broad zone	66,410	400	6000 m (approximate)
500 m broad zone	65,838	500	6000 m (approximate)

Area name	Area size, km^2	Target minimum depth, m	Maximum depth, m
600 m broad zone	65,365	600	6000 m (approximate)

3.2.1 Option A: Landward boundary approximating the 300 m contour

This alternative would designate a broad coral zone from the US-CAN EEZ boundary to the boundary between the New England and Mid-Atlantic Council regions, with the landward boundary based on the 300 m contour and the seaward boundary at the EEZ.

3.2.2 Option B: Landward boundary approximating the 400 m contour

This alternative would designate a broad coral zone from the US-CAN EEZ boundary to the boundary between the New England and Mid-Atlantic Council regions, with the landward boundary at the 400 m contour and the seaward boundary at the EEZ.

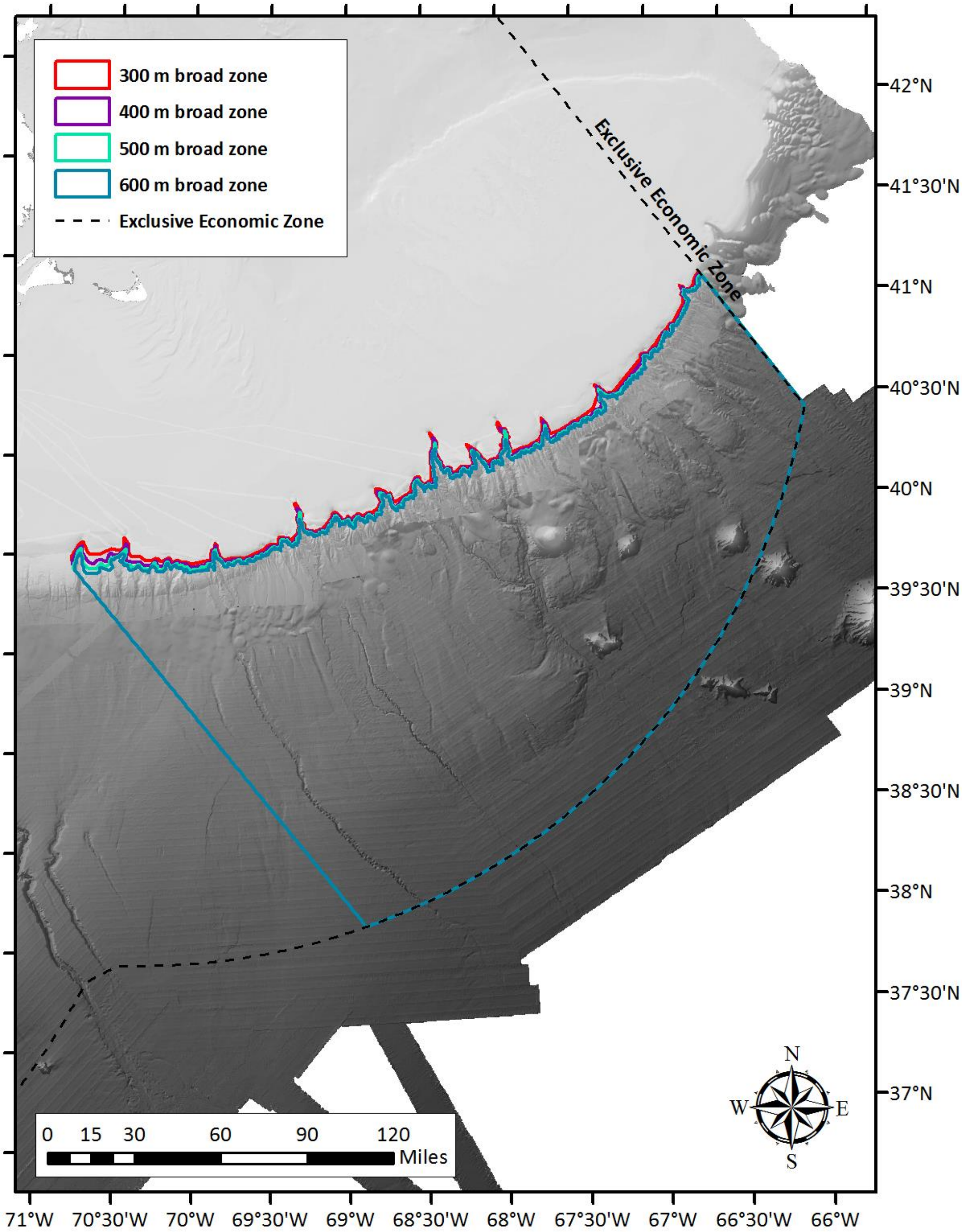
3.2.3 Option C: Landward boundary approximating the 500 m contour

This option would designate a broad coral zone from the US-CAN EEZ boundary to the boundary between the New England and Mid-Atlantic Council regions, with the landward boundary at the 500 m contour and the seaward boundary at the EEZ.

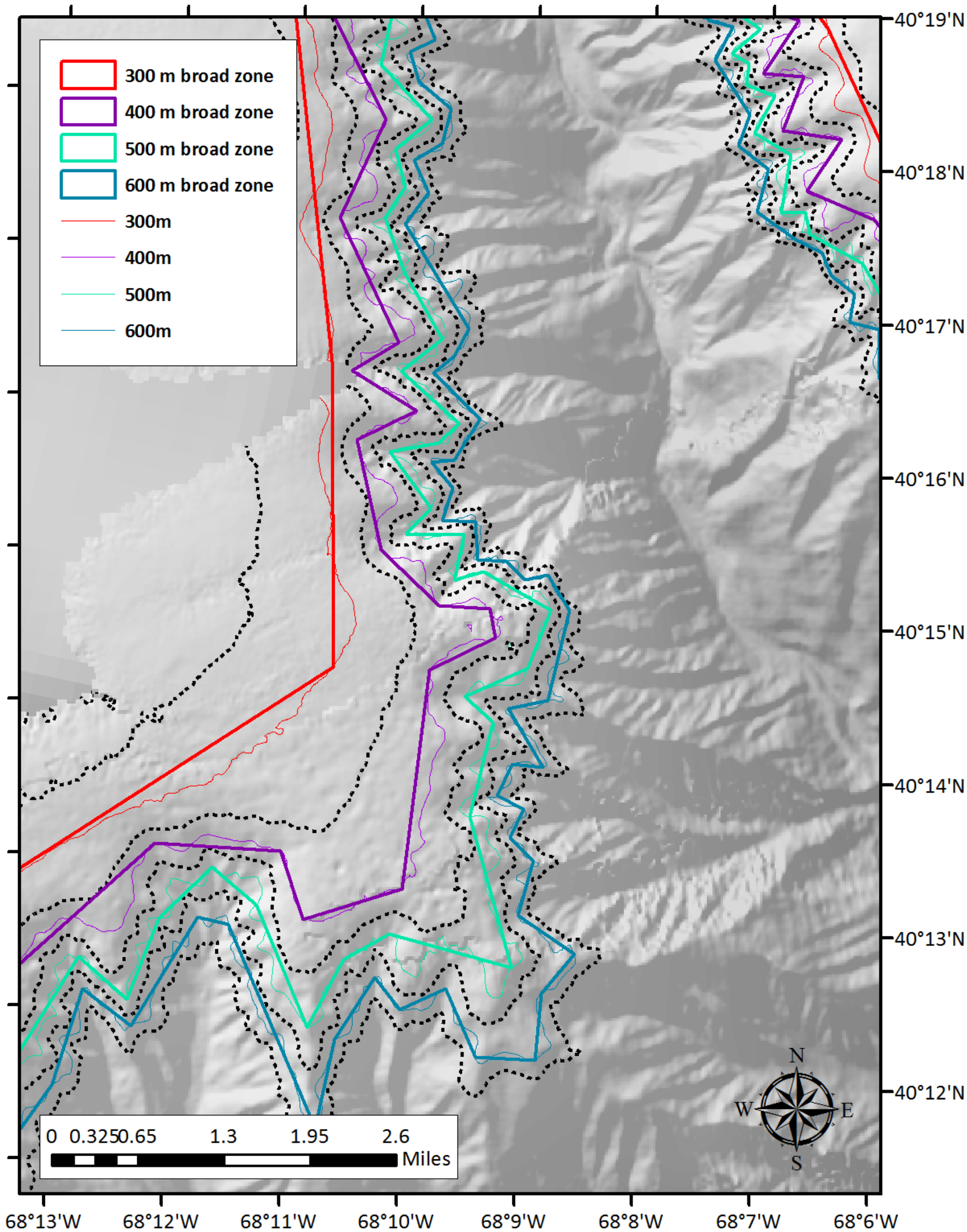
3.2.4 Option D: Landward boundary approximating the 600 m contour

This option would designate a broad coral zone from the US-CAN EEZ boundary to the boundary between the New England and Mid-Atlantic Council regions, with the landward boundary at the 600 m contour and the seaward boundary at the EEZ.

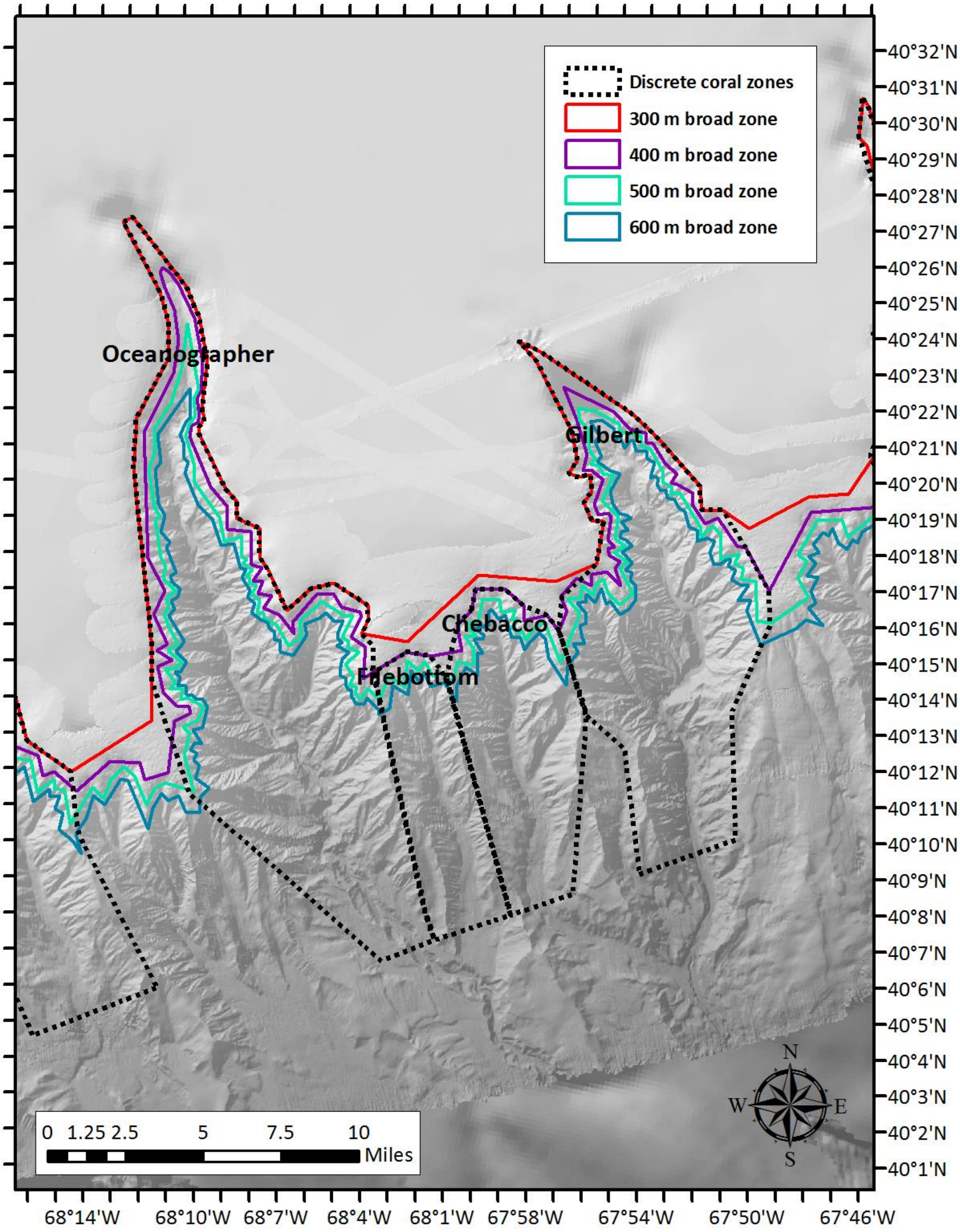
Map 2 – Broad coral protection zones based on 300, 400, and 500 meter contours.



Map 3 – Broad zones alternatives at the shoulder of Oceanographer Canyon. Because the areas are so steeply sloping, the contours are often only 1-2 km apart between the canyons, and even more closely spaced within the canyons. The deeper boundaries are necessarily more complex (more segments and waypoints) than the shallower boundaries. Heavy straight lines indicate the broad zone boundaries, and thinner lines in matching colors show the underlying contour that was simplified. The black dotted lines indicate the 250, 350, 450, 550, and 650 m contours, and serve as upper and lower depth bounds for the broad zones.



Map 4 – Broad zone boundaries with discrete coral zones. Compare Oceanographer, and Gilbert, which follow the 300m zone, with Filebottom and Chebacco, which follow the 400m zone.



3.3 Discrete deep-sea coral zone designations

Discrete deep-sea coral zones overlap individual canyons, seamounts, or other features. These discrete coral zones are intended to encompass known aggregations of corals as well as steeply sloping habitats likely to have exposed rock outcroppings that provide suitable attachment sites for corals. Because the discrete zones do not overlap one other, any combination of areas could be selected.

The following sources of data were used to develop a list of recommended deep-sea coral zones, and to generate boundaries for those zones. Available data are similar for the different types of zones (canyon, seamount, Gulf of Maine), with variations as noted below. The major data types include information on the presence, abundance, and locations of various types of corals, terrain data such as depth and slope, and model outputs that predict areas where suitable habitats for particular taxonomic groups of corals are likely to occur. It is important to note the linkages between these data sets, which were generally collected or developed in an integrated, iterative fashion, rather than in an independent or stepwise manner. For example, historical coral distribution records combined with terrain and other environmental data were used in the habitat suitability model, and model outputs were in turn used to direct recent field sampling for coral habitats. Interest in coral habitats based on historical data helped drive collection of high resolution bathymetric data, which in turn informed selection of recent dive sites.

Deep-sea coral observations: Deep-sea coral observations from (1) an historical database and (2) recently conducted remotely operated vehicle (ROV) dives, autonomous underwater vehicle (AUV) dives, and camera tows were used as a starting point to identify areas of conservation interest. See section 5.2.1 for details about these data.

Terrain data (bathymetry and slope): Bathymetry and slope are key data sets for describing seafloor terrain and identifying areas that may contain deep-sea corals, as many taxa have been found in higher abundances attached to vertical rock walls and other steep terrain. Bathymetry data sets are also referred to as digital elevation models, or DEMs. These bathymetric datasets were used to identify area boundaries, and also to calculate minimum, maximum, and mean depths of candidate management areas.

- The primary source of bathymetry data for the canyons comes from a series of Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) on NOAA's research vessels Hassler, Bigelow, and Okeanos Explorer. These mapping expeditions took place from February 2012 through August 2012. Data were collected at 25m resolution.
- For the deepest portions of the canyons, the abyssal plain, and the seamounts, 100 meter resolution multibeam bathymetry data are available. These data were collected as part of a NOAA-initiated collaboration to fill data gaps identified during an inventory of data holdings to support potential claims under the United Nations Convention on the Law of the Sea (UNCLOS). Data are available for download from the University of New Hampshire Center for Coastal and Ocean Mapping Joint Hydrographic Center (http://ccom.unh.edu/theme/law-sea/law-of-the-sea-data/atlantic).
- In the Gulf of Maine, a 10 meter resolution multibeam bathymetric dataset was used for Outer Schoodic Ridge, a 20 meter resolution multibeam bathymetric dataset was used in Western Jordan Basin, and a 1/3 arc-second (approximately 10 m) bathymetric data set (the Bar Harbor DEM) was used in the Mount Desert

Rock area and surrounds. The Outer Schoodic Ridge and Western Jordan Basin data were collected during a fall 2013 ECOMON cruise aboard the Okeanos Explorer (Auster et al. 2014). The Bar Harbor DEM is described in Friday et al. 2011.

- A lower resolution 250 meter DEM from The Nature Conservancy's Northwest Atlantic Marine Ecoregional Assessment, which is largely based on the Coastal Relief Model, is available in other areas where higher resolution data do not exist.

Maps in this document show hill-shaded bathymetry, which allows for the shape of the seafloor to be visualized more easily. Hill-shaded surfaces are generated using Geographic Information System (GIS) software, by simulating what the terrain would look like if a light was shone over the surface from a specific angle and elevation. Values of 315 and 35 degrees with a vertical exaggeration of 3x were used for the maps in this document.

Slope is a measure of the rate of change in bathymetry, and slope surfaces can be derived directly from any digital elevation model. Slope surfaces were also generated for other digital elevation models and high slope areas are highlighted on the maps of each discrete coral zone. The canyons generally contain larger areas of very high slope as compared to the seamounts or Gulf of Maine areas. For areas where very steep terrain is less prevalent, including the seamounts and the Gulf of Maine areas, slopes greater than 10 or 20 degrees are mapped instead of slopes above 30 degrees.

When interpreting bathymetric data, it is important to recognize the potential for artefacts in the data, which appear as a sudden change in depth. These artefacts can occur at seams, where data collected at different times are joined together to form a single coverage. These visible seams are due to small differences in instrument calibration. These abrupt jumps in bathymetry values can cause false slopes at the seams, which are not reflective of features on the seafloor. Though less probable and less severe, such artefacts can also occur at the boundaries between multibeam swaths collected at different times with the same ship and instrument, especially when data are collected across years. Caution is also needed at the edges of multibeam coverage and in the vicinity of holidays (pixels without valid data), where fewer bottom contacts are averaged and higher statistical noise may be present. These are all common and well-known features of multibeam echosounder data. It is widely accepted that expert interpretation is required to avoid considering such areas as true bottom features, and such expert guidance is standard practice in the hydrographic field. Where such artefacts are present in the maps presented below, they are noted on the maps in the text.

Habitat suitability model: Direct observations of corals are only available for a small portion of each area, thus requiring inference about the spatial extent of suitable coral habitats in various locations. A habitat suitability model (Kinlan et al., in review) was developed for the northeast region that predicts areas of lower and higher suitability for various types of corals. The model is described further in section 5.3. The combined high and very high suitability areas for the Gorgonian Alcyonacea and non-gorgonian Alcyonacea combined were used to develop the canyon zones.

3.3.1 Canyon coral zones

Coral zones are recommended within twenty submarine canyons off the southern boundary of Georges Bank. From west to east, these canyons include Alvin, Atlantis, Nantucket, Veatch, Hydrographer, Dogbody, Clipper, Sharpshooter, Welker, Heel Tapper, Oceanographer, Filebottom, Chebacco, Gilbert, Lydonia, Powell, Munson, Nygren, an unnamed canyon, and Heezen. All of these areas have recent ROV or towed camera dives indicating the presence of coral habitats. Some areas have historical records as well.

Boundaries of these zones are based on the most up to date information on coral observations, high resolution terrain data, and habitat suitability model results. Coral zone boundaries are primarily based on bathymetry and slope, and were designed to encompass the full extent of the canyon feature from the shelf break to the point where the slope begins to flatten out at the edge of continental rise. The 3° slope contour was used to identify the shelf break in previous PDT coral analyses, and this convention is adopted here as well. The 3° slope contour is typically lies somewhere between 200 and 300 meters depth off of New England. Because the shallow edge of the high resolution ACUMEN bathymetry dataset overlaps these contours, this data set was not suitable for defining a 3° slope contour. Therefore, the slope contour was developed using the TNC NAMERA DEM. This slope contour roughly approximates the landward coral zone boundary in the shelf incising canyons, and in some of the slope confined canyons as well. The landward boundary of other slope confined canyons begins slightly deeper, which is consistent with the slope and habitat suitability model outputs (more on this below).

Areas of the canyons with high slope (greater than 30°) have been shown to have corals most of the time during recent ROV and towed camera surveys, and corals have been found in areas with very high slope (greater than 36°) during all recent dives. Thus, these high and very high slope areas, which are derived from the ACUMEN bathymetry, were a useful guide for defining the width of the canyon zones (west to east dimension), as well as the seaward boundaries of the zones.

The high and very high habitat suitability outputs for gorgonian Alcyonacea, and non-gorgonian Alcyonacea were also considered when developing canyon zone boundaries. These high and very high suitability model outputs often align well with the high and very high slope areas described above. Similar to the slope outputs, the model results were used to help define the width of the canyon zones, and well as their landward and seaward extents. A buffer of 0.4 nautical miles around the high suitability outputs was generated to roughly reflect the degree of spatial uncertainty in the model results. As appropriate, the zones include these buffer areas as well. The PDT prioritized the high resolution bathymetry and slope data over the model outputs when developing boundaries because these high resolution data are best for accurately bounding the spatial extent of the canyon features. The suitability outputs are a useful guide, but are based on a lower resolution data set. This diverges slightly from the approach used by the MAFMC. In their coral amendment, the FMAT included high and very high habitat suitability areas, plus the buffer, in their initial canyon zone boundary recommendations, but these areas were ultimately scaled back in the heads of the canyons by the time the boundary development process had concluded after their coral workshop. More tightly focused boundaries at this initial stage will hopefully result in the need for fewer changes as these areas make their way through the Council process.

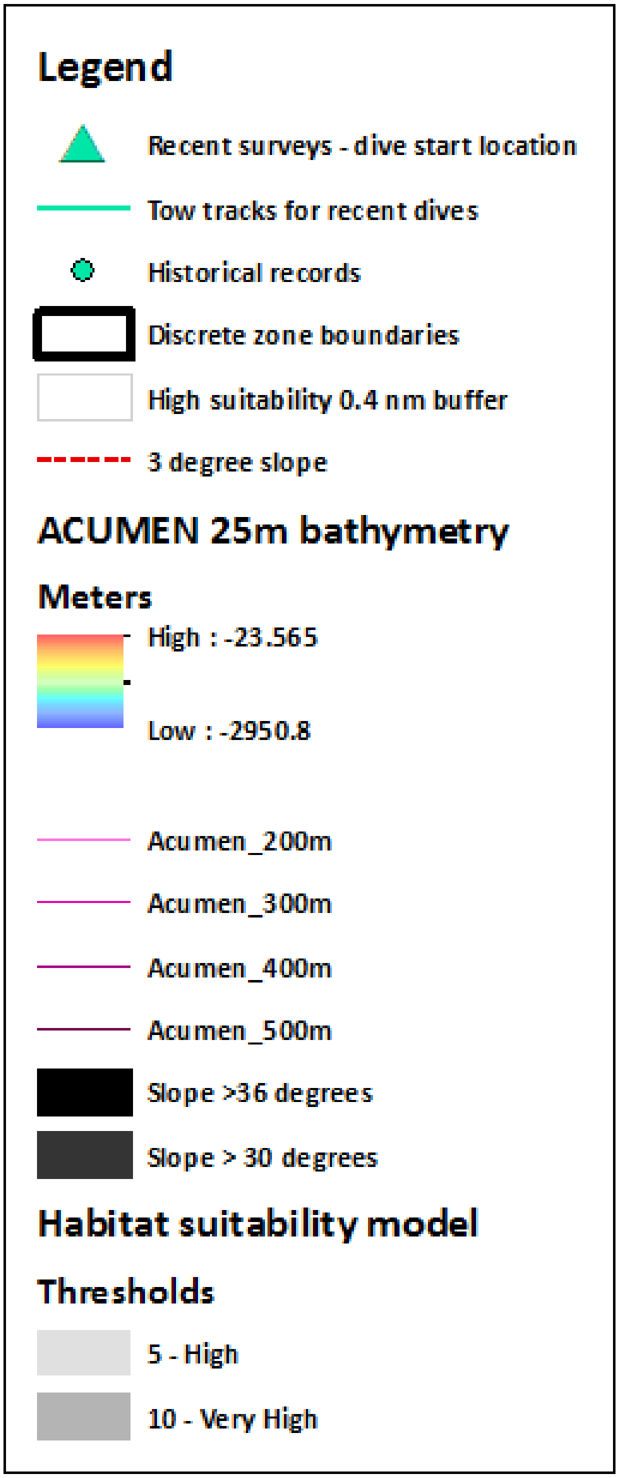
Finally, the locations of historic and recent coral observations are noted within each of the canyon zones. In general these observations fall solidly within zones developed using bathymetry, slope, and suitability model results, so while they are confirmatory of the presence of coral habitats in a canyon zone, they are not really a driving factor behind the zone boundaries. Some specific historical observations and all of the recent dives are discussed in the text.

The rationale for each discrete zone designation is described in more detail below, and is accompanied by two maps. Maps for each canyon shows a draft set of boundaries and the underlying coral distribution, bathymetry, slope, and habitat suitability data layers. Two sets of maps were prepared for this document, one with the habitat suitability layers, and one without, because the maps without habitat suitability more clearly show the shapes of the canyons. Each write up includes the approximate area in square kilometers of each proposed zone.

The legend below (Figure 1) applies to each of the canyon zone maps that follow. It shows locations of recent ROV and towed camera dives (green triangles, with green line tow paths) and coral locations in the historical database (green circles). Coral orders represented in the historical database include stony corals (order Scleractinia); sea pens (order Pennatulacea); soft corals (order Alcyonacea); and black corals (order Antipatharia).

The maps also depict depth, hill-shaded relief (red to blue shading) and contour lines (purple) from the ACUMEN data. Note that the 200m contour is rather incomplete in the ACUMEN data and is not often depicted fully on the maps. The 3° slope contour (red dotted line) is shown on each map as well. Areas of high slope (> 30°) and very high slope (> 36°) are identified in dark grey and black. The hill-shaded relief indicates the shapes of the canyon and helps to indicate the path of the thalweg, or main axis of the canyon. Seams in the bathymetry data and resulting slope artefacts are noted in the text and on the maps. Finally, one of the maps for each area depicts the high and very high habitat suitability areas (grey shading), including a 0.4 nm buffer (white shading). These layers are semi-transparent so that the underlying bathymetry data can be seen through them.

Figure 1 – Legend for canyon area maps



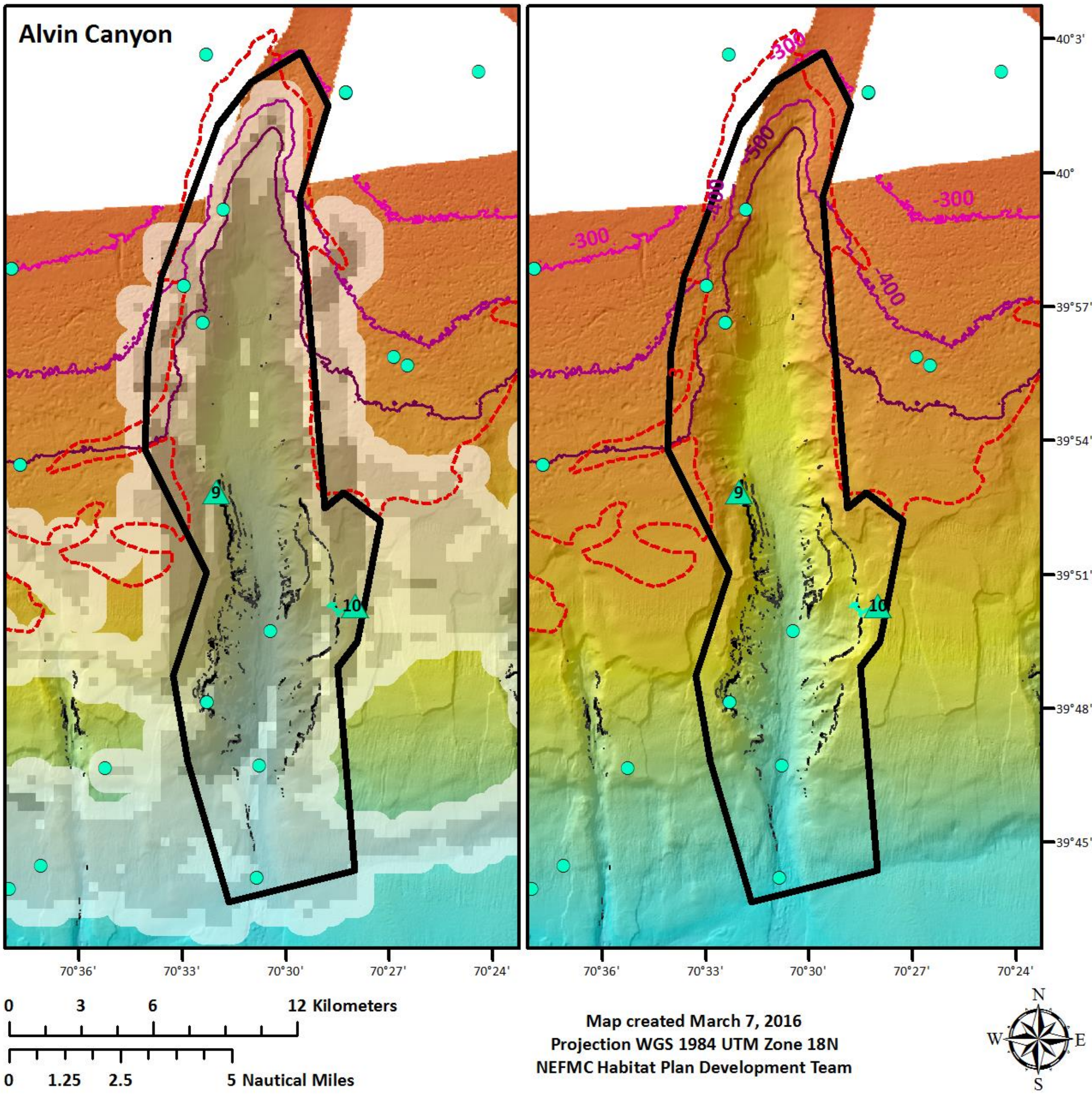
3.3.1.1 Alvin Canyon

Alvin Canyon incises the continental shelf, encompassing an area of approximately 200 km^2. The proposed zone follows the 300-meter depth contour at the head of the canyon and aligns closely with the 3° slope contour. The proposed zone encompasses areas of high and very high suitability as well as areas of high slope (greater than 30 degrees), which tend to occur in the deeper portion of the canyon. High suitability areas extend beyond the boundaries of the zone to the east and west, but very high suitability areas are mostly confined to the suggested boundaries. There are no issues with seams in the bathymetric data in this canyon.

There are eleven historical records of coral observations that fall within the proposed zone, including observation of stony corals, sea pens, and soft corals. The two observations just outside the recommended zone boundary are a cup coral (*Dasmosmilia lymani*), which is type of hard coral, and the soft coral *Duva florida*. Both were older records from 1883 such that the exact location of the records is somewhat uncertain. There were two 2013 Okeanos coral survey tows in the Alvin Canyon area at depths ranging from 846 to 927 meters below sea level (Cruise EX1304L1, dives 9 and 10)[2]. Both the east and west walls were surveyed. Both dives traversed a range of soft sediment and rock wall/overhang habitats, and corals were observed on both dives, especially in rocky areas.

[2] Do not have detailed logs for these dives.

Map 5 – Alvin Canyon discrete zone

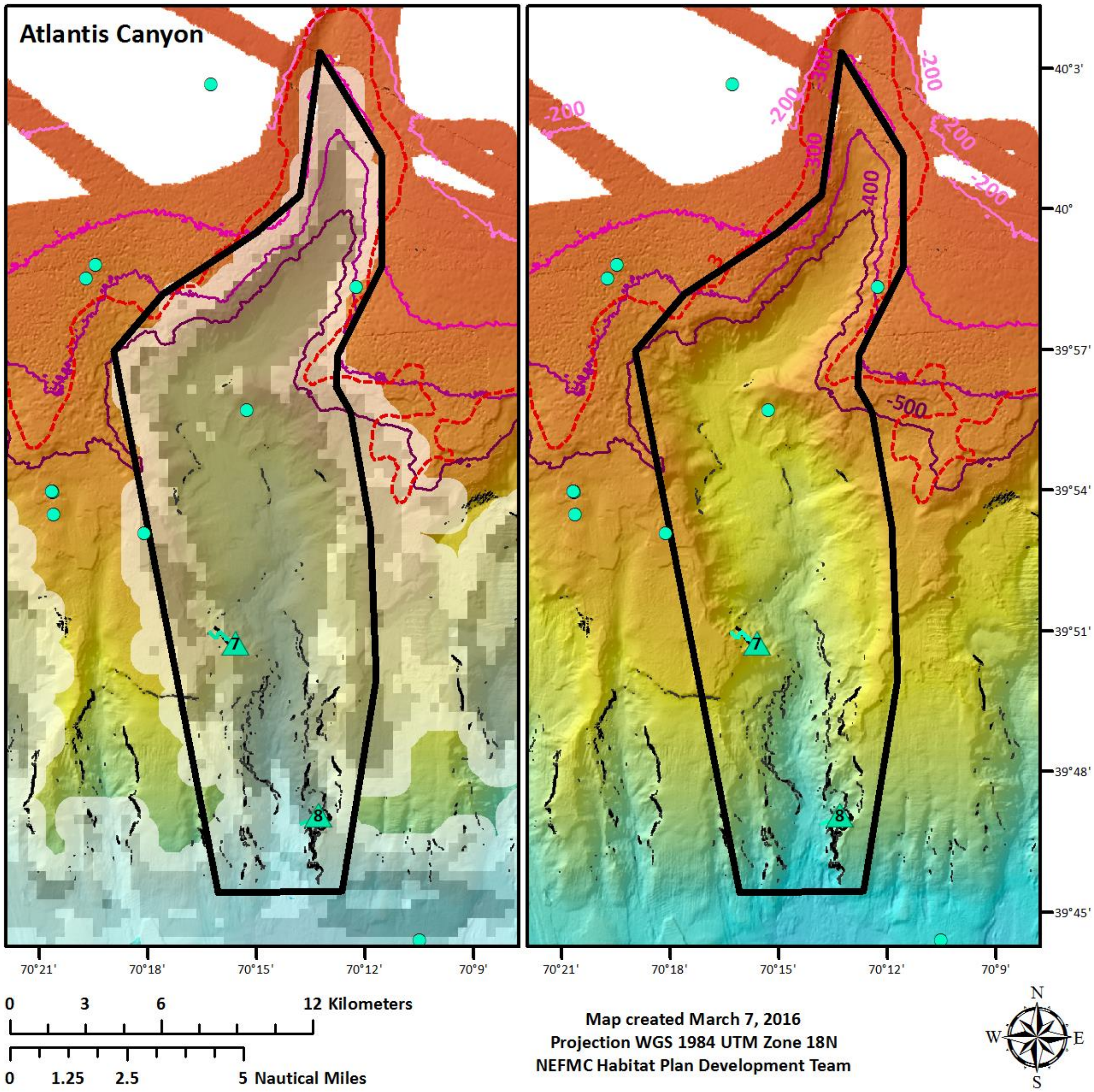


3.3.1.2 Atlantis Canyon

Atlantis Canyon incises the continental shelf break, encompassing an area of approximately 200 km^2. The proposed zone follows the 300-meter depth contour at the head of the canyon and aligns closely with the 3° slope contour. The proposed zone encompasses areas of high and very high suitability as well as areas of high slope (greater than 30 degrees), which tend to occur in the deeper portion of the canyon. There are smaller canyon-type features to the east and west of the proposed zone. There are no issues with seams in the bathymetric data in this canyon.

There are two historical observations that fall within the proposed zone, one stony coral and one sea pen. There have also been two recent tows in Atlantis Canyon on the Okeanos Explorer in 2013 (Cruise EX1304L1, dives 7 and 8), at depths ranging from 885 to 1,794 meters below sea level. Both the east and west walls were surveyed. Corals were observed during both dives. Dive 7 found colonial stony corals, soft corals, and black corals, plus cup corals, which are a solitary type of stony coral. Diverse types of stony, soft, and black corals were also found on Dive 8, in addition to sea pens.

Map 6 – Atlantis Canyon discrete zone

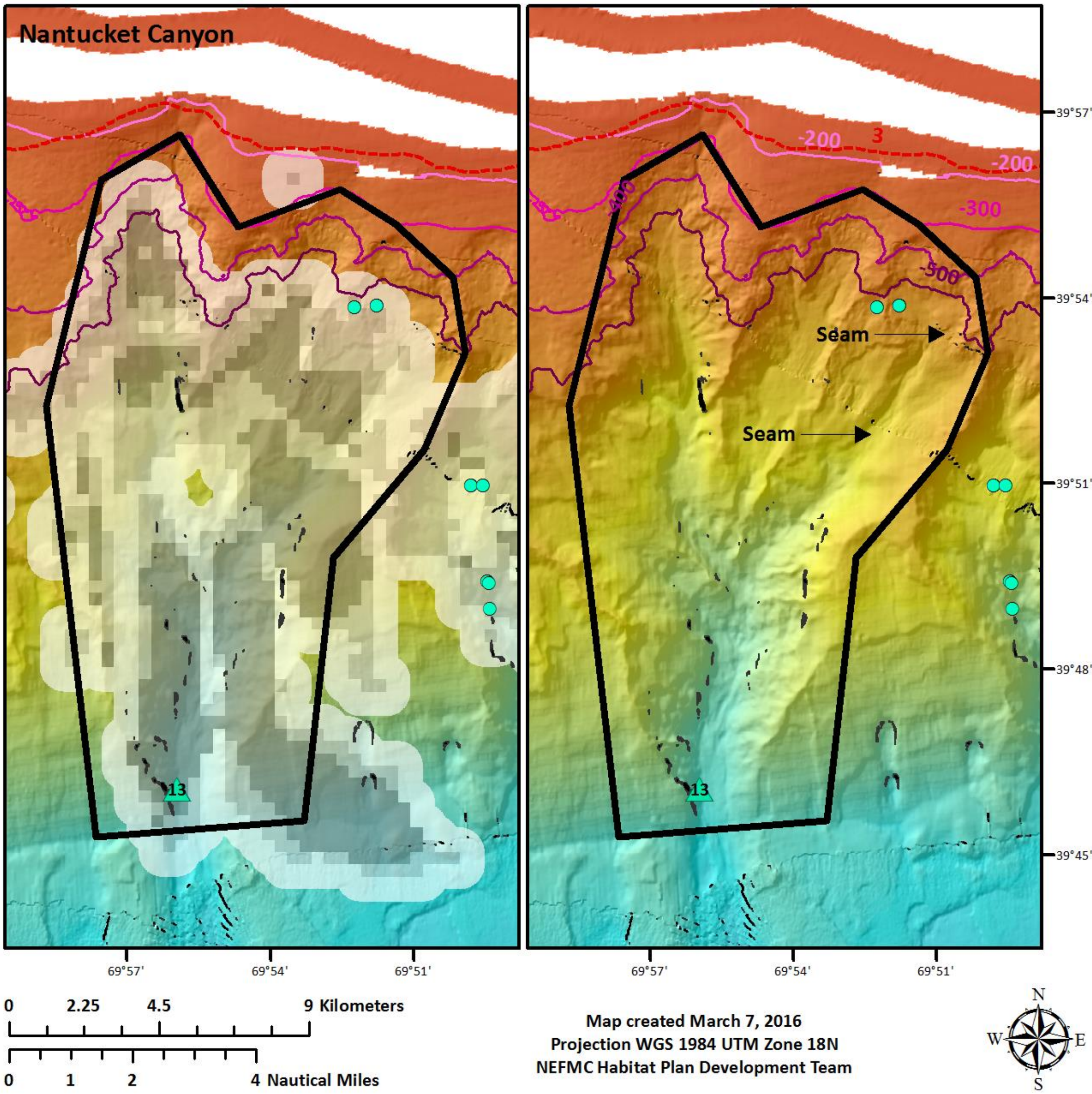


3.3.1.3 Nantucket Canyon

Nantucket Canyon lies seaward of the 3° slope contour, encompassing an area of approximately 200 km^2. It is a dendritic canyon, with three major branches. Although Harris and Whiteway (2011) classify Nantucket as shelf-incising, there is not a substantial curve in the 3° slope contour at the head of the canyon, such that it could be argued that it is more appropriately classified as slope-confined. The proposed zone roughly follows the 300-meter depth contour at the head of the canyon. It encompasses areas of high and very high suitability as well as areas of high slope (greater than 30 degrees), which tend to occur in the deeper portion of the canyon. There are areas to the east of the proposed zone that indicate high likelihood of coral presence. Some apparent high slope areas in the northeastern portion of the zone appear to be artifacts due to seams in the bathymetry data.

There are seven historical coral observations within Nantucket Canyon, including observations of stony corals. There was one recent tow in Nantucket Canyon on the Okeanos Explorer in 2014 (Cruise EX1404L3, dive 13). The dive was on the southwest wall and attained a maximum depth of 1,881 meters. Corals observed included soft corals, stony corals, black corals, and sea pens.

Map 7 – Nantucket Canyon discrete zone

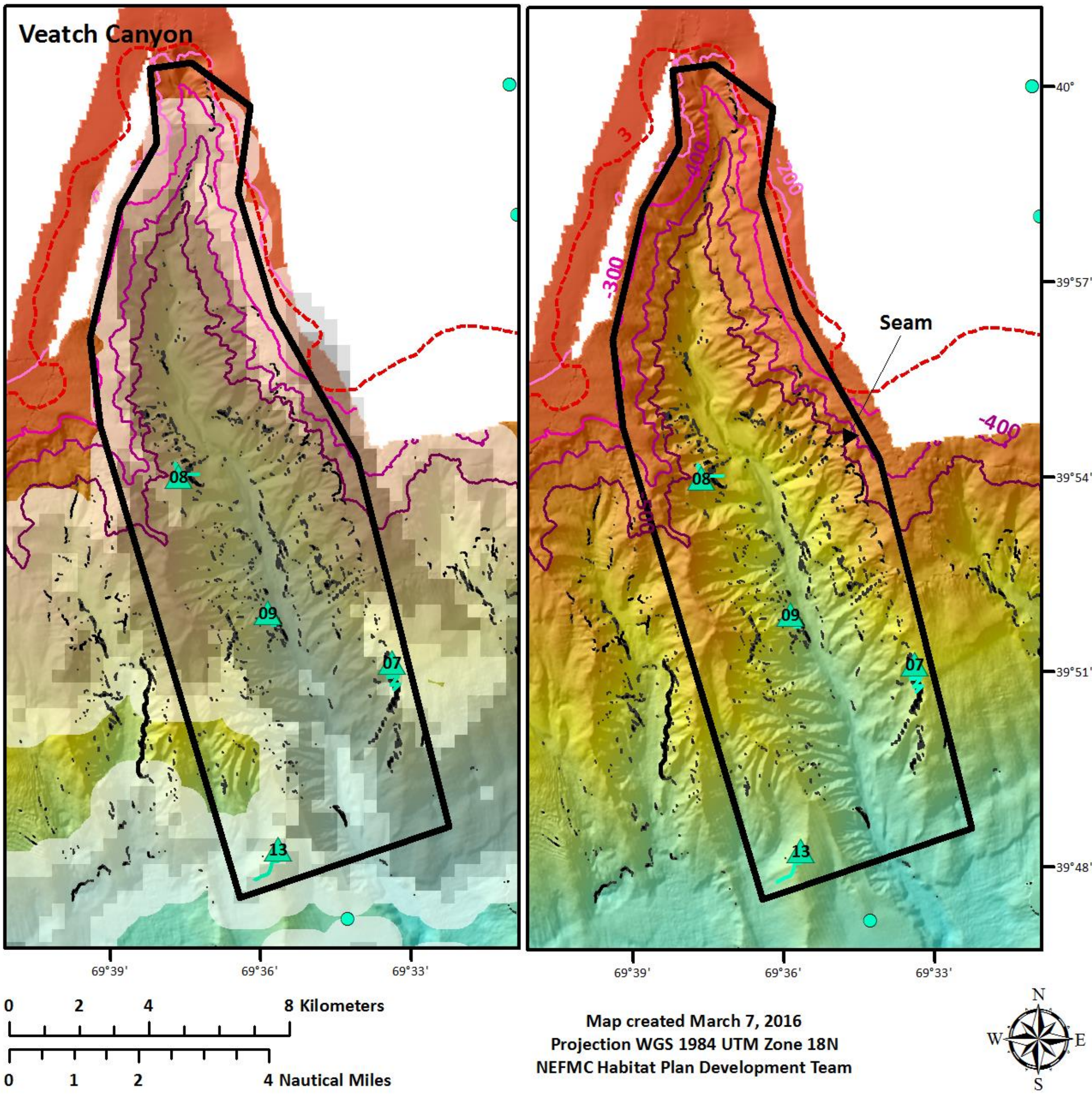


3.3.1.4 Veatch Canyon

Veatch Canyon incises the continental shelf break. The recommended zone encompasses an area of approximately 125 km^2 and is between 200m and 300m in the head of the canyon. Most of the recommended zone is mapped as very high habitat suitability. High suitability areas extend to the east and west of the boundary, overlapping smaller slope-confined canyons on either side of Veatch. Some apparent high slope areas in the head of the canyon are artifacts due to seams in the bathymetry data. The true high slope areas tend to occur mainly in the deeper portions of the canyon, beyond the shelf break.

While there are no historical observations of coral presence in Veatch Canyon area, there have been five recent dives. Three towed camera dives were completed during 2012 (Cruise HB1204). The results of this cruise are summarized by coral group (stony, soft, black, sea pen) in terms of the number and percentage of images per dive with each type of coral. Three tows were conducted with TowCam during Bigelow cruise HB1204. Corals were found on a smaller percentage of images collected during Dive 8, with only stony and soft corals observed. Dives 7 and 9, which were in deeper parts of the canyon, and corals from all four groups (black, stony, soft, sea pens) were found in a larger percentage of the images. The 2012 dives indicated that between 570m and 750m, the canyon has mostly sedimented habitats, locally with some draped chalky rocks. Between 1050m and 1250m there are hard bottom canyon walls dominated by the soft coral *Acanthogorgia* and the stony corals *Solenosmilia* and *Desmophyllum*, all sparsely distributed. Between 1290m and 1424m, the seafloor is dominated by chalky rock bottom intermingling with flat, fully sedimented areas. On hard bottom rocks and walls there is a diverse coral fauna, including the soft corals *Parmuricea*, *Anthomastus*, *Paragorgia*, *Swiftia*, *Clavularia*, *Acanthagorgia*, and bamboo corals; the stony coral *Desmophyllum*; and the black coral *Parantipathes*, . On soft sediments at this deeper depth range, cerianthid anemone and the soft coral *Anthomastus* were noted. Dive 13 during Okeanos Explorer cruise EX1304L1 (1400 m) focused on a cold seep area, and found mussel beds and soft coral (*Paragorgia*) colonies and individual hard coral (*Desmophyllum*) attached to carbonate sediments.

Map 8 – Veatch Canyon discrete zone

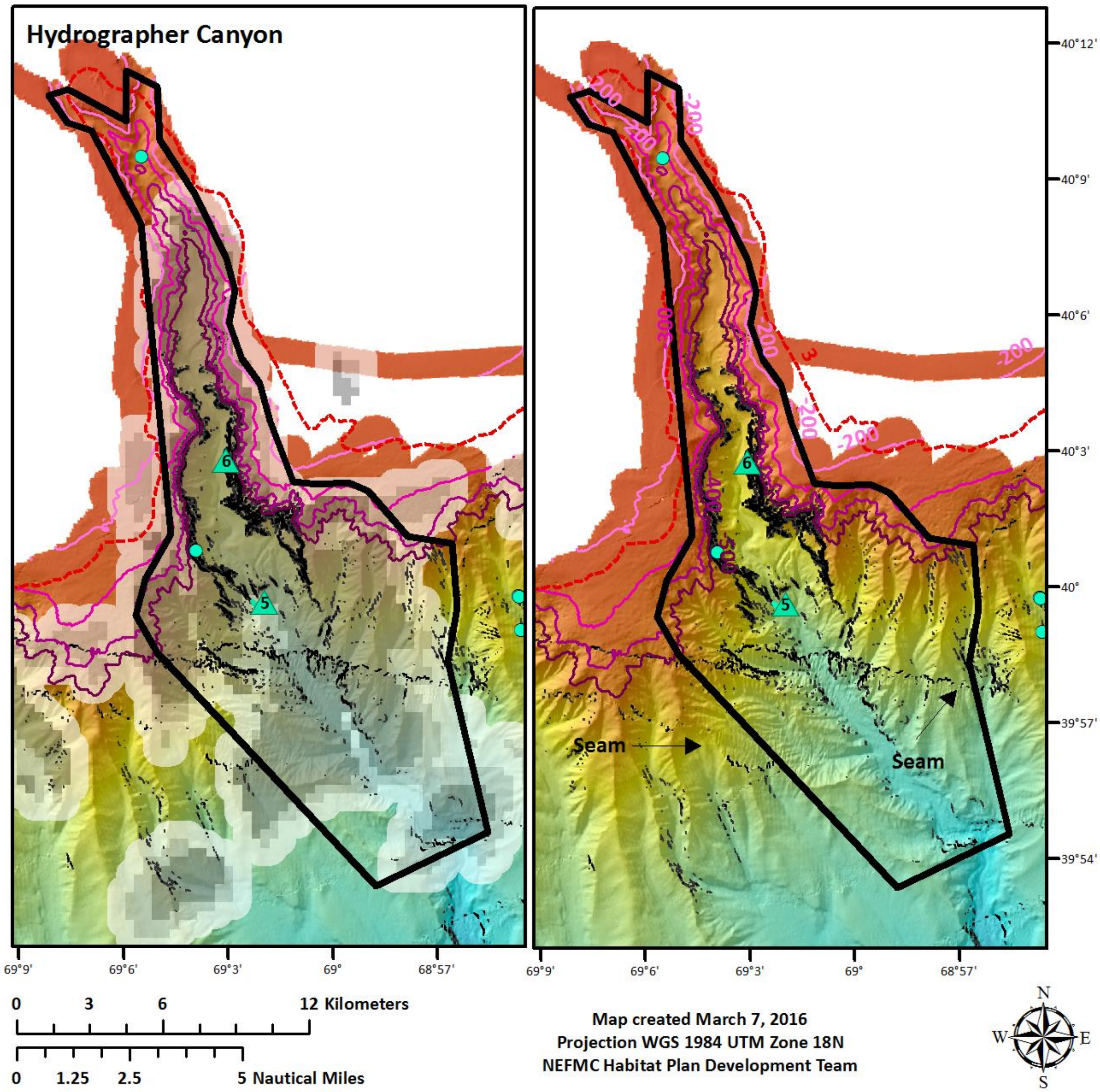


3.3.1.5 Hydrographer Canyon

Hydrographer Canyon is a narrow canyon that incises the continental shelf break, encompassing an area of approximately 200 km^2. The proposed zone follows the 200-meter depth contour at the head of the canyon. The areas of high slope (i.e. greater than 30 degrees) are found in the narrow portion of the proposed canyon zone, midway between the mouth and foot of the canyon. The zone also encompasses the high and very high habitat suitability output results. The effect of "seams" in the dataset are also visible on the map, and should be ignored.

There are two historical observations of coral presence within Hydrographer Canyon, both soft corals. There have also been two recent coral cruise tow in the area on the Okeanos Explorer in 2013 (Cruise EX1304L1, dives 5 and 6), where both the east and west walls of the canyon were surveyed. Dive 5 (1299-1418m) found stony, soft, and black corals of various species, including some smaller colonies noted as new recruits. Dive 6 (610-907m) found soft and stony corals, including *Lophelia pertusa*, which is a reef building species of stony coral.

Map 9 – Hydrographer Canyon discrete zone

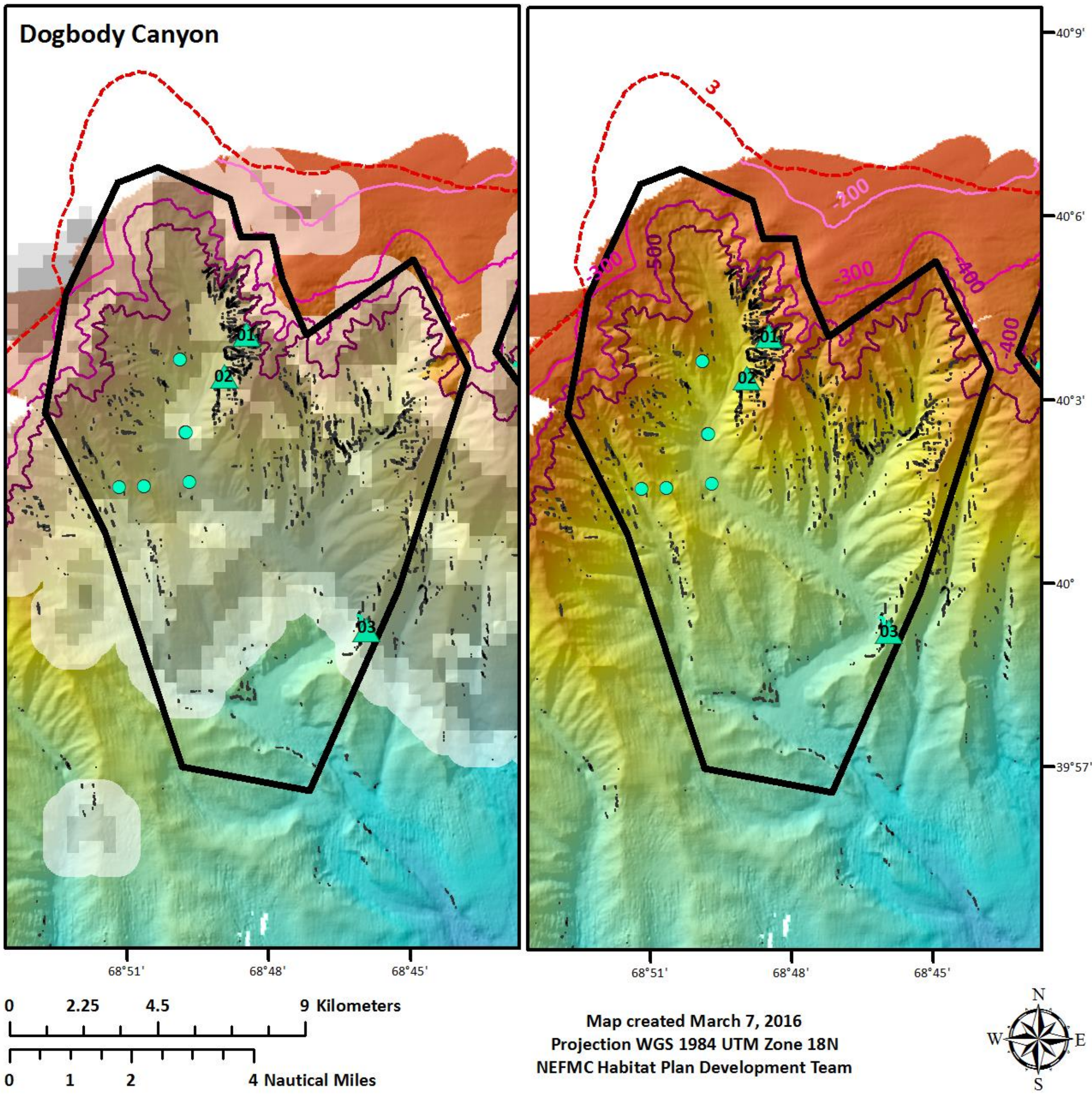


3.3.1.6 Dogbody Canyon

Dogbody Canyon is a dendritic canyon that incises the continental shelf break, encompassing an area of approximately 150 km^2. The proposed zone follows the 300-meter depth contour at the head of the canyon and is seaward of the 3° slope contour. The main thalweg is somewhat sinuous with a smaller branch to the east. Most of the canyon is predicted to have high or very high habitat suitability for soft corals, and both branches include large areas of high slope, in relatively shallow water compared to some of the other canyons. There are no issues with seams in the bathymetric data in this canyon.

There are eight historical observations of soft coral presence within the area. There have also been three recent coral cruise dives in the canyon area, at depths ranging from 558 to 1,620 meters below sea level. On Cruise HB1504, dive 1 (558-675m), corals were locally uncommon, and sponges were found. On dive 2 (894-1,014m) corals were locally abundant and diverse, and soft corals, stony corals, and black corals were observed. On dive 3, corals were locally rare with low diversity, and only soft corals were observed.

Map 10 – Dogbody Canyon discrete zone

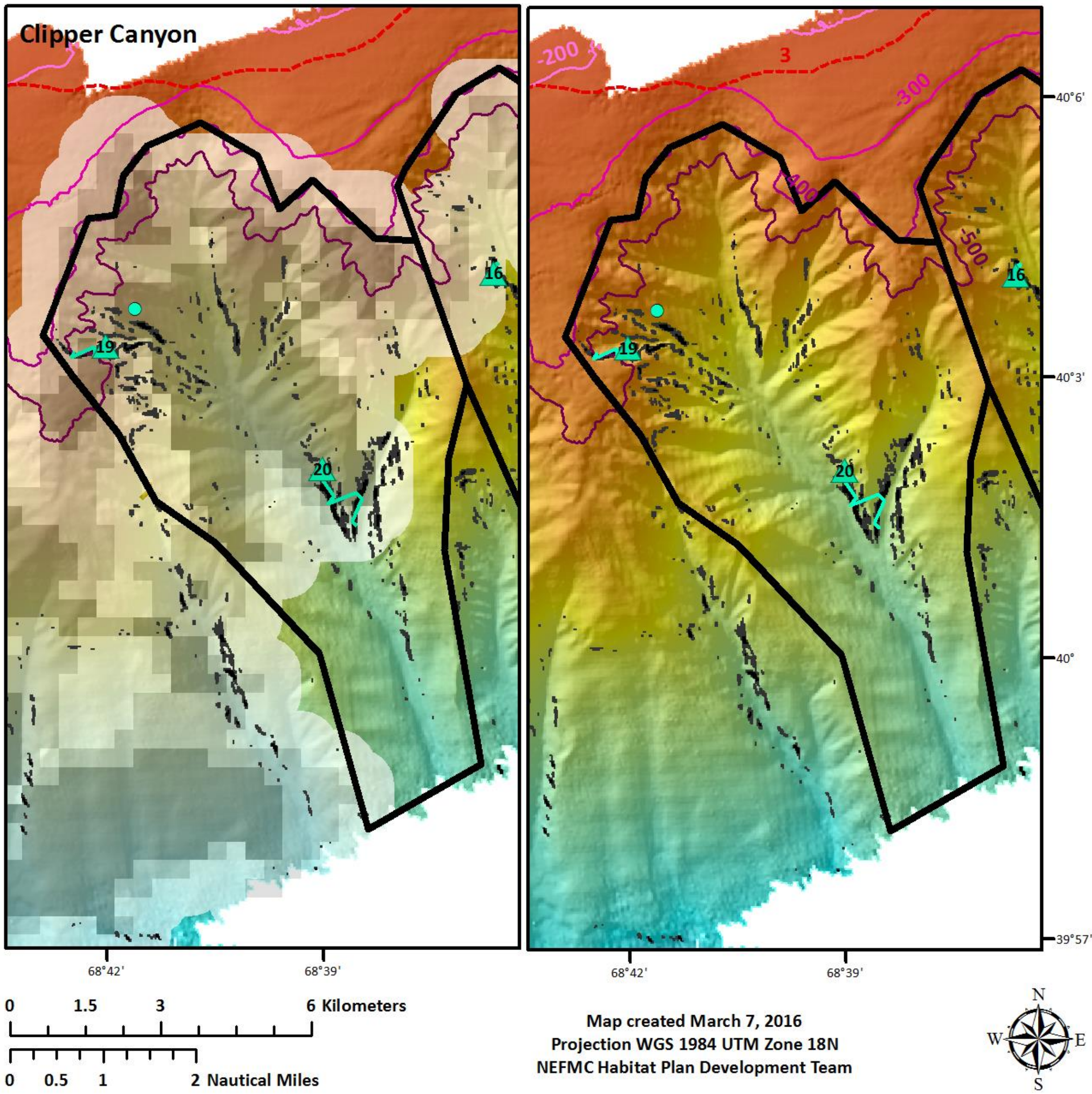


3.3.1.7 Clipper Canyon

Clipper Canyon is slope-confined, encompassing an area of approximately 50 km^2, which puts it among the smaller canyons off the Northeast continental shelf. The proposed zone follows the 400-meter depth contour at the head of the canyon. Clipper has one main branch and a smaller branch to the east. The habitat suitability model predicts the shallower portions of the zone as suitable coral habitat. The high/very high suitability footprint coincides spatially with areas of high and very high slope. Areas of high slope are found along both branches of the canyon, near tows 19 and 20.

There is one historical observation of soft coral presence within the proposed zone. There have been two recent tows with TowCam on HB1504. Soft corals were observed on both tow 19 (495-571m) and tow 20 (1,216-1,455m).

Map 11 – Clipper Canyon discrete zone

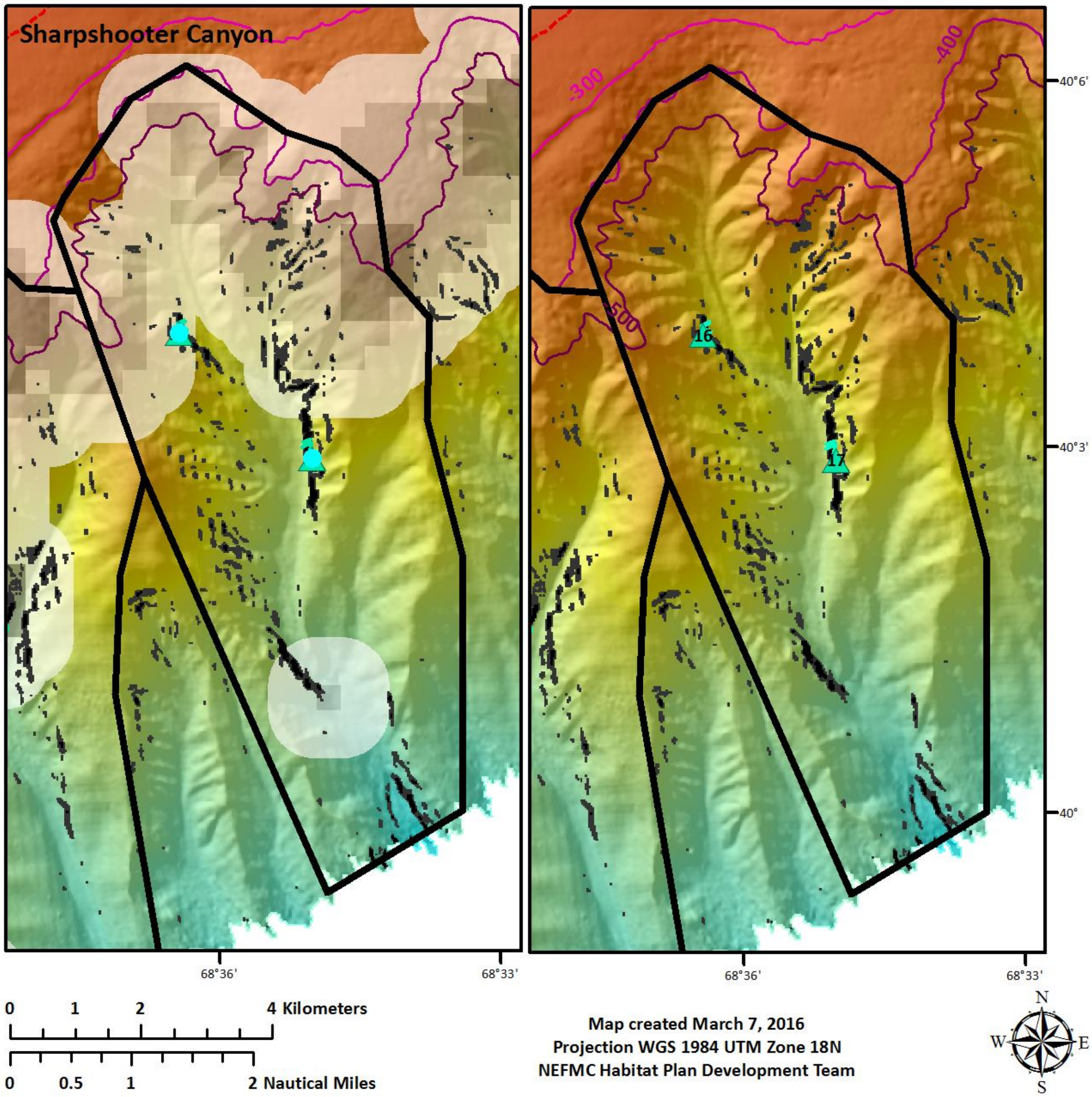


3.3.1.8 Sharpshooter Canyon

Sharpshooter Canyon is slope-confined, encompassing an area of approximately 50 km^2, which puts it among the smaller canyons off the Northeast continental shelf. The proposed zone follows the 400-meter depth contour at the head of the canyon. Much of the proposed zone was not identified as high and very high habitat suitability based on the model output results. However, the proposed zone follows the shape of the canyon, and includes areas of high slope at various depths. There are no issues with seams in the bathymetric data in this canyon.

There are no historical observations of coral presence within the zone. However, there have been two recent TowCam tows during cruise HB1504, tow 16 (800-901m) and tow 17 (1,168-1,144m). On tow 17, soft corals and stony corals were observed. Tows 16 and 17 were conducted in two of the larger contiguous areas of high slope.

Map 12 – Sharpshooter Canyon discrete zone

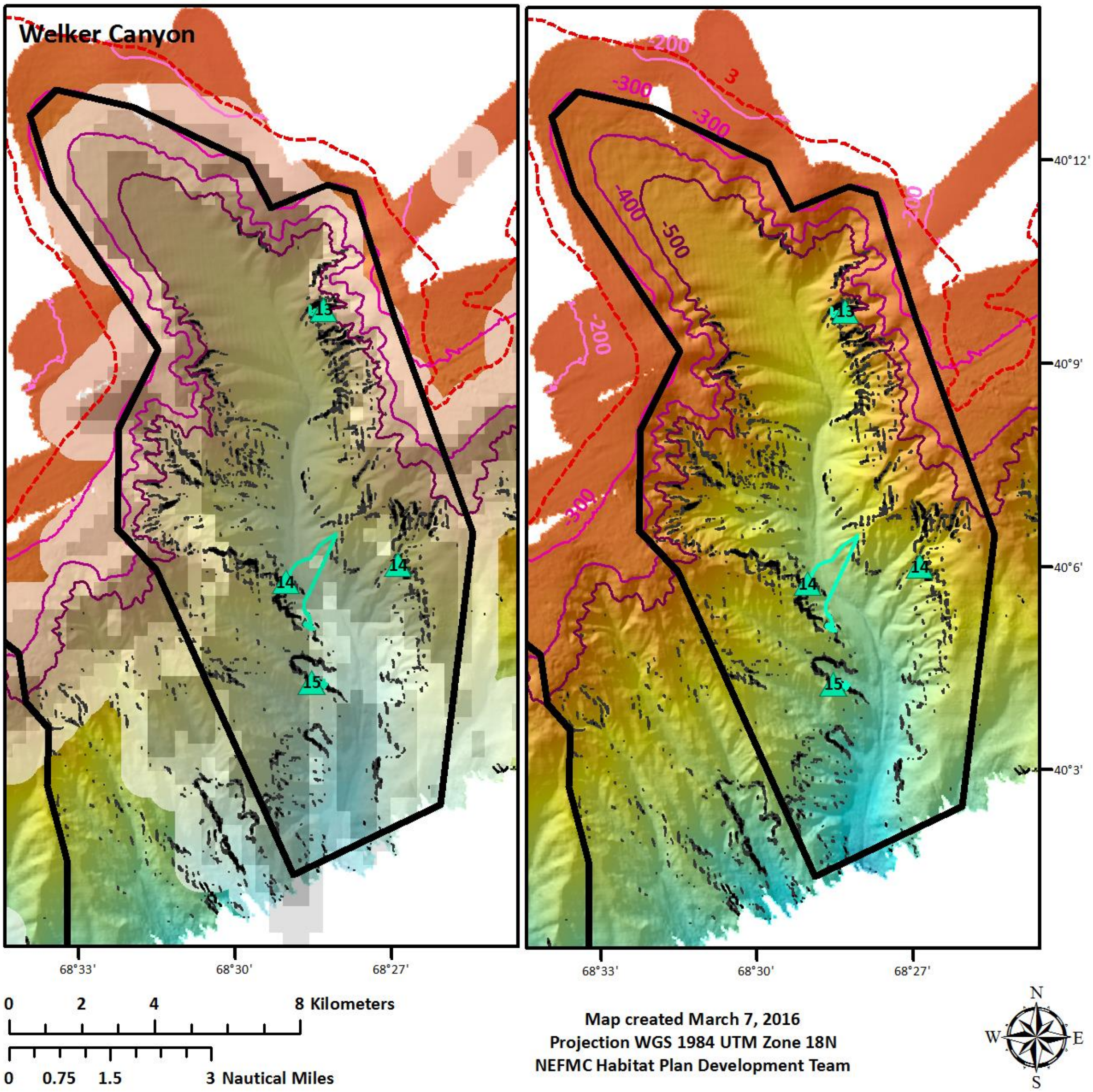


3.3.1.9 Welker Canyon

Welker Canyon incises the continental shelf break, encompassing an area of approximately 150 km^2. The proposed zone follows the 300-meter depth contour at the head of the canyon. The head of the canyon is not very steeply sloped, but there are large areas of high slope along both walls. Most of the proposed zone is predicted to be high or very high suitability soft coral habitat, and areas of high slope are found throughout the zone. There are no issues with seams in the bathymetric data in this canyon.

There are no historical records of coral presence within the proposed zone. However, there have been four recent tows/dives within the proposed zone. Three tows took place TowCam Cruise HB1504 (dives 13-15), and one dive took place on leg 2 of the 2013 Okeanos Explorer Cruise EX1304L2 (dive 14). Both walls were surveyed. On dive 13 of Cruise HB1504 (559-778m), soft and stony corals were observed. On dive 14 of Cruise HB1504 (851-1,156m), soft corals, stony corals, and black corals were observed. On dive 15 of Cruise HB1504, soft corals were observed. On dive 14 of Cruise EX1304L2 (1,377-1,445m), a wide diversity of corals were observed, including at least 17 species in all four major groupings.

Map 13 – Welker Canyon discrete zone

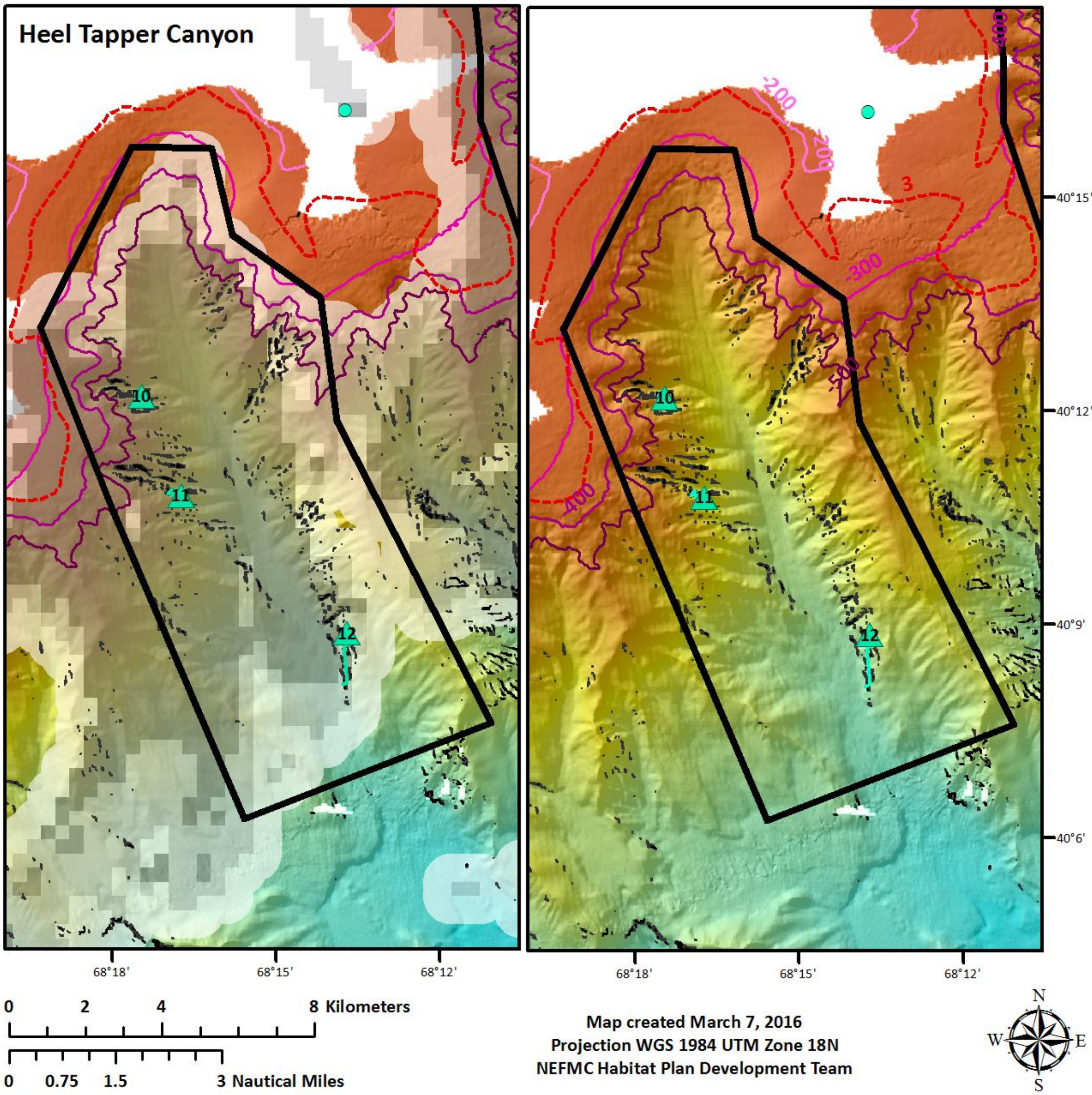


3.3.1.10 Heel Tapper Canyon

Heel Tapper Canyon incises the continental shelf break, encompassing an area of approximately 100 km^2. The proposed zone follows the 300-meter depth contour at the head of the canyon. The areas of high slope are also encompassed in the proposed zone. The area to the west of the proposed zone includes very high habitat suitability model output; however, higher resolution bathymetric data show that the areas of high slope are located within the proposed discrete coral zone.

There are no historical observations of coral presence in Heel Tapper Canyon. However, there have been recent ROV dives in the area, which include three tows on NOAA's Fisheries Survey Vessel Bigelow in 2015 (Cruise HB1504). These three ROV dives at depths ranging from 666 to 1,444 meters observed soft corals (*Thourella*, *Paramuricea*, and *Acanella*).

Map 14 – Heel Tapper Canyon discrete zone

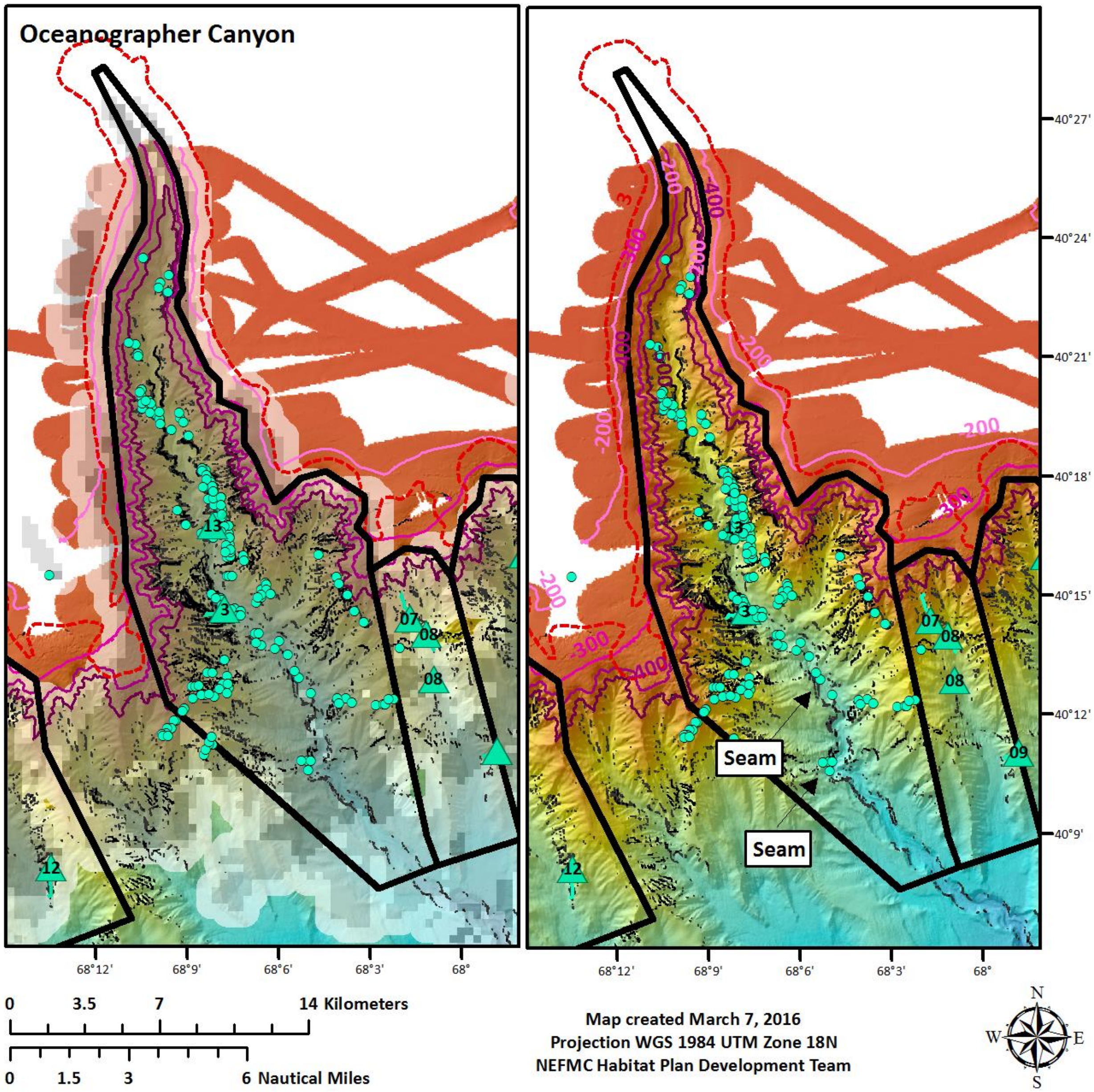


3.3.1.11 Oceanographer Canyon

Oceanographer Canyon incises the continental shelf break, encompassing an area of over 200 km^2. It is the largest of the proposed canyon zones. The proposed zone follows the 300-meter depth contour at the head of the canyon and the boundary is largely within the 3° slope contour. Oceanographer has a clear main axis with a smaller branch on the eastern side. The areas of high slope and the areas predicted to have high/very high habitat suitability for soft corals are encompassed in the proposed zone. There are a few areas of seams in the bathymetry data that lead to high slope artefacts, but these are difficult to discern amidst the large areas of high slope.

There are 166 historical observations within the proposed zone, including observations of soft corals and stony corals. Some additional areas to the west of the proposed zone have historical observations as well. In addition, there have been two recent Okeanos Coral Cruise tows within the proposed zone (EX1304L2), and both the eastern and western walls were surveyed. Dive 3 (983-1,239m) and Dive 13 (1,102-1,248m) both encountered diverse habitat types and at least 16 species of stony, soft, and black corals. The colonial stony coral *Lophelia* was observed during Dive 3.

Map 15 – Oceanographer Canyon discrete zone

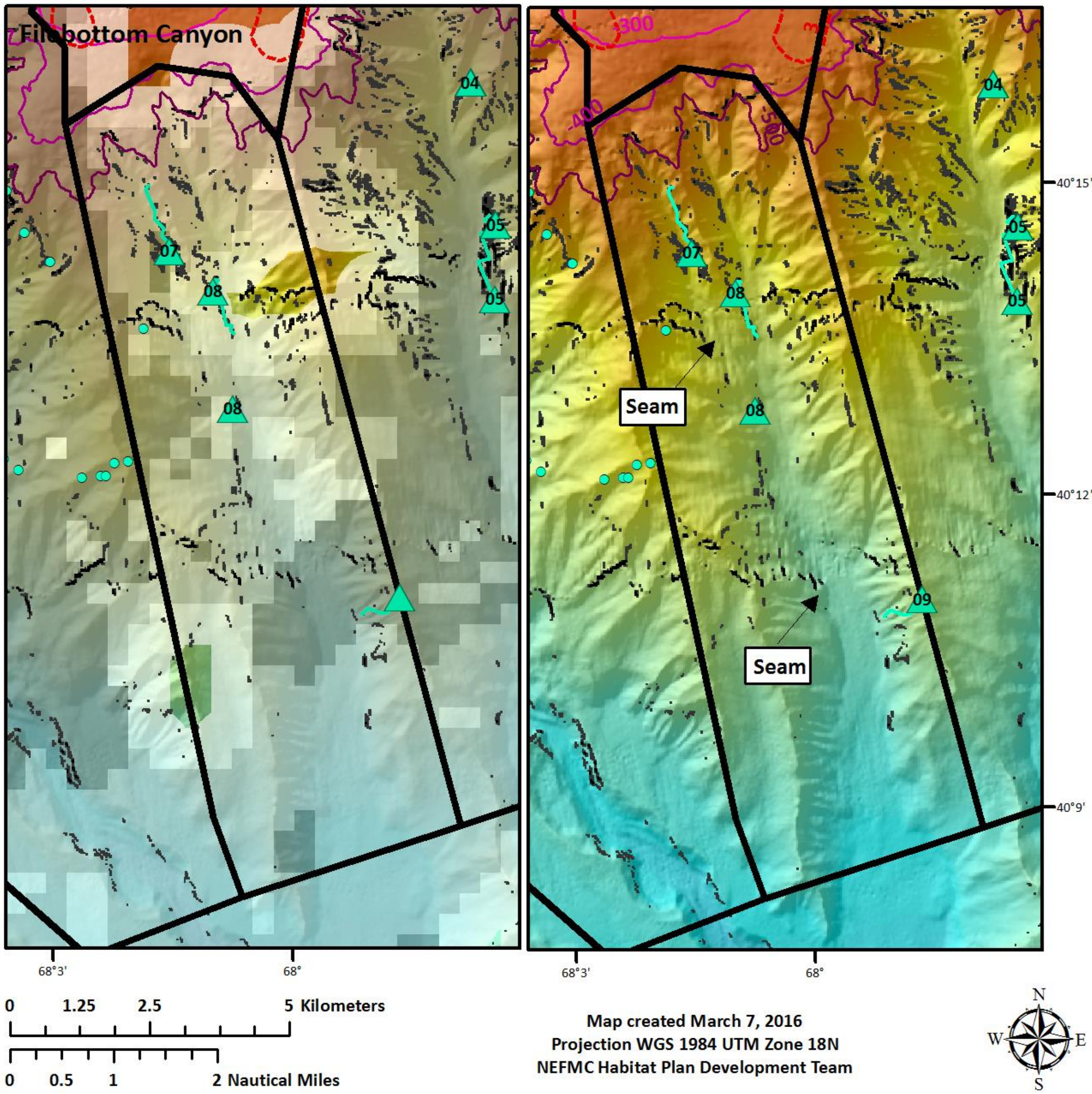


3.3.1.12 Filebottom Canyon

Filebottom Canyon is slope-confined, encompassing an area of approximately 50 km^2. It is immediately adjacent to Oceanographer Canyon to the west and Chebacco Canyon to the east. The proposed zone follows the 300-meter depth contour at the head of the canyon. There are fewer areas of high slope as compared to some other canyons, and some of the high slope areas shown on the map are artefacts resulting from seams in the data. Much of the zone is predicted to have suitable habitat for corals, although there is less overlap with the very high suitability layer as compared to some of the other coral zones proposed.

There is one historical record within the zone, including observations of soft corals. In addition, there have been four recent ROPOS Cruise HB1504 tows in the area. Dive 7 (664-887 m) and dive 8 (1,029-1,077m) both observed stony and soft corals; Dive 8 was repeated, so there are two records on the map.

Map 16 – Filebottom Canyon discrete zone

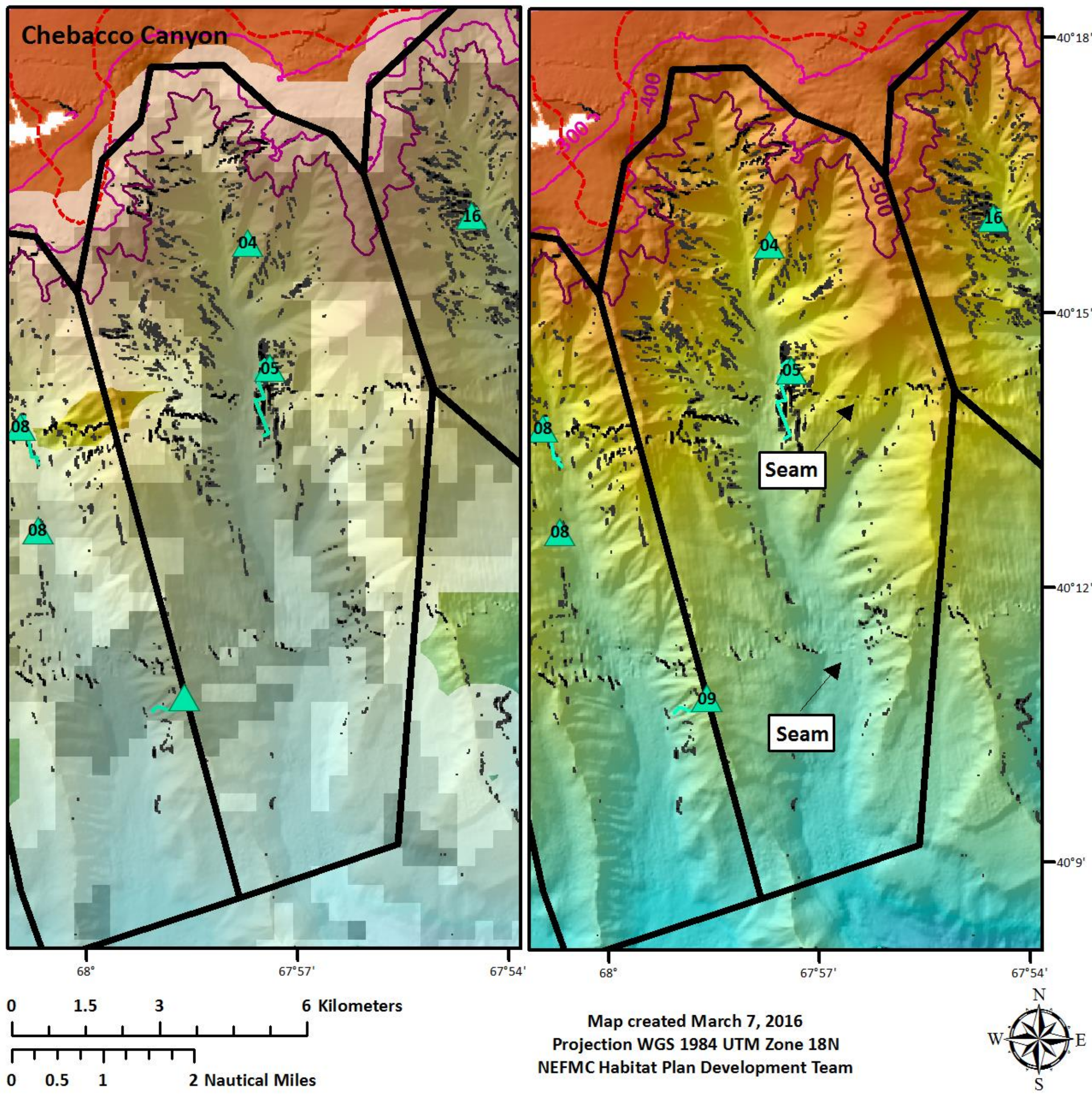


3.3.1.13 Chebacco Canyon

Chebacco Canyon is slope-confined, encompassing an area of approximately 100 km^2. It is larger and steeper than nearby Filebottom. The proposed zone follows the 400-meter depth contour at the head of the canyon. Some of the high slope areas shown on the map are artefacts resulting from seams in the data. Much of the zone is high or very high predicted habitat suitability for soft corals.

There are no historical observations within the proposed zone. However, there have been two recent tows within the area on the same ROPOS Cruise HB1504. Both tows were completed on the east wall. Tow 4 (801-875 m) observed stony corals, and Tow 5 (1,133-1,260m) observed soft corals, stony corals, and black corals.

Map 17 – Chebacco Canyon discrete zone

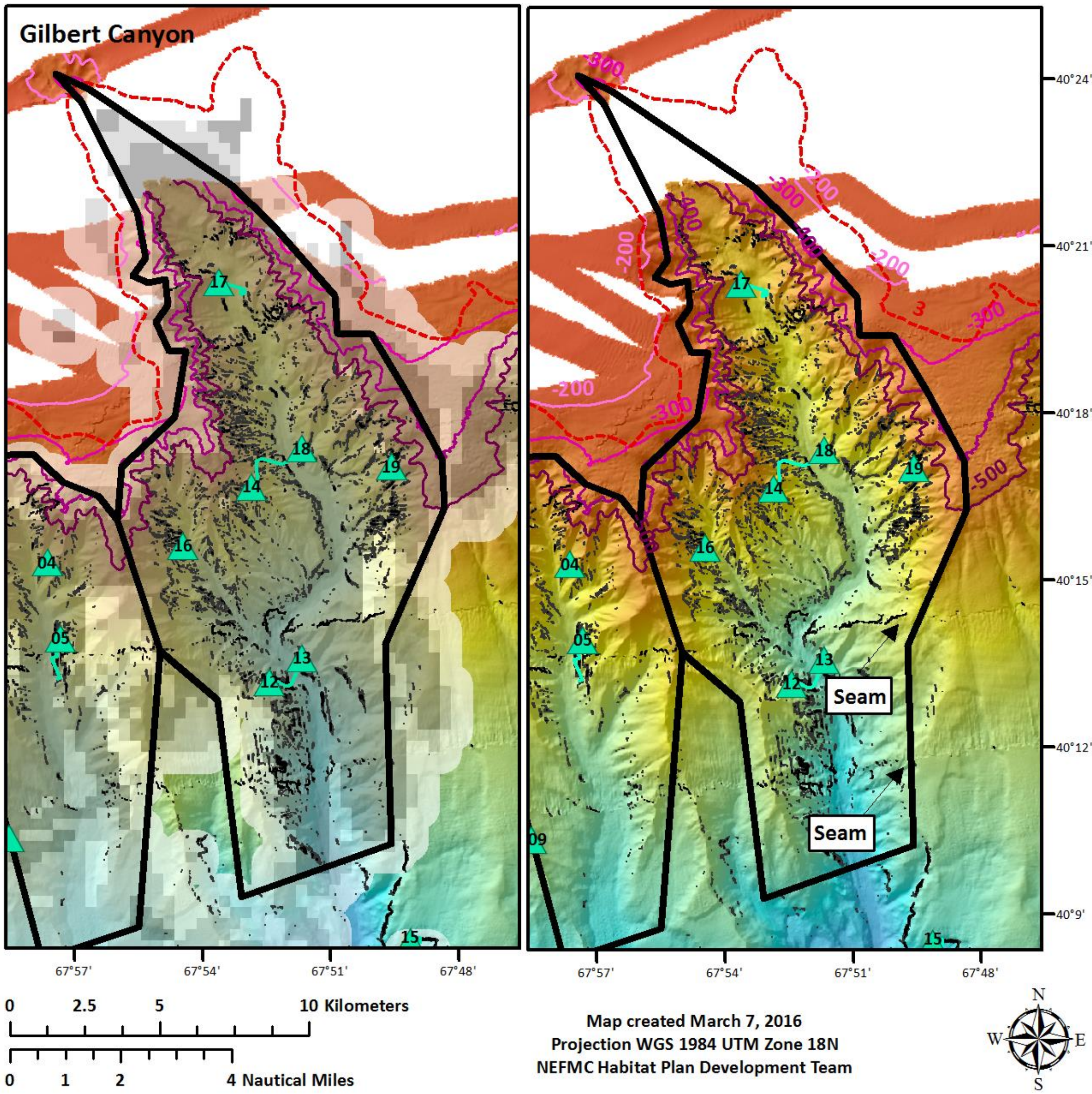


3.3.1.14 Gilbert Canyon

Gilbert Canyon incises the continental shelf break, and has two major branches. The main thalweg is located to the east, and there is another limb to the west. The recommended zone encompasses an area of approximately 175 km^2, following the 300-meter depth contour at the mouth of the canyon. The recommended zone is mapped mostly as very high suitability habitat. There are substantial high slope (greater than 30 degrees) areas encompassed within the proposed zone. A few high slope artefacts are observed due to seams in the bathymetry but these are somewhat difficult to discern on the map.

There are no historical observations of coral presence in the area, but there are a number of recent tows conducted during a 2012 TowCam cruise (HB1204), seven within the proposed boundary and one outside it in deeper water. The tows covered various locations throughout the canyon including near the head and on multiple walls and tributaries. All of the tows found soft corals, with the percentage of images with soft corals ranging from 2% to 54%. Other coral types were found in the canyon as well, including black corals, stony corals, and sea pens. Two tows of the eight revealed markedly high abundance and diversity in corals. These tows were on the western wall between 1370m and 1679m and in the canyon head between 640m and 820m. The western canyon slopes had the greatest abundance and diversity of corals, with the hard rock bottom hosting solitary stony corals and a few colonial stony corals (*Solenosmilia*), mostly on rocky outcrops. Soft coral diversity (*Paramuricea*, *Acanella*, and *Paragorgia*, etc.) was high in this canyon due to the diversity of habitats. Sea pen abundance was also high in the canyon. Soft corals in the head of the canyon (640 to 820m) were highly abundant but dominated by a single type of coral (likely *Acanella*).

Map 18 – Gilbert Canyon discrete zone

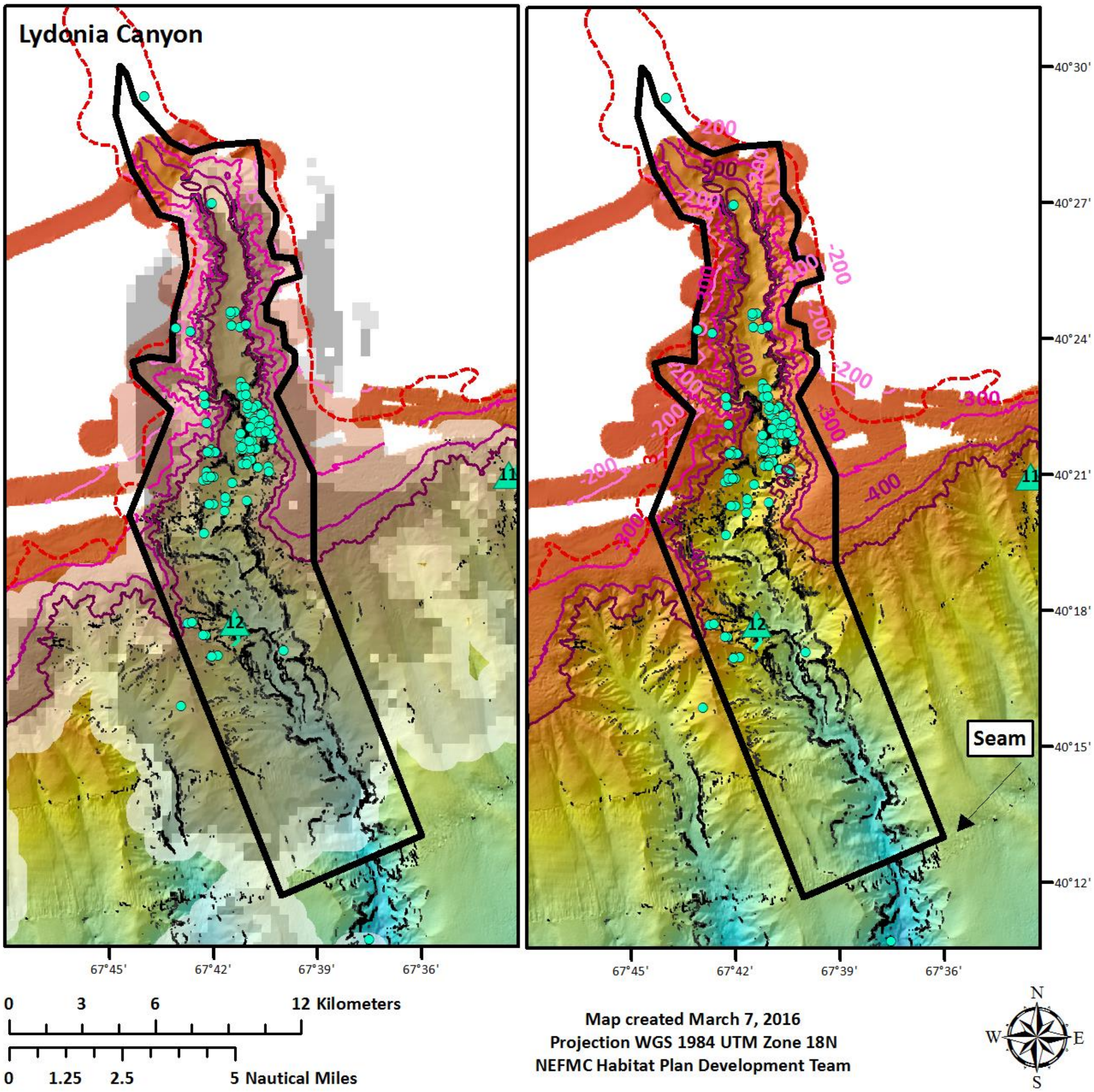


3.3.1.15 Lydonia Canyon

Lydonia Canyon incises the continental shelf break, encompassing an area of over 200 km^2, second in size only to Oceanographer Canyon. The proposed zone follows the 200-meter depth contour at the head of the canyon. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 142 to 2,249 meters below sea level. Much of the zone is predicted to be highly or very highly suitable habitat for soft corals. In addition, there are areas to the west and east of the boundary which are also predicted to be suitable coral habitat. However, most of the areas of high slope are encompassed within the proposed zone, including within the head of the canyon.

There are 105 historical observations of coral presence in the area, including observations of soft corals, sea pens, and stony corals. There has also been one recent ROV dive within the proposed zone, onboard the R/V Okeanos Explorer, cruise EX1304L2, dive 12; 1,135-1,239m. A large number of species (at least 15) from all four coral groups were observed during the dive.

Map 19 – Lydonia Canyon discrete zone

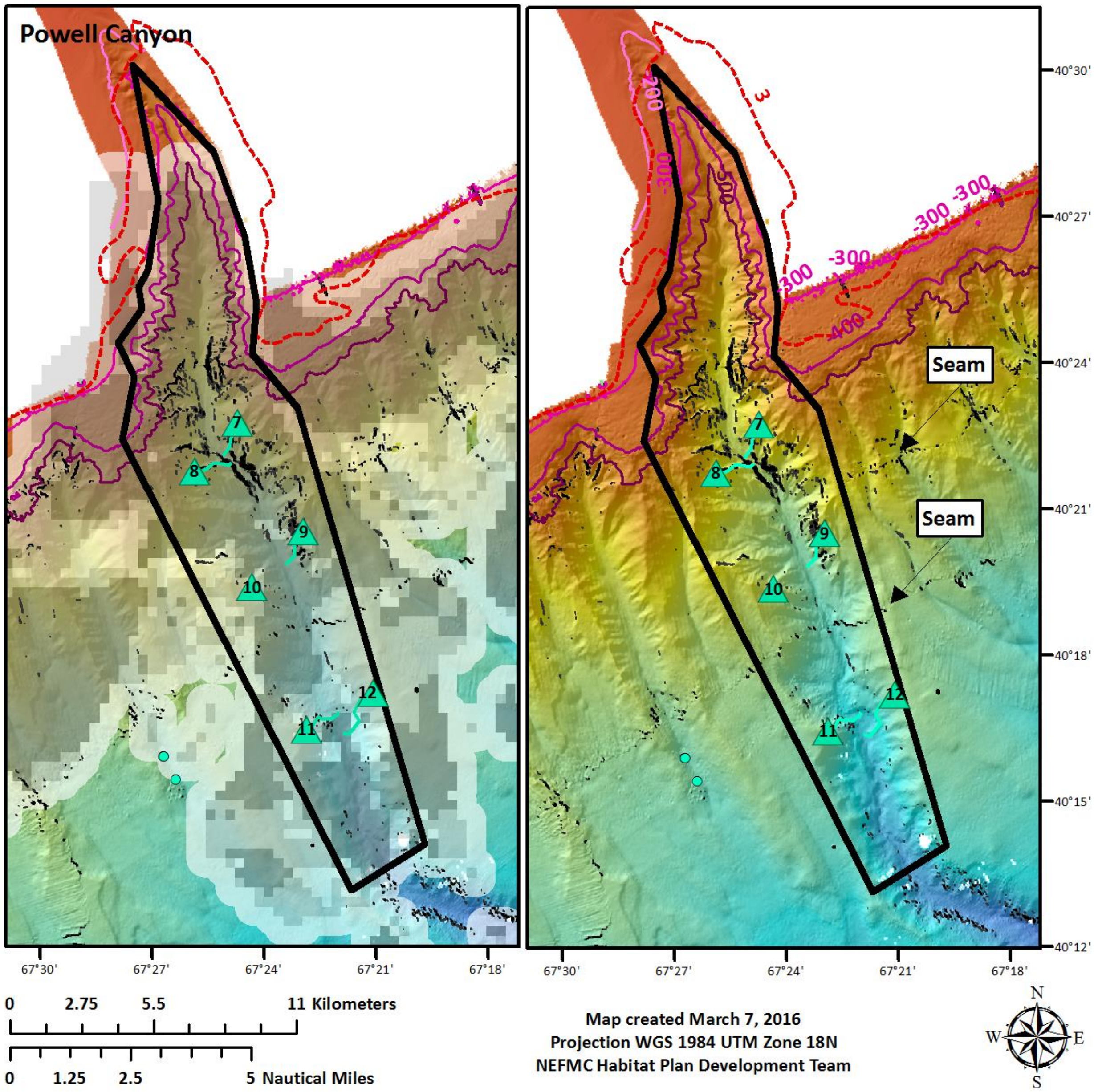


3.3.1.16 Powell Canyon

Powell Canyon incises the continental shelf break, encompassing an area of approximately 200 km^2. The proposed boundary follows the 300-meter depth contour along the head of the canyon. The areas predicted to have a high likelihood of coral presence based on the habitat suitability model are also encompassed in the zone, along with the areas identified as high slope areas. The areas of high slope are concentrated just beyond the shelf break and in the deepest parts of the canyon. There is an east-west seam in the data in the middle of the zone.

There are no historical observations of coral presence within the proposed zone. However, there have been five recent tows with TowCam. These were completed during cruise HB1302 aboard the F/V Bigelow. Observations were made of stony corals, soft corals, sea pens, and black corals.

Map 20 – Powell Canyon discrete zone

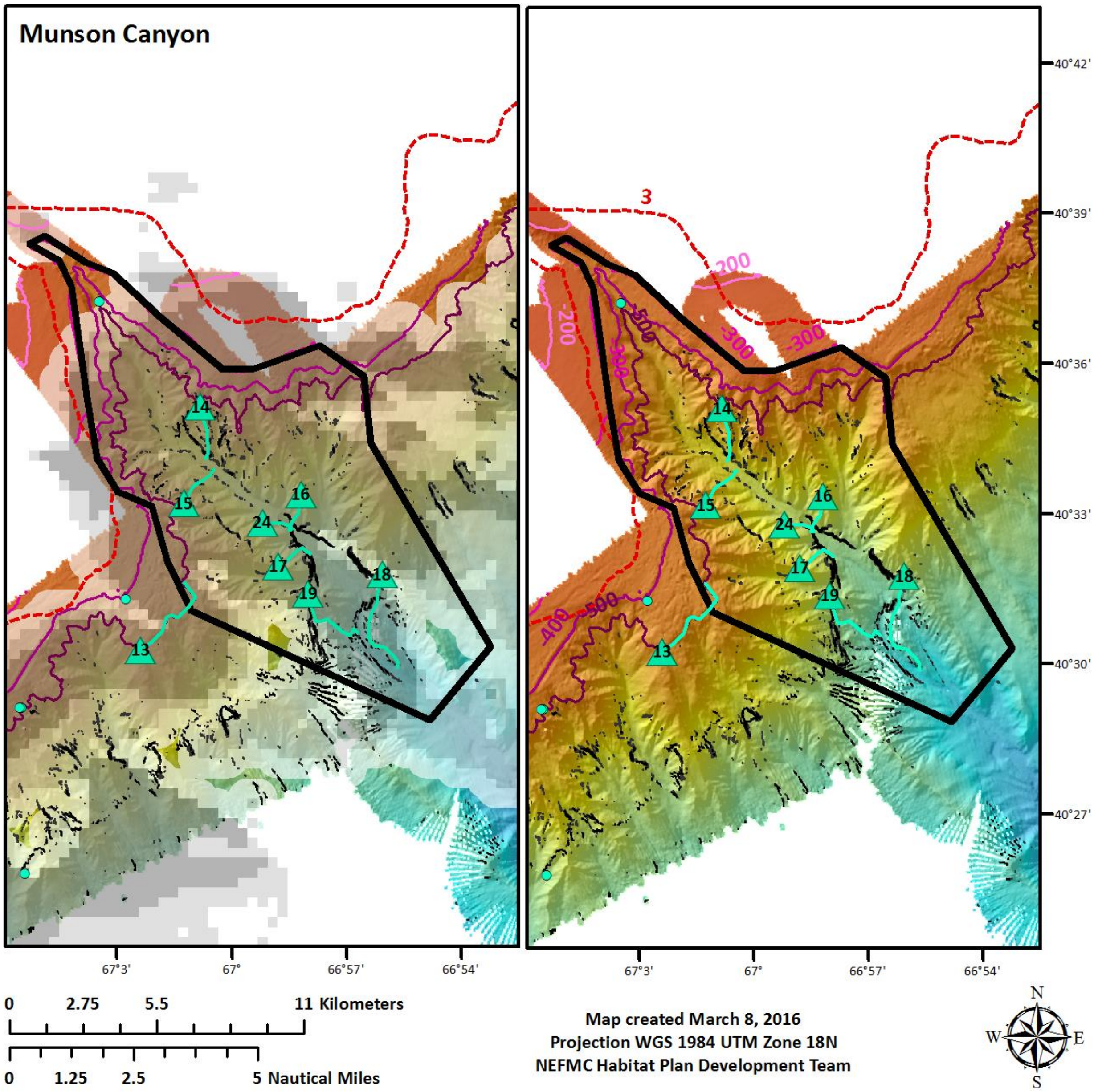


3.3.1.17 Munson Canyon

Munson Canyon incises the continental shelf break, encompassing an area of approximately 100 km^2. The proposed boundary follows the 300-meter depth contour along the head of the canyon. Munson has one main branch and a smaller branch to the east. Most of the canyon is identified as having high and very high likelihood of coral presence based on the habitat suitability model. Areas of high slope can be found throughout the zone, except in the shallowest portion of the canyon.

There is one historical observation of soft coral presence in the area. There have been six recent coral cruise tows using TowCam within the proposed zone. These were completed from the R/V Bigelow during cruise HB1302, tows 15-19 and 24. Recent cruise information includes observations of soft corals, stony corals, sea pens, and black corals. Tow15 (550-1,089m) had low abundance and diversity of corals present in the area. Dive 24 (1,084-1,472m) included locally abundant and diverse corals, and areas with no corals.

Map 21 – Munson Canyon discrete zone

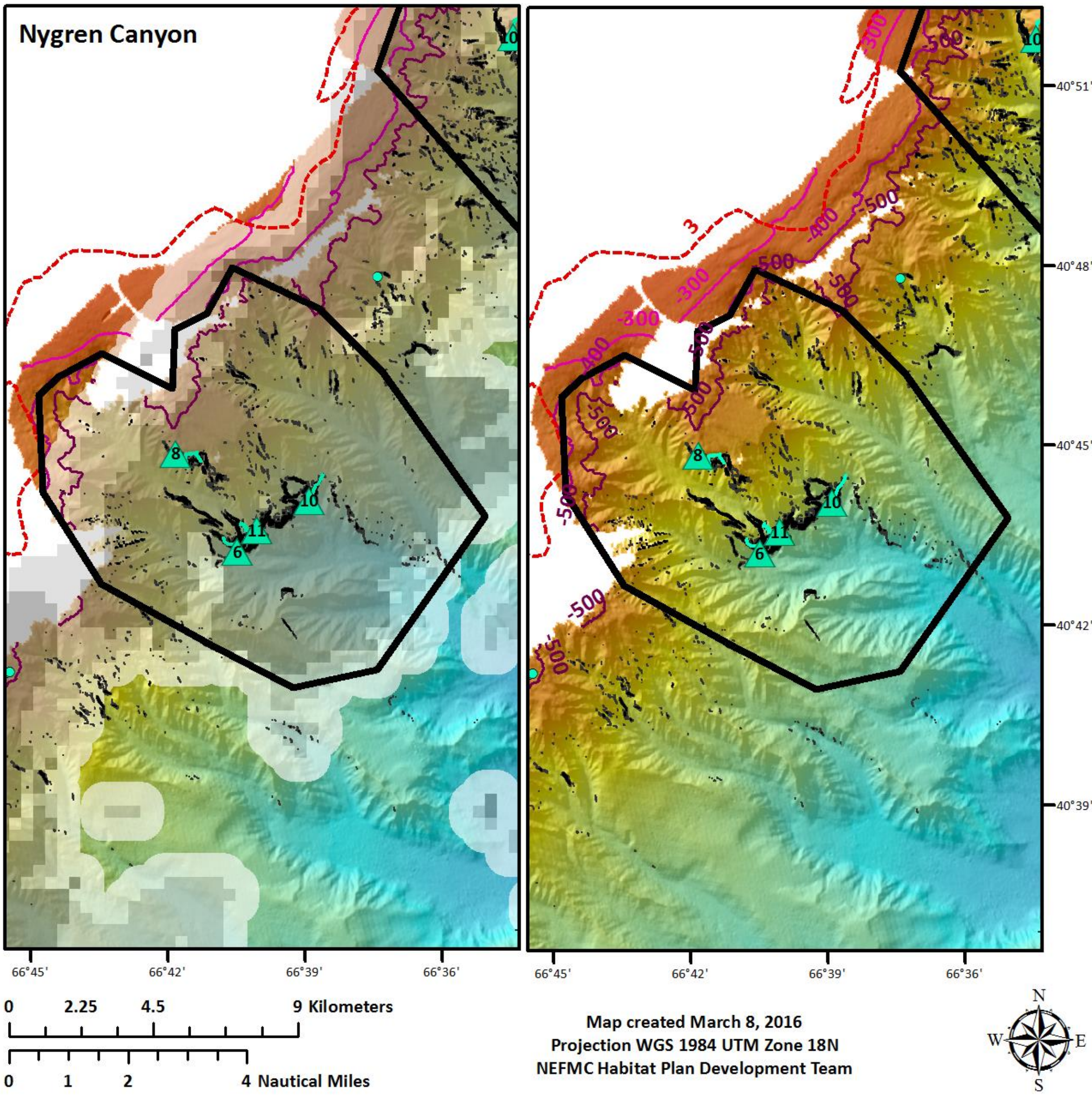


3.3.1.18 Nygren Canyon

Nygren Canyon is a dendritic, slope-confined canyon that encompasses an area of approximately 100 km^2. The recommended zone follows the 400-meter depth contour along the head of the canyon. Most of the canyon is identified as having high and very high likelihood of coral presence based on the habitat suitability model. Areas of high slope are concentrated in the middle of the proposed zone, but can be found on all major branches of the canyon. The very high suitability areas coincide with the very high slopes. Both the landward and seaward depths of the recommended zone were developed to correspond with the habitat suitability results.

There are no historical observations of coral presence in this area. However, there have been two recent dives in the area during leg 2 of the 2013 Okeanos Explorer Cruise EX1304L2. Dive 6 (1310-1590m) traversed a diverse range of habitats, including soft sediments, a cold seep, and exposed rock faces. Corals found included soft corals (at least 17 species), black corals (three species), stony corals (three to four species), and sea pens (three species). Dive 8 (678-914m) traversed a shallower area of the canyon, with sediments ranging from soft sediment with large boulders to rugged steep terrain with sediment-draped rock. A diverse coral fauna was observed during this dive, as well as a diversity of fishes and other fauna.

Map 22 – Nygren Canyon discrete zone

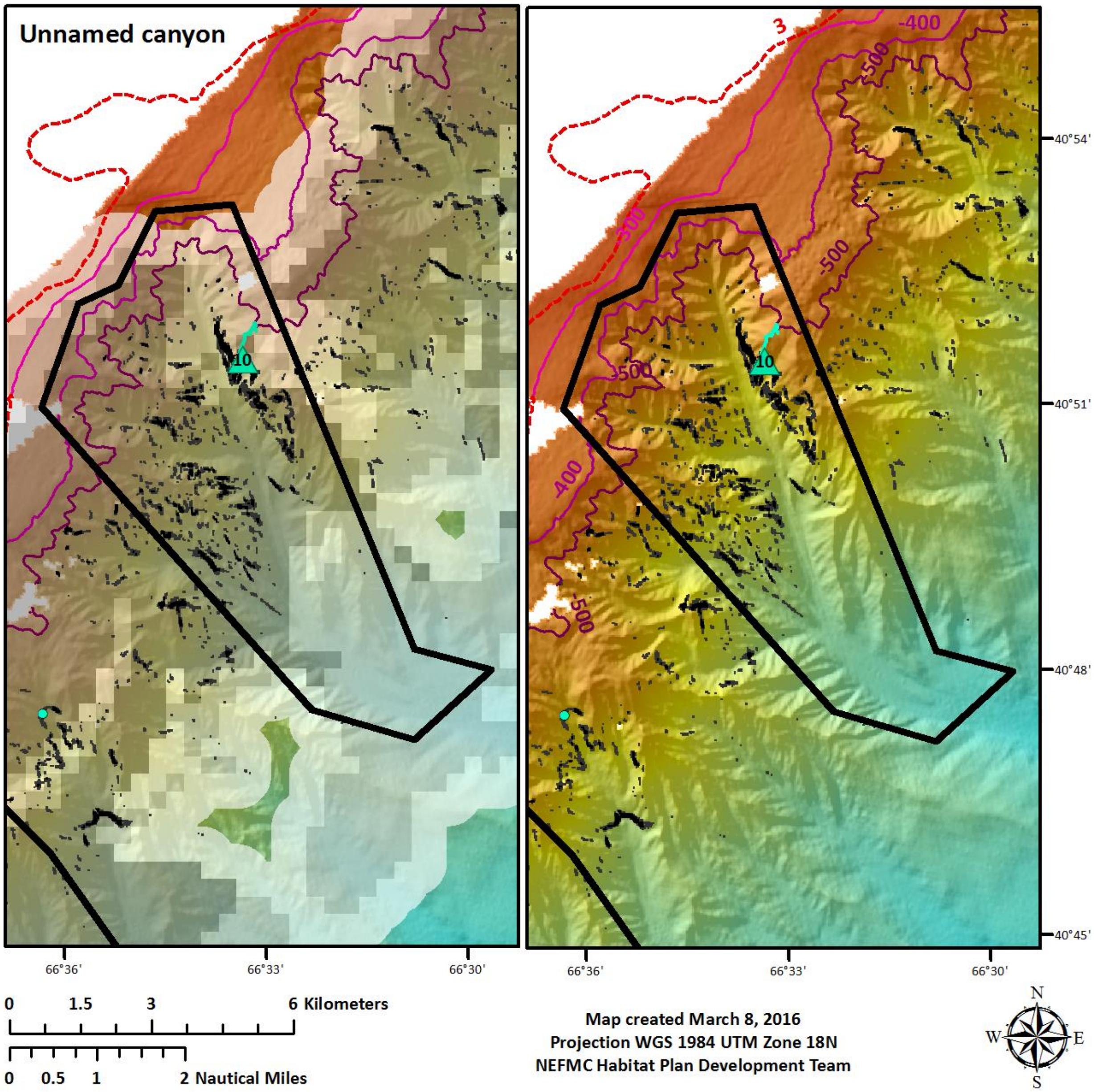


3.3.1.19 Unnamed Canyon

This unnamed, slope-confined canyon is relatively small, encompassing an area of approximately 50 km^2. The recommended zone follows the 400-meter contour along the head of the canyon. Most of the canyon is identified as having high or very high likelihood of coral presence based on the habitat suitability model. Areas of high slope can be found throughout the zone, and generally coincide with areas of very high habitat suitability.

There are no historical observations of coral presence in the area. There was a 2013 ROV dive in the canyon (Okeanos Explorer Cruise EX1304L2, dive 10, 497-824m). The dive track transited diverse habitat types and geological features, including soft sediments over rocky ledges, sediment with coral rubble, and a steeply sloping wall. The wall ledges harbored various coral types, including stony corals (solitary cup corals and colonial species) and soft corals. At the top of the slope the dive concluded on a sediment field with scattered rocks, colonized by attached organisms including soft corals (*Acanthogorgia*).

Map 23 – Discrete zone in unnamed canyon located between Heezen and Nygren Canyons

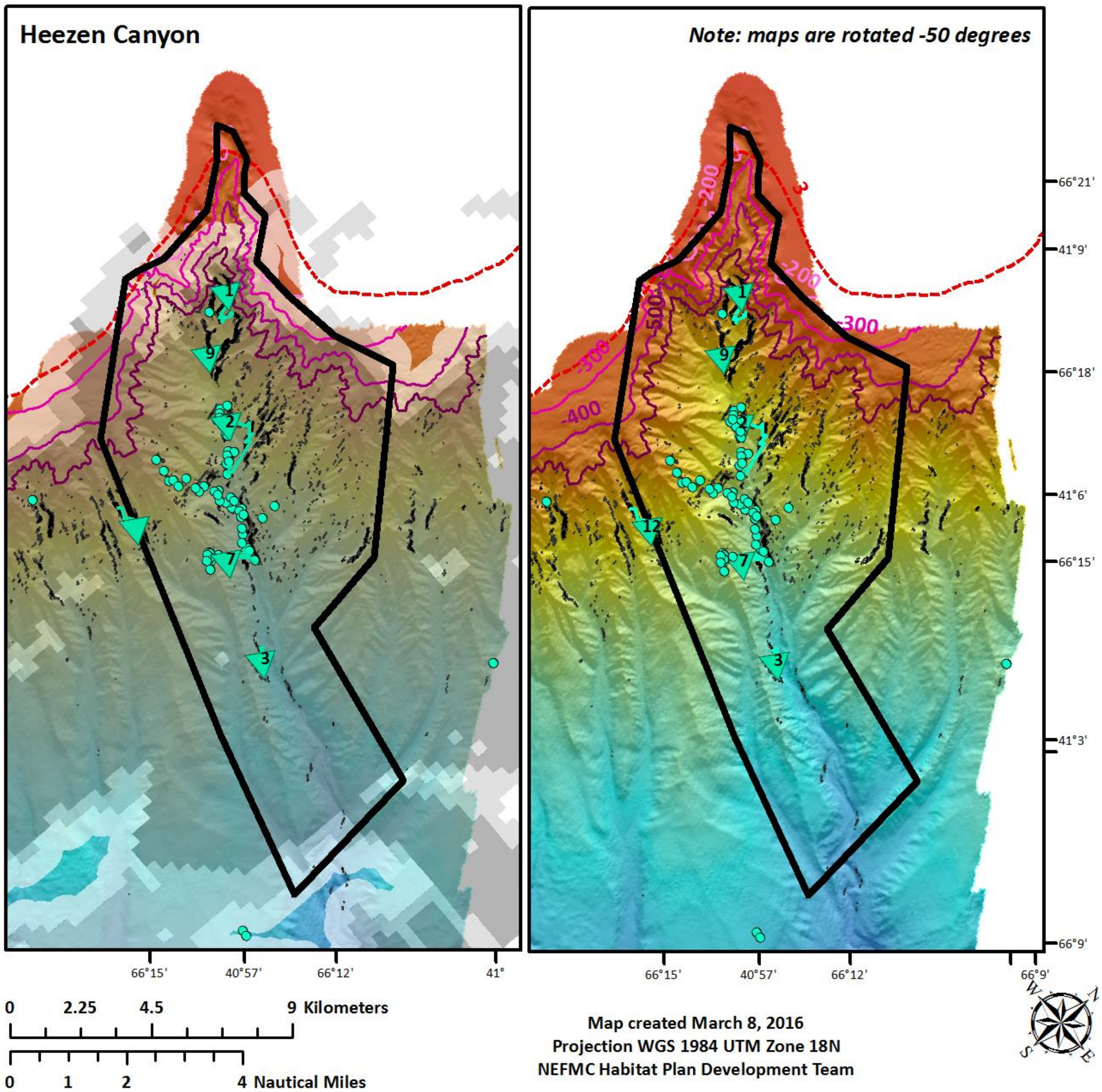


3.3.1.20 Heezen Canyon

Heezen Canyon incises the continental shelf break, encompassing an area of approximately 125 km^2. The proposed zone follows the 200-meter contour at the head of the canyon. Most of the recommended zone is identified as having high and very high likelihood of coral presence based on the habitat suitability model. Areas of high slope can be found throughout the zone, except in the shallowest and deepest portion of the canyon.

There are 67 historical records within the recommended zone, including observations of stony corals, soft corals, and sea pens. Two dives were completed in the area during the 2013 Okeanos Explorer Cruise EX1304L2. Dive 7 (1615-1723m), traversed varied habitat types along the southwestern flank of the canyon. Various coral taxa were found, including soft corals (*Paramuricea*, *Acanella*, *Clavularia*, and *Radicipes*), stony corals (the colonial *Solenosmilia*), black corals (*Stichopathes*), and sea pens (*Umbellela*). Dive 9 (703-926m), was in a shallower portion of the canyon along the southwestern wall. Vertical rock faces traversed during the dive were inhabited by enormous soft coral (*Paragorgia*, *Primnoa*, and *Paramuricea*) colonies. Other coral taxa were also observed during the dive.

Map 24 – Heezen Canyon discrete zone



3.3.2 Seamount coral zones

Coral zones are proposed for the four seamounts within the US EEZ. The four seamounts vary in size, depth range, and slope. The seamount bathymetry data are lower resolution than the canyon data (100 meter vs. 25 meter) but nonetheless provide a clear indication of the spatial extent of each seamount. The boundaries were drawn based on these bathymetry data and are intended to encompass the full extent of each seamount. Areas of high slope are also shown on the maps. In general, there are fewer areas of slope greater than 30° than in the canyons, so areas with slopes greater than 20° are shown. Overall, the seamount zones are somewhat larger than the canyon zones, ranging from approximately 200-500 km^2. Contours are shown in 500 meter intervals. Note that while the depth color shading uses the same coloration as the canyon maps, it is on a different scale.

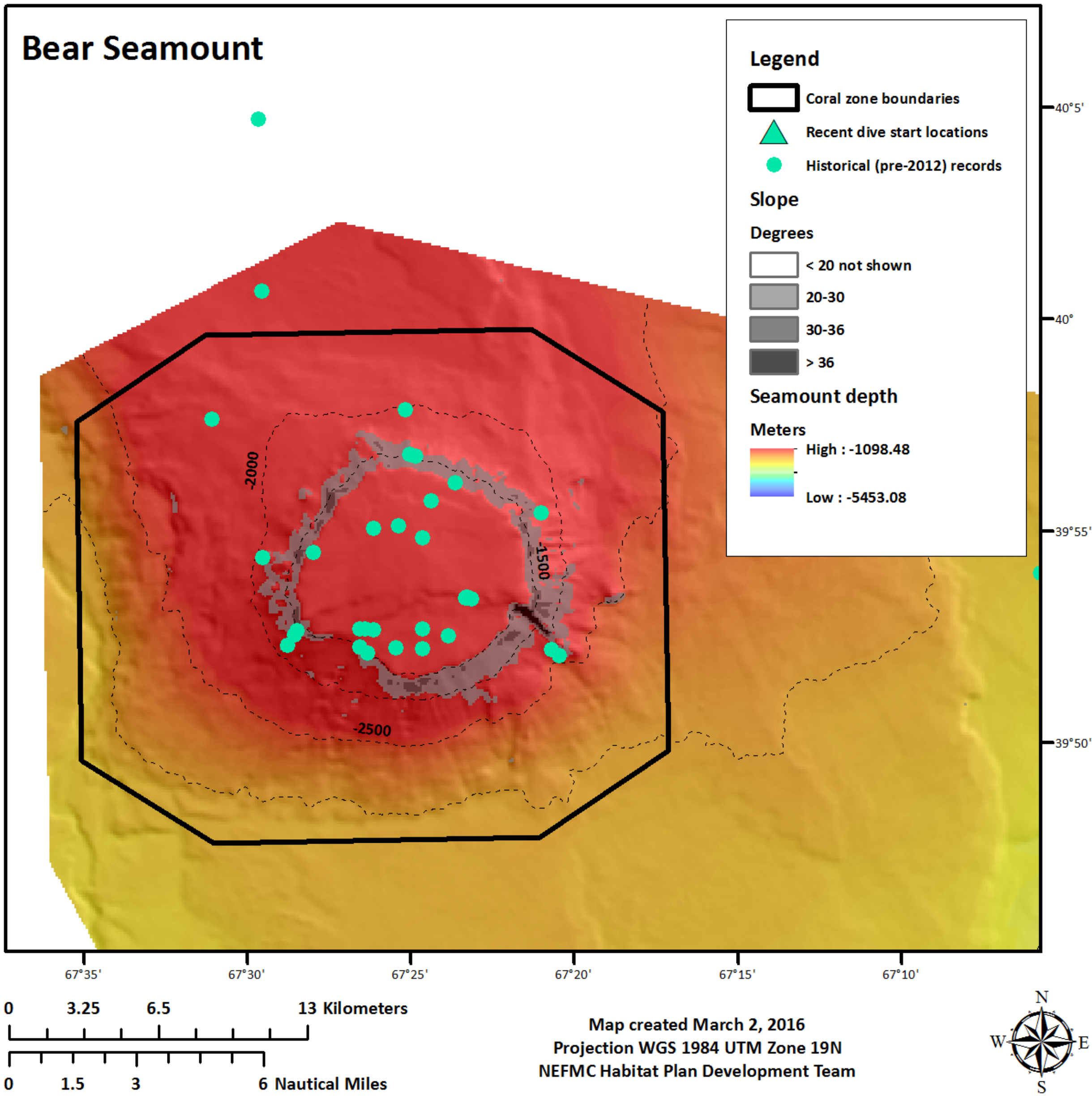
All four of the discrete seamount zones are fully encompassed within the Northeast Canyons and Seamounts Marine National Monument and are also fully contained within each of the broad zone alternatives. The individual zones are not overlapping and individual alternatives could be selected independently from one another.

Potential fishing restriction measures for the seamount zones are described in section 3.4.

3.3.2.1 Bear Seamount

Bear is the largest of the New England seamounts. The summit is approximately 1100m below sea level, and the base of the seamount is at over 3000m. While it was not visited during recent (2012-2015) cruises, all four groups of corals (soft, stony, sea pens, and black corals) had been previously documented in the area.

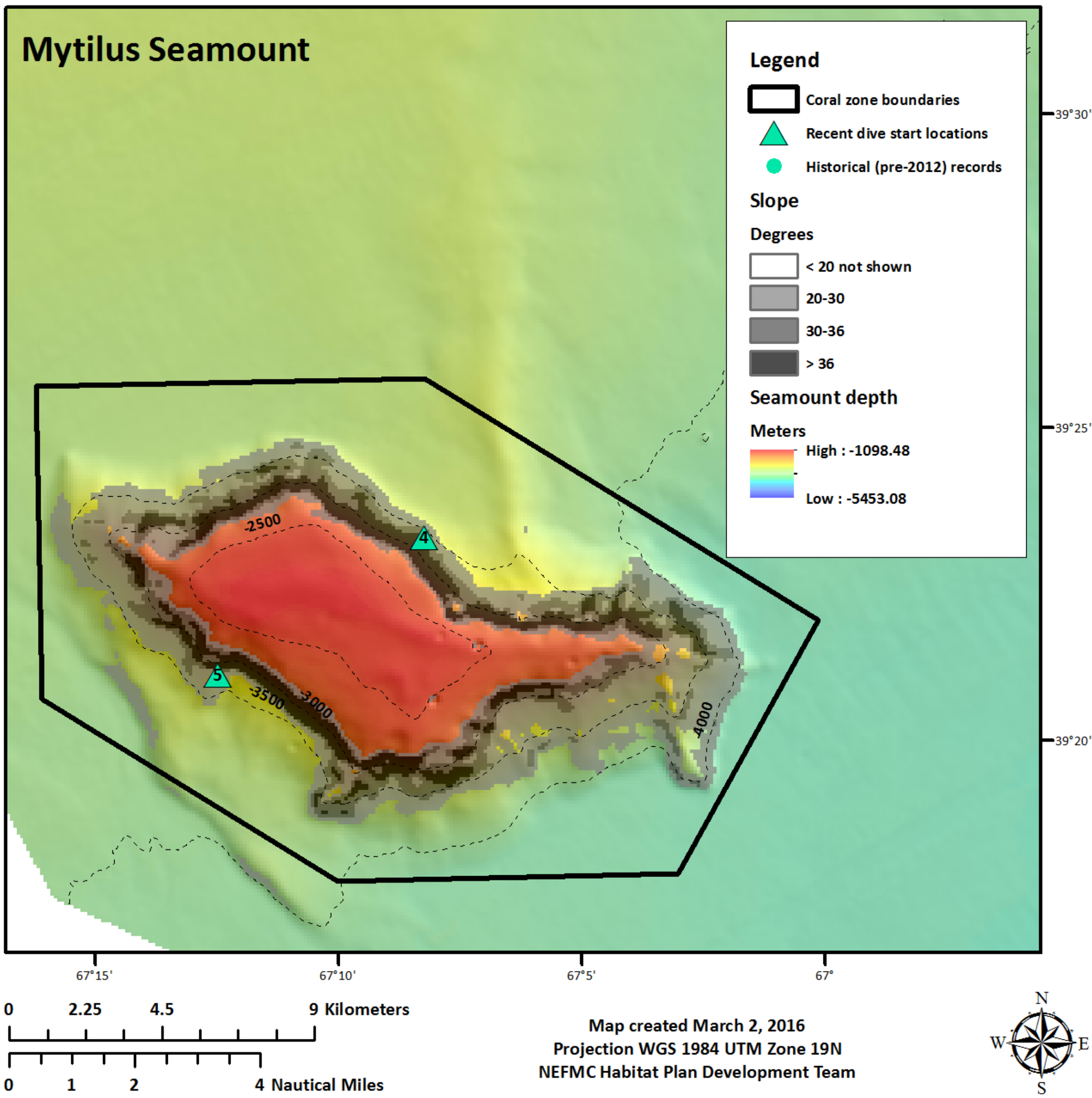
Map 25 – Bear Seamount coral zone boundary



3.3.2.2 Mytilus Seamount

Mytilus is the deepest of the four seamounts, with a minimum depth of 2,396m and a maximum depth within the proposed coral zone boundary of 4,183m. Mytilus Seamount was surveyed during leg 2 of the 2013 Okeanos Explorer cruise EX1304, dives 4 and 5. Dive 4 documented a diverse array of soft corals as well as two species of black coral. Sea pens, soft corals, and black corals were noted during Dive 5. A diversity of sponges was observed during both dives.

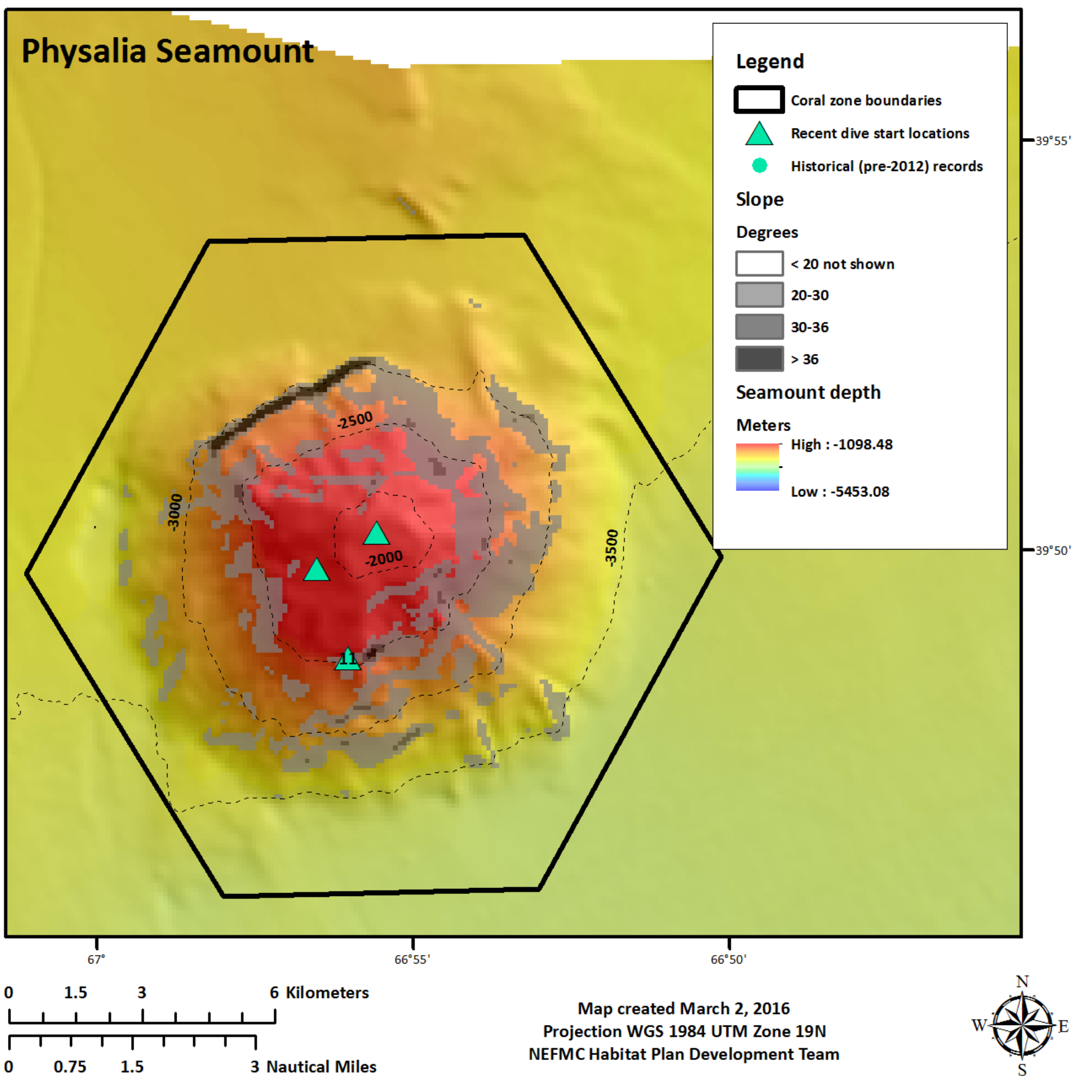
Map 26 – Mytilus Seamount coral zone boundary



3.3.2.3 Physalia Seamount

Physalia and Retriever seamounts have similar minimum and maximum depths. The summit of Physalia is at approximately 1900m, and the deepest part of the proposed zone is at over 3700m. Physalia was surveyed for the first time in 2012 using AUV technology (Kilgour et al. 2014). Two dives were conducted at and just off the summit of the seamount. Coral presence was confirmed during both dives, with sea pens found in fine sediment areas, and additional coral types observed were observed at low densities where soft sediments shifted to hard sediments, or on rock walls, ledges, and pavements. The Okeanos Explorer returned to Physalia in 2014 during cruise EX1404. Dive 11 was made at moderate depths on the southern side of Physalia. Results were consistent with observations from the 2012 cruise, with corals observed during the dive but at relatively low abundance and diversity. During this most recent dive, sponge diversity was greater than coral diversity.

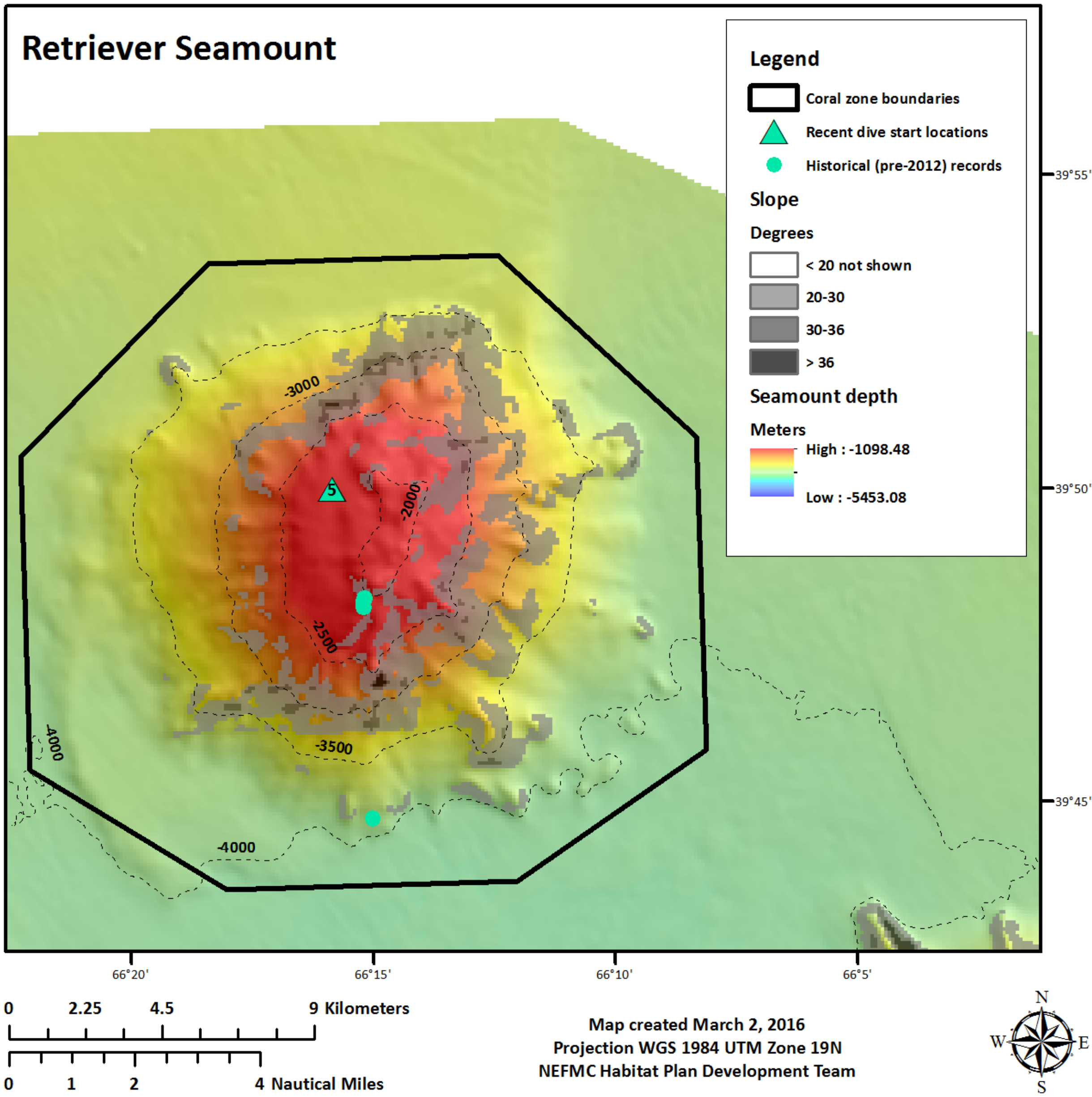
Map 27 – Physalia Seamount coral zone boundary



3.3.2.4 Retriever Seamount

The summit of retriever seamount is at approximately 1900m, and the deepest part of the proposed zone is at depths of over 4,000m. Dive 5 during EX1404 Leg 3 aboard the Okeanos Explorer explored the west slope of the seamount. A rock outcrop area on the dive harbored an array of coral species and other attached organisms.

Map 28 – Retriever Seamount coral zone boundary



3.3.3 Gulf of Maine coral zones and boundaries

Deep-sea corals have been known to occur in the Gulf of Maine since the nineteenth century (Watling and Auster 2005), but targeted camera surveys to assess coral distribution have been conducted only in the last fifteen years, with most of this type of survey activity occurring since 2013. Recent activities include both towed camera and ROV dives in various locations throughout the Gulf (see Auster et al. 2014, Auster et al. 2014 for details on 2013 and 2014 cruises). Coral habitats observed during 2002, 2003, and 2013-2015 surveys were classified as either low density corals or coral gardens. A density of 0.1 colonies per m^2 is the threshold that the International Council for the Exploration of the Sea (ICES) used to define coral garden habitat (ICES 2007). Coral habitats in some areas of the Gulf of Maine exceed the coral garden threshold density (see sections below for details), although coral management zones are recommended in areas with both classifications. The recommended zones are Outer Schoodic Ridge, Mount Desert Rock, three sites in Western Jordan Basin, one site in Central Jordan Basin, and Lindenkohl Knoll, which is in Georges Basin. All sites with multiple dive observations, specifically Outer Schoodic Ridge, Mount Desert Rock, the 114 Bump site in Western Jordan Basin, Central Jordan Basin, and Lindenkohl Knoll, had at least one dive where coral garden habitats were found.

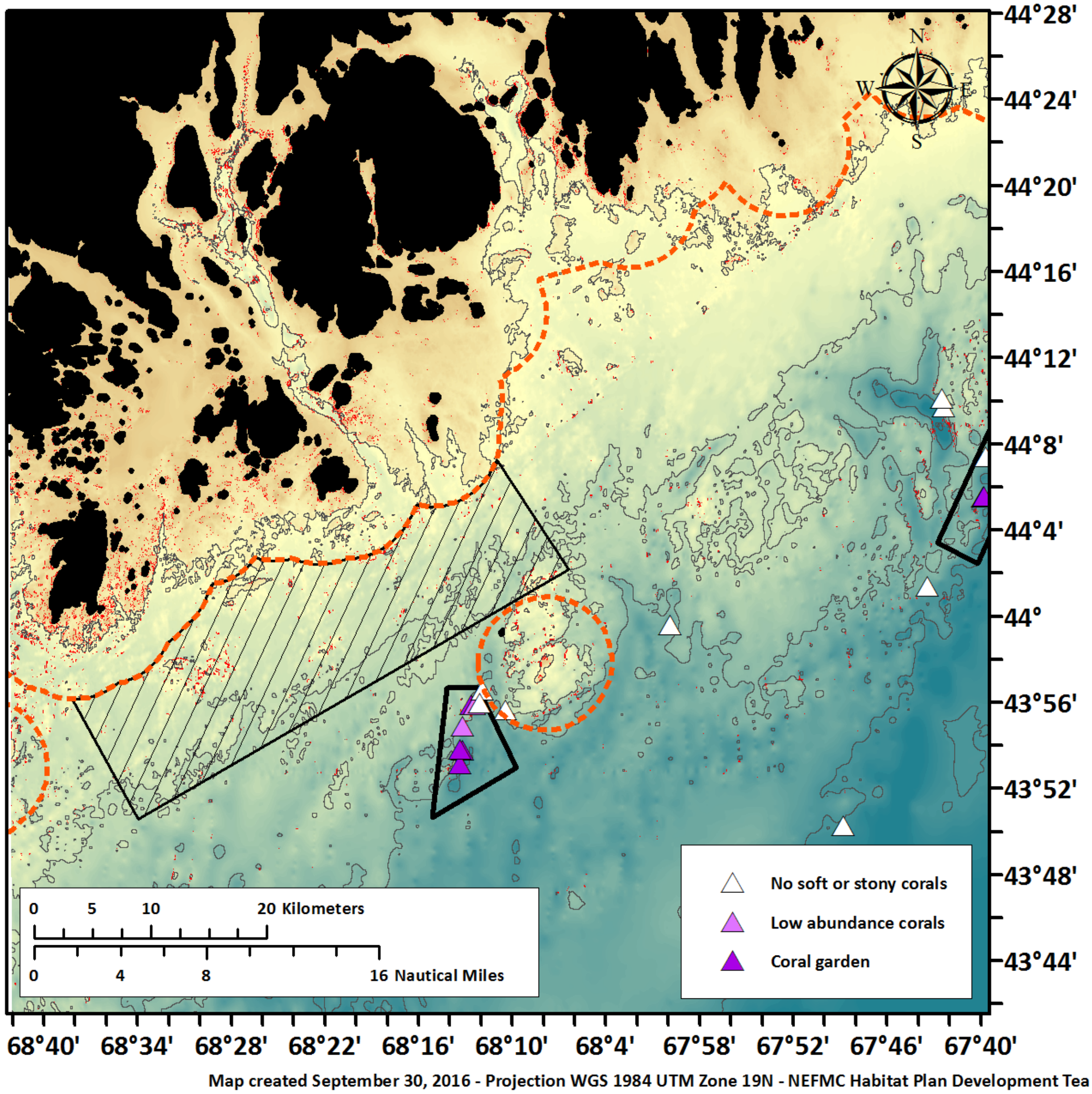
In general, the boundaries of the recommended coral zones were developed to encompass dive sites where corals were positively identified. Other recently collected data that inform the delineation of coral zones include high resolution multibeam bathymetry in the Outer Schoodic Ridge and Western Jordan Basin regions. Because the spatial extent of high resolution bathymetric data is limited, it is not possible to delineate zone boundaries based on full spatial extent of specific terrain features, as is the case with the canyon and seamount sites. However, the bathymetric data confirm the presence of similar terrain at sampled locations and nearby unsampled locations, such that suitable habitat can be inferred beyond the dive sites.

3.3.3.1 Mount Desert Rock

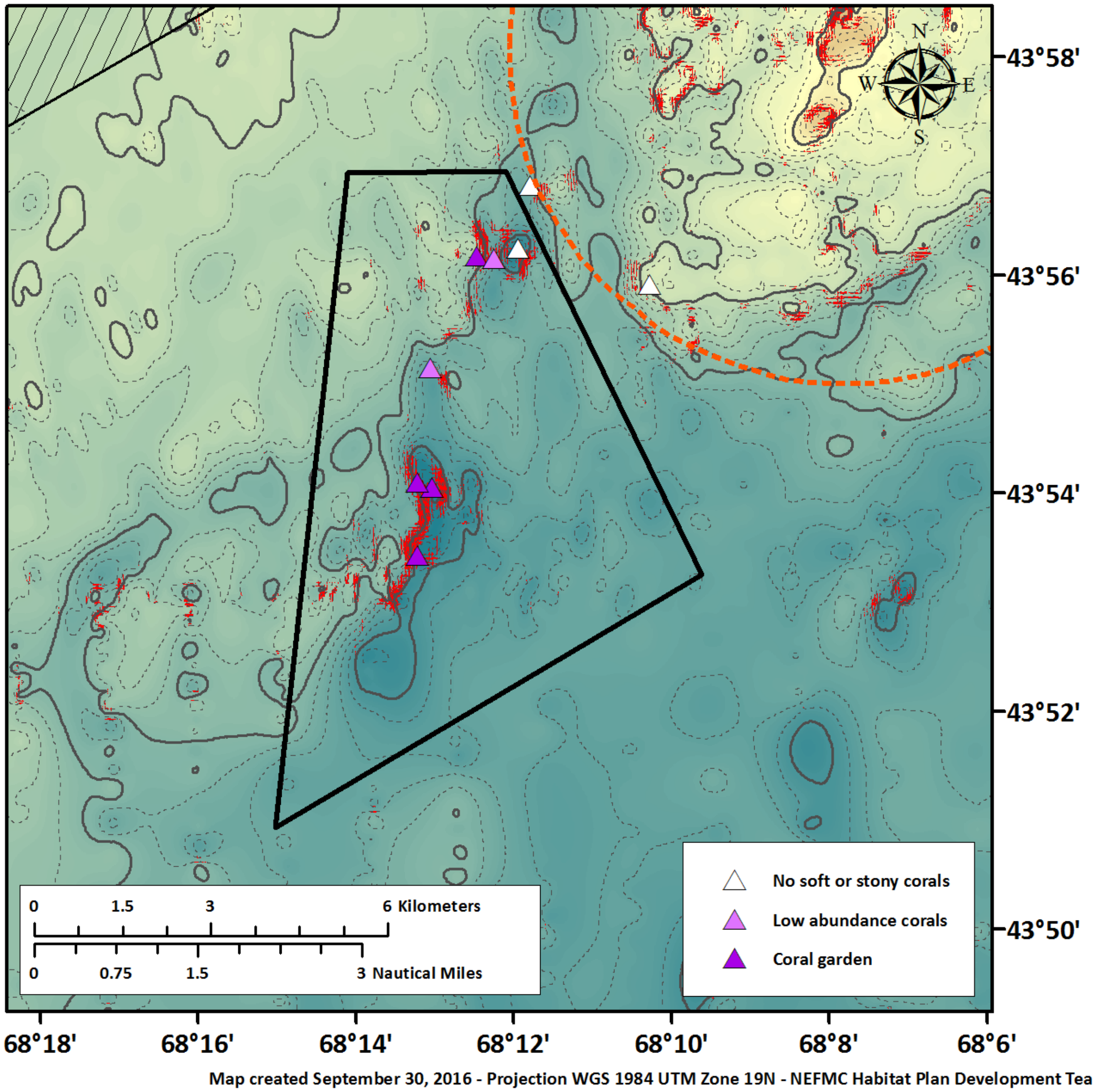
Mount Desert Rock is a small, rocky island off the eastern Maine coast which lies approximately 20 nm south of Mount Desert Island (Map 29). The proposed coral zone lies just outside state waters, southwest of Mount Desert Rock, and has depths ranging from approximately 100m to 200m (Map 30). The coral zone encompasses an area of approximately 47 km^2/18 mi^2.

Both low density coral habitats and coral garden habitats have been observed within the proposed coral zone, with the coral garden sites aligning with high slope areas. Six dives with corals and one nearby dive without corals have been conducted in the proposed zone since 2002, specifically dive 224 during 2002, dive 235 during 2003, tows 24 and 32 during 2013, and tows 10 and 11 in 2015. The 2013 and 2015 tows were all completed with the ISIS2 towed camera system. The 2015 tows exhibited dense soft coral communities, and fine-grained sediment areas encountered during Tow 11 exhibited very high densities of sea pens.

Map 29 – Regional siting of Mount Desert Rock Coral Zone (heavy black outline). The hatched area is the Eastern Maine Habitat Management Area adopted via Omnibus EFH Amendment 2 as a mobile bottom-tending gear closure. State waters are outlined in orange.



Map 30 – Mount Desert Rock Coral Zone, including recent dive locations and relative abundance of corals. Contours are in 10 m intervals with 50 m intervals highlighted.



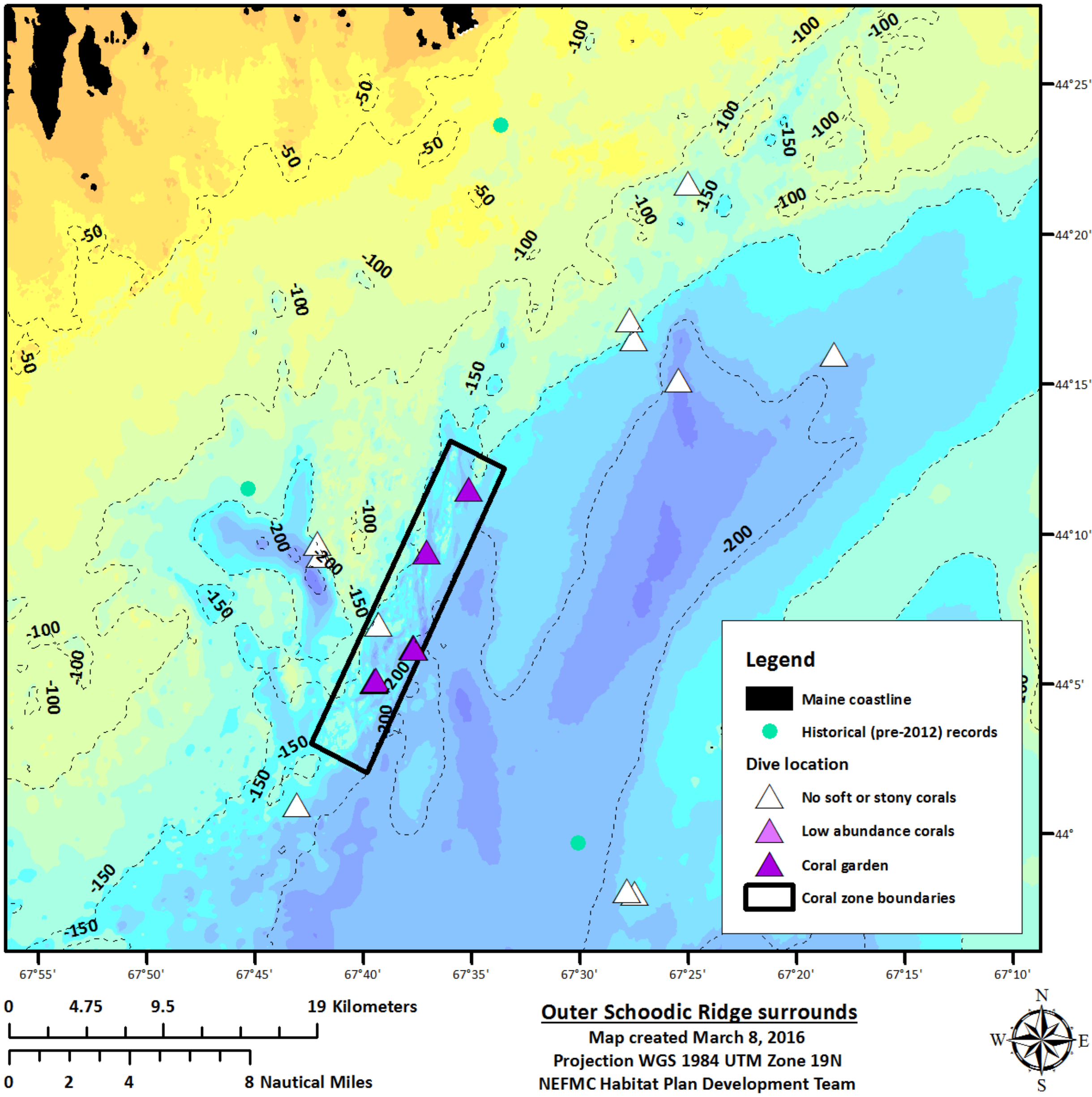
3.3.3.2 Outer Schoodic Ridge

The Outer Schoodic Ridge lies roughly 25 nm southeast of Mt. Desert Island (Map 31), within Statistical Area 511 and Maine Lobster Management Zone A. The coral zone encompasses a portion of the ridge that has been recently mapped with multibeam and surveyed using ROV. Recent high resolution bathymetric mapping details the complex, slot canyon terrain in the area. These data indicate that depths in the recommended zone range from 104m to 248m, with a mean depth of 174m. The coral zone is approximately 79 km^2/31 mi^2.

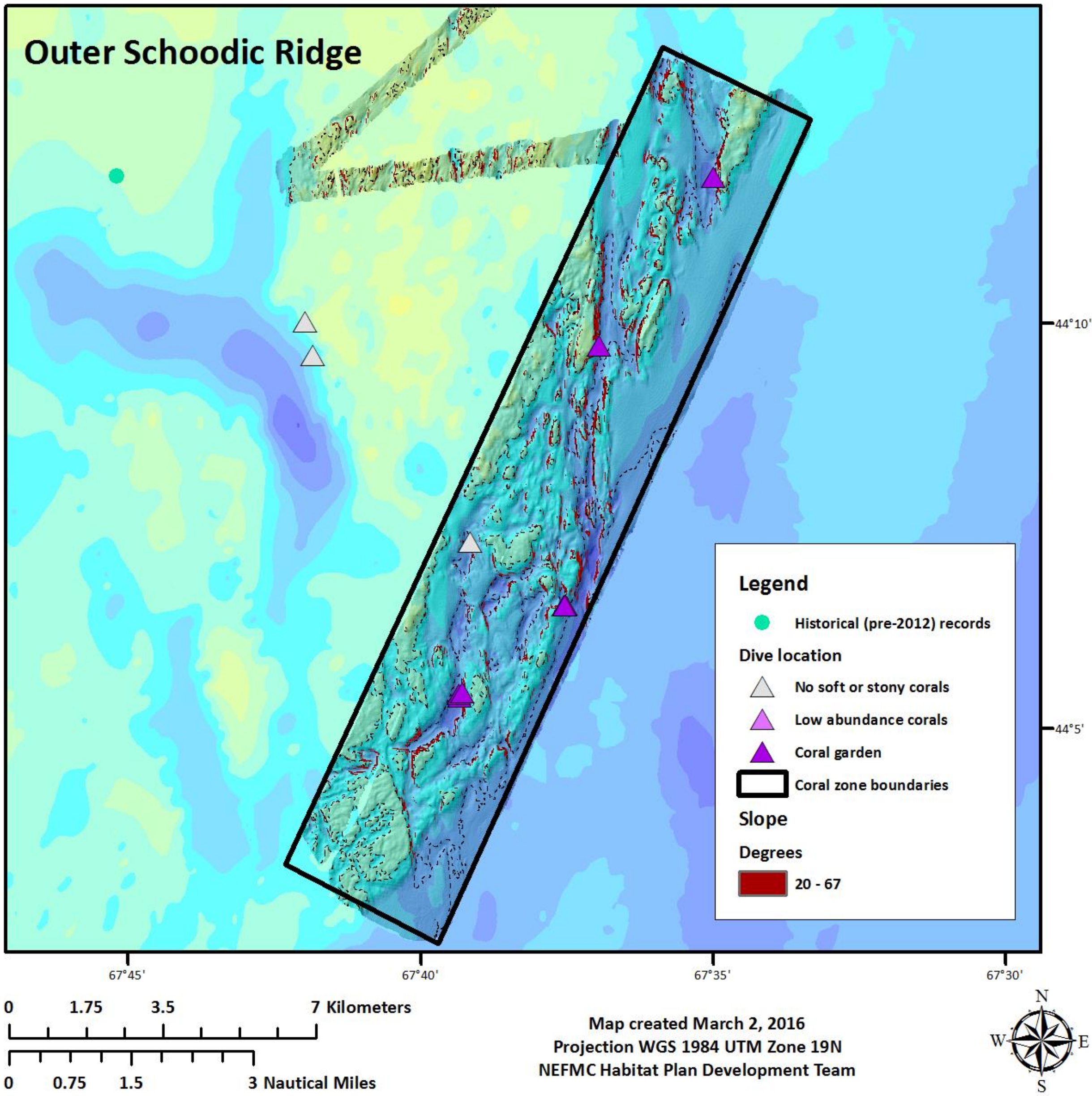
Corals at this location were studied during eight ROV dives and two camera tows during 2013, 2014, and 2015. Structure forming corals within the Outer Schoodic Ridge zone are mostly soft corals, although some smaller stony corals are also present. Highest densities of soft corals (e.g. 15.7-38.6 colonies per m^2) occur on short, steep, vertical rock faces. Common species include primarily *Primnoa resedaeformis*, along with *Paramuricea placomus* and *Acanthogorgia* cf. *armata.* Areas outside these very steep rock faces with scattered gravels and smaller rock outcrops support lower densities of corals, primarily *P. placomus*, co-occurring with other structure-forming species such as burrowing cerianthid anemones, and sponges, as well as sea pens (*Pennatula aculeata*). All but one of the dives found corals at coral garden densities. Sea pens and sponges were noted during the remaining dive.

Steeply sloped features that are likely to provide suitable attachment sites for corals are found in the vicinity of the dive sites, throughout the area with high resolution bathymetry data. Based on the presence of steep terrain, the entire footprint of this data set, aside from a small amount of data to the west of the area in shallower waters, is recommended as a coral zone. It is possible that there are additional corals outside the recommended zone boundaries, but corals were not observed during dives at similar depths nearby (Map 31).

Map 31 – Area surrounding the Outer Schoodic Ridge Coral Zone. Contours are at 50 meter intervals. Relative coral densities during recent dives are shown in purple shading.



Map 32 – Outer Schoodic Ridge Coral Zone and high resolution bathymetry. Areas of high slope are shown in red. Relative coral densities during recent dives (triangles) are shown in purple shading.

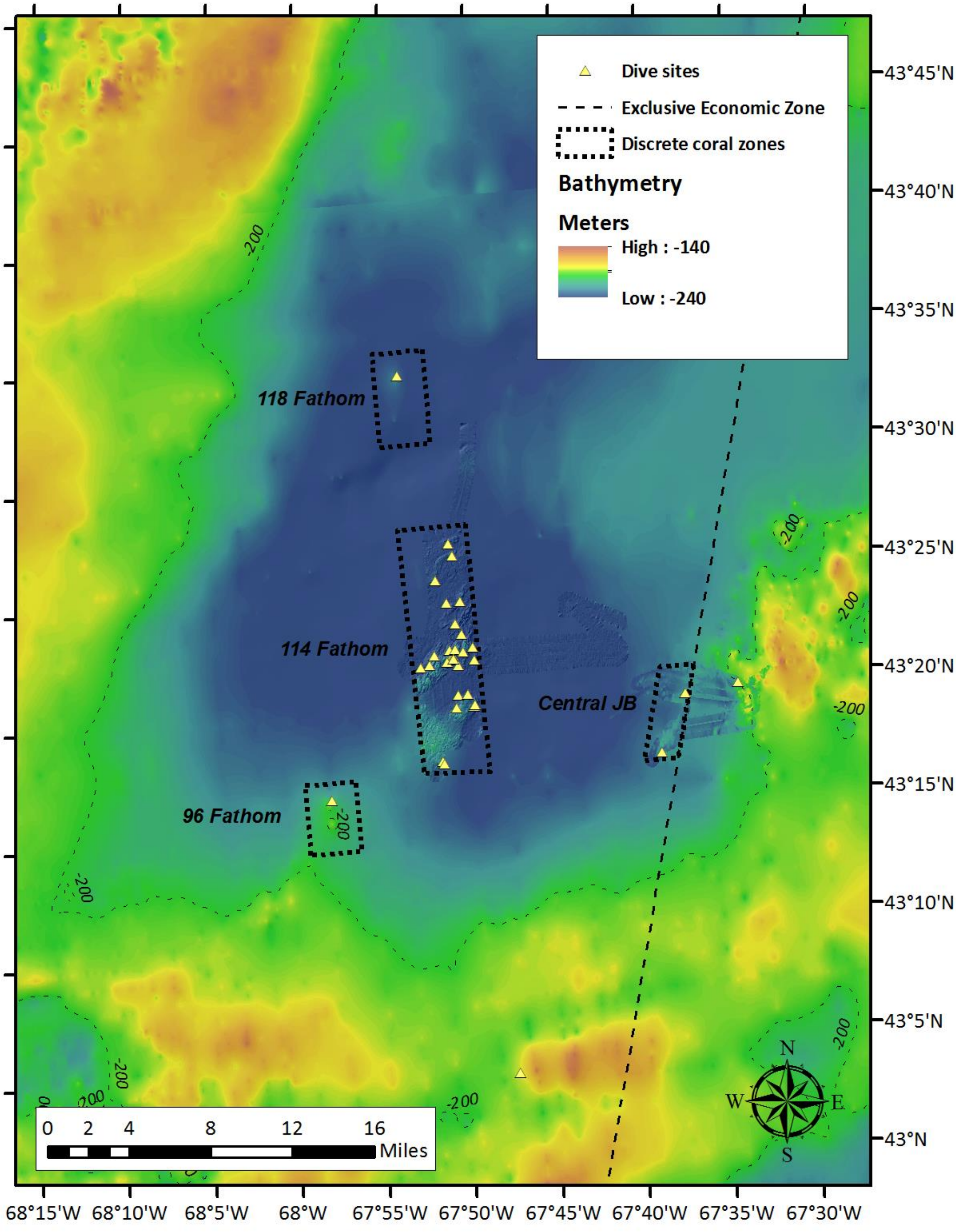


3.3.3.3 Jordan Basin

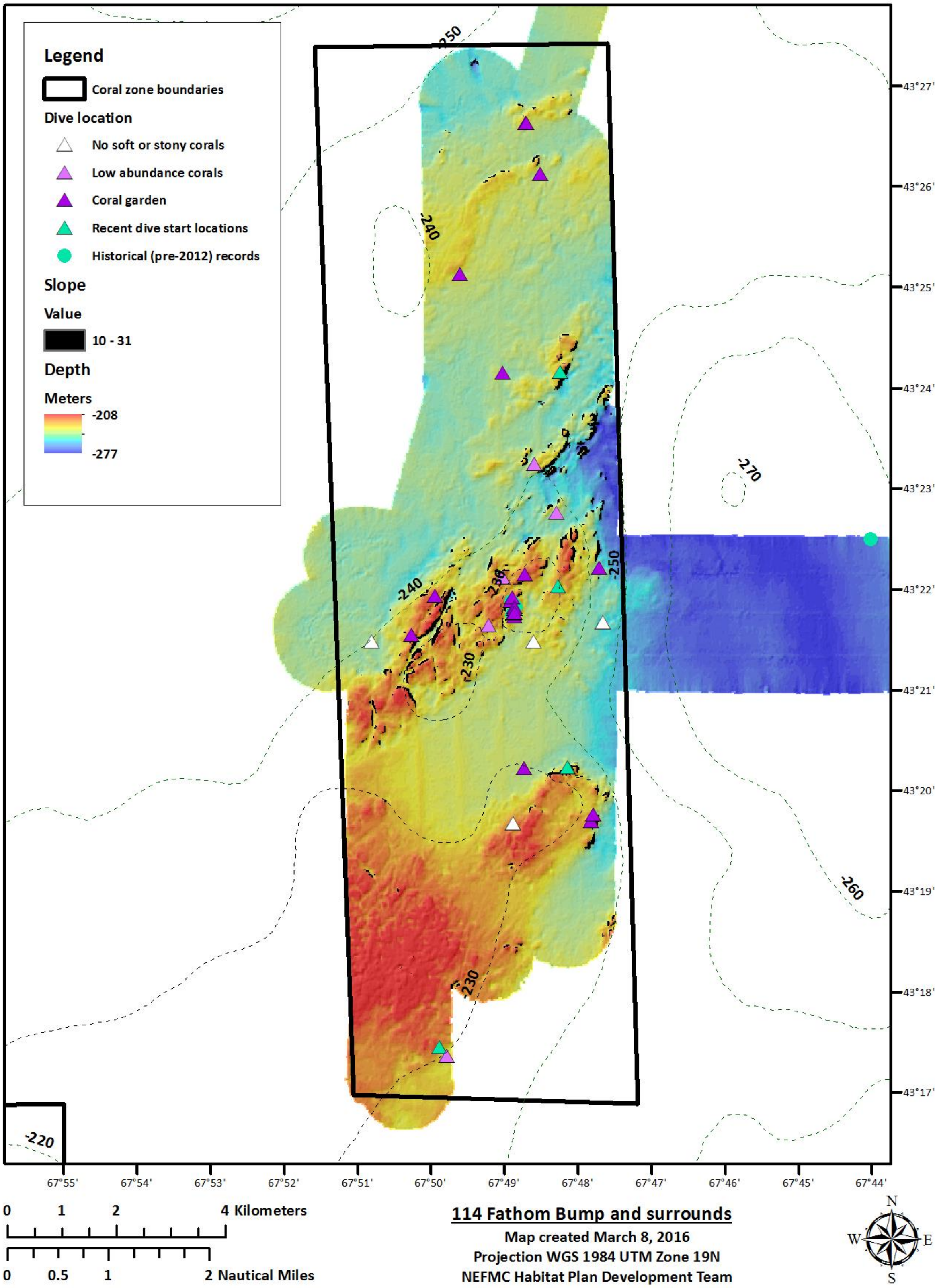
Jordan Basin, which straddles the EEZ boundary, has depths ranging from approximately 175 to 250 meters. Deep-sea corals have been observed on shallower rocky features within the basin, which are named for their charted depths: 98 Fathom Bump (179m), 114 Fathom Bump (208m), and 118 Fathom Bump (216m). A site in Central Jordan Basin encompasses depths of approximately 220m to 235m. All four sites are shown on Map 33. They areas range in size: Central Jordan Basin 19 km^2/7 mi^2, 96 Fathom Bump 23 km^2/9 mi^2, 118 Fathom Bump 39 km^2/12 mi^2, 114 Fathom Bump 103 km^2/40 mi^2.

The 114 Fathom Bump and its immediate surrounds is the best mapped of these four sites, and has the greatest number of dives (Map 34). According to the high resolution multibeam bathymetry, depths in the recommended zone range from 208m to 276m, with a mean depth of 240m. Similar to Outer Schoodic Ridge, coral garden habitats on 114 Fathom Bump are dominated by soft corals (mostly *Paramuricea placomus,* along with *Primnoa resedaeformis* and *Acanthogorgia* cf. *armata*), with the highest densities on steep rock walls. Lower density coral habitats have also been found at 96 Fathom Bump and118 Fathom Bump sites, which have been surveyed with only a single dive each. Two dives within the Central Jordan Basin site have documented coral presence, with lower density coral habitats found in at the northern dive site, and higher density coral habitats at the southern site.

Map 33 – Discrete coral zones in Jordan Basin.



Map 34 – Larger scale image of the high resolution bathymetry at the 114 Fathom Bump zone. This map uses a different color scale than the previous map of the Western/Central Jordan Basin region.

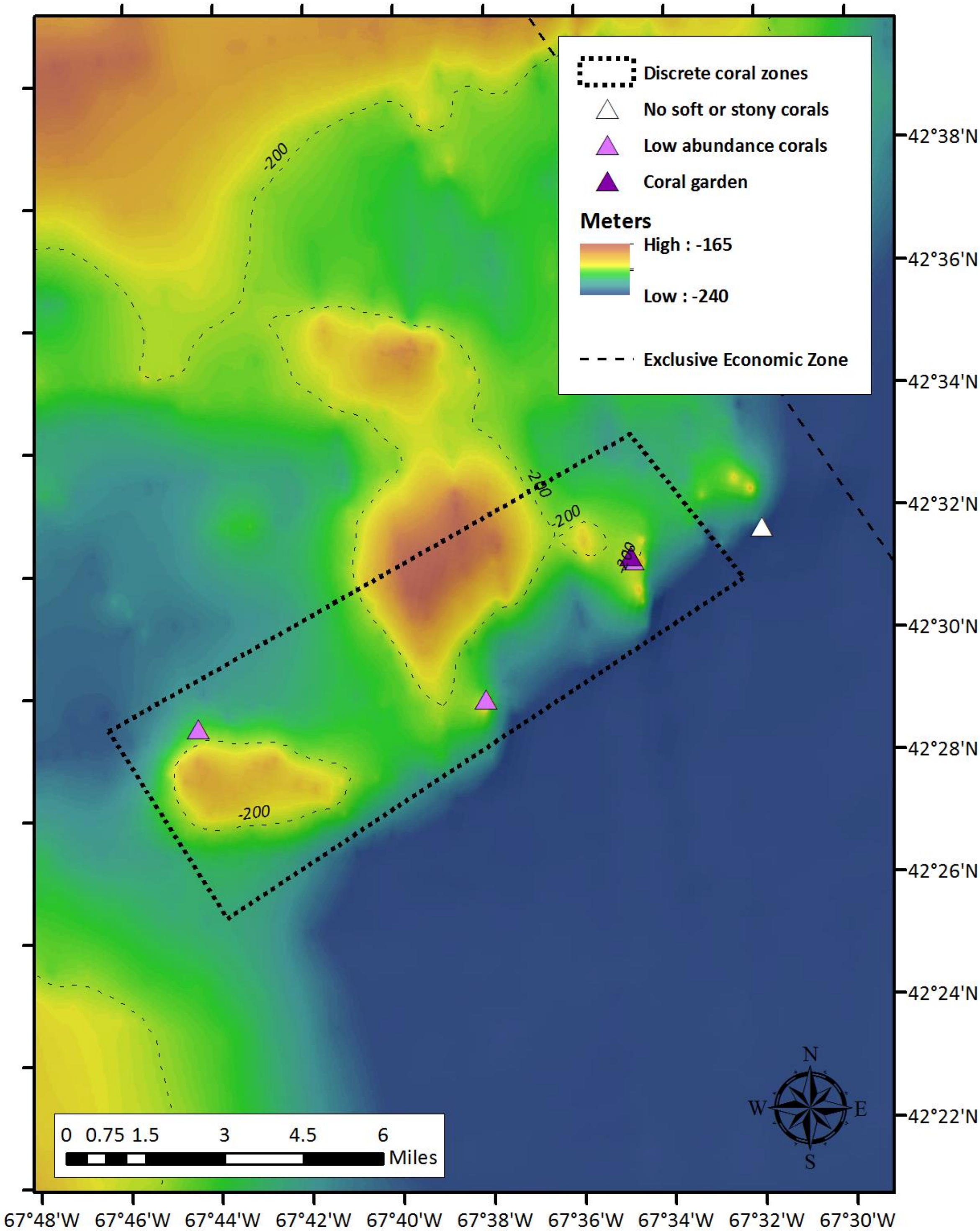


3.3.3.4 Lindenkohl Knoll

Georges Basin, just north of Georges Bank, includes the deepest waters in the Gulf of Maine (approximately 200 fa, over 360 m). Lindenkohl Knoll is a somewhat shallower feature on the western side of Georges Basin, roughly 25 miles north of the northern edge of Georges Bank. The eastern boundary of the Lindenkohl Knoll Coral Zone is just over two nautical miles from the Hague Line. The recommended zone is approximately 114 km^2 (44 mi^2) and has depths ranging from approximately 165m to 255m.

Four 2015 camera tows found corals at both coral garden densities of greater than one colony per meter squared (one tow) and lower densities (three tows). The soft coral *Paramuricea* was the most commonly occurring species. One dive located just east of the coral zone did not document any corals.

Map 35 – Recommended Lindenkohl Knoll coral zone.



3.4 Fishing restriction options for coral zones

The following range of fishing restriction alternatives are under consideration within the coral zones described above. Different measures could be used in broad vs. discrete zones, or in different discrete zones, depending on the fisheries that occur there and the degree of precaution desired. Note that broad and discrete zones could be used in combination, with different types of measure applied in each.

3.4.1 Option 1. Prohibit bottom-tending gears

This option would prohibit the use of bottom-tending fishing gears in deep-sea coral zones, but would allow the use of gears that do not contact the seabed. Restricted gear types would include bottom-tending otter trawls, bottom-tending beam trawls, hydraulic dredges, non-hydraulic dredges, bottom-tending seines, bottom-tending longlines, sink or anchored gillnets, and pots and traps. This list is intended to be comprehensive, but some of these gears may not be active in the coral zones currently. Pots and traps could be exempted from this restriction by adopting one or both of the sub-options listed below in combination with this alternative.

Vessels may transit the coral zones provided bottom-tending trawl nets are out of the water and stowed on the reel and any other fishing gear that is prohibited in these areas is onboard, out of the water, and not deployed. Fishing gear would not be required to meet the definition of "not available for immediate use" in 50 CFR § 648.2. These transit provisions are consistent with those adopted by the Mid-Atlantic Fishery Management Council for their coral zones.

3.4.1.1 Sub-option A: Exempt the red crab fishery from coral zone restrictions

This sub-option would exempt the red crab trap fishery from bottom-tending gear restrictions. This exemption would be limited to vessels fishing under a limited access red crab permit (Category B or C).

3.4.1.2 Sub-option B: Exempt other trap fisheries from coral zone restrictions

This sub-option would exempt vessels in all other pot and trap fisheries from coral zone restrictions. This exemption would cover vessels fishing for lobster and Jonah crab with federal waters lobster permits, as well as any other vessels fishing with traps or pots.

3.4.2 Option 2: Prohibit use of mobile bottom-tending gears

This option would prohibit the use of mobile bottom-tending fishing gears in deep-sea coral zones, but would allow the use of fixed gears and any gears that do not contact the seabed. Restricted gear types would include bottom-tending otter trawls, bottom-tending beam trawls, hydraulic dredges, non-hydraulic dredges, and bottom-tending seines. This list is intended to be comprehensive, but some of these gears may not be active in the coral zones currently.

Vessels may transit the coral zones provided bottom-tending trawl nets are out of the water and stowed on the reel and any other fishing gear that is prohibited in these areas is onboard, out of the water, and not deployed. Fishing gear would not be required to meet the definition of "not available for immediate use" in 50 CFR § 648.2. As above, these transit provisions are consistent with those adopted by the Mid-Atlantic Fishery Management Council.

3.5 Framework provisions for deep-sea coral zones

These options would allow the measures adopted via this amendment to be changed via framework adjustment versus fishery management amendment. This would not preclude the Council from determining, or NMFS from recommending, that an amendment is a more appropriate vehicle for consideration of the change. In some cases, an amendment might be more appropriate, particularly if the impacts of an action are likely to be substantial. Note also that decisions about whether an environmental assessment vs. environmental impact statement are prepared are separate from the decision to pursue a framework or an amendment. One or more of the following alternatives in this section could be selected.

3.5.1 Option 1. Add, revise, or remove coral zones via framework adjustment

This alternative would allow coral zones to be added, revised, or removed via framework adjustment.

3.5.2 Option 2. Change fishing restrictions in coral zones via framework adjustment

This alternative would allow the Council to change the types of fishing gears restricted within deep-sea coral zones via framework.

3.6 Special Access Programs, exploratory fishing, and research in coral zones

The alternatives in this section would create programs to allow special access fishing, exploratory fishing, and/or research activities within coral zones (comparison in Figure 2). The concepts in these alternatives come from existing special access programs in the groundfish, scallop, and herring fisheries, the exempted fishing permit process, and the Northwest Atlantic Fishery Organization exploratory fishing program. There is also an alternative that would allow such programs to be created in a framework adjustment action.

Figure 2 – Major elements of special access and exploratory fishing programs within coral zones

Special access program track:	Exploratory track:	Research track:
Maintain permit in an authorized fishery	Apply for exempted fishery permit	Develop project consistent with definition of scientific research
Request letter of authorization for the special access program	Document target species catch and coral interactions	Request letter of acknowledgement
Comply with program operational and reporting requirements while fishing	If warranted, add target species to special access program via rulemaking	Data used for updates to coral management measures as appropriate

3.6.1 Special access program fishing

This alternative would implement a special access program within some or all of the deep-sea coral zones. The objectives of the program would be as follows:

(1) To allow for continued fishery access to some or all coral areas
(2) To ensure that such fishing does not conflict with coral conservation objectives

This program would generate sufficient data to understand fishing distributions in coral zones, as well as interactions between fishing and corals. The intention here is to specify in detail the possible the operational requirements for a vessel that wishes to fish within a coral zone.

The main distinction between this program and a categorical exemption from gear restrictions for the red crab fishery (section 3.4.1.1) or other trap fisheries (section 3.4.1.2) is that this program could have additional reporting requirements and/or spatial restrictions, while fisheries under categorical exemption would operate under current restrictions with no additional reporting requirements.

Which vessels? A program to allow fishing activities in specified deep-sea coral zones could potentially apply to any vessel that is restricted from operating in a particular coral zone according to the measures selected in section 3.4 (fishing restrictions for coral zones). This could include vessels fishing with any type of bottom tending gear, or only those fishing with mobile bottom-tending gear, depending on the alternative selected.

Alternatively, the Council could restrict participation in special access programs to vessels participating in specific fisheries, based on permit type.

Which areas? The Council would need to determine where special access program fishing would be allowed. Such activities could be authorized in all designated coral zones, or only in certain coral zones. Areas authorized for a special access fishery could vary by fishery to include only those areas fished currently or in the recent past. Sub-areas of broad zones might also be appropriate.

Operational requirements: When fishing in an exempted/special access fishing program in a coral area, vessel operators could be subject to additional requirements. These might include:

1. Gear requirements: The Council may wish to specify gear restrictions that are different from what is currently authorized under the various FMPs in order to better protect corals from fishing impacts. This could include limits on rollers or rockhoppers, for example.
2. Seasonal requirements: This is an element of some existing special access programs and is listed for completeness, but would probably not be necessary here. Corals are almost certain to be equally vulnerable to fishing impacts year round.
3. Total amount of effort or target species landings: The Council could specify the number of trips allowed for each vessel authorized in the special access program in order to limit the total amount of fishing that could occur in coral areas. Or, the Council could consider exemptions from certain fishery regulations when operating in coral zones. For example, trip limits might be counterproductive to conservation objectives if discarding occurs and additional bottom time is therefore required to land the same amount of the target species. Ensuring coral protection should remain the focus though. In the case of corals, effort limitation might not be a useful tool because the impact/recovery relationship is such that the initial impact is most damaging, such that any effort occurring in locations with lots of corals could be problematic from a conservation standpoint. This underscores the importance of only allowing special access fishing to occur in locations where interactions between that type of fishing and the coral types known or thought to occur would be minimal to begin with.
4. Move-along provision if any corals are caught: This type of provision would require the vessel to stop fishing if corals are encountered and move to a new location. The Council could specify a zero or non-zero threshold of coral bycatch that would trigger a move-along clause. While the Northwest Atlantic Fisheries Organization (NAFO) has advanced the use of such approaches, these types of thresholds are difficult to develop because coral catch rates vary by coral species, gear and area (Auster et al. 2010). Whether the threshold is zero or non-zero, this type of provision would require the vessel operator to be able to identify corals in the catch.
5. Coral retention requirement: Would require any corals caught to be retained and brought back to shore for analysis, to determine the species caught.

6. Reporting requirements:
    a. For vessels that are equipped with one as a requirement of a fishery they participate in, use of a vessel monitoring system with half-hourly polling
    b. Enhanced documentation of fishing location and catch. For each tow of mobile gear or set of fixed gear:
        i. Start and end location and depth of all tows
        ii. Catch weights by species, including target and non-target fishes and invertebrates identified to the lowest taxonomic level possible
        iii. Alternatively, use an observer.
    c. File fishing vessel trip reports as usual.

Letter of authorization: A special access program would likely require a letter of authorization. The fishing that would occur under the letters of authorization typically needs to meet a range of requirements. These types of information could be included in the request:

1. Vessel identifying information and point of contact
2. Must be filed by the application deadline. A deadline would need to be specified so that vessel owners would know how far in advance they need to request a letter of authorization. In the case of research-related exempted fishery permits, the project proponents are asked to apply 60 days before the permit is to be used. Requests could be submitted on a rolling basis, similar to research-related applications, or only within a certain window each year. If the latter option is selected, the deadline could be 60 days before the start of a particular fishing year, or the deadline might be the same for all fisheries (e.g. November 1 to take effect January 1 of the following year).
3. Target and incidental species expected to be harvested and discarded:
    a. For species regulated under a federal FMP, it is assumed all size limits, possession limits, and trip limits would still apply. The vessel would need to have a permit to fish under that FMP and comply with any limitations associated with the category of permit held, unless the special access program rules are different.
    b. For non-target/incidental species including corals and protected species, the application would need to specify a list of species that might be encountered and how catch of those species would be monitored and documented.
4. The vessel would need to be in good standing at the time the request is made. This means no open violations, must be current with reporting requirements, etc.
5. A description of any fishing gear to be used would be required. This would include roller gear or other sweep attachments on trawl vessels, number and size of traps in a string, type of line connecting traps in a string, etc. All gear would need to comply with existing regulations for use outside of coral areas.

3.6.2 Exploratory fishing

This alternative would implement an exploratory fishing program within some or all of the deep-sea coral zones. The objectives of an exploratory program would be as follows:

(1) To allow for exploration of the feasibility (technological, economic) of new fisheries
(2) To collect data that indicate whether the new fishery conflicts with coral conservation objectives

Steps in the exploratory fishing process would be as follows:

1. Apply for an exempted fishing permit and letter of authorization to conduct research/exploratory fishing
2. Document feasibility of the fishery including evidence that the fishery does not compromise coral conservation objectives
3. Longer term, as appropriate, add the target species to the list of special access program species via rulemaking

Which vessels? Presumably, any vessel could apply for an exploratory fishing permit, whether they were currently permitted to operate in regional fisheries or not.

Which areas? As above, the Council would need to determine where exploratory fishing activity would be allowed. Such activities could be authorized in all designated coral zones, or only in certain types of coral zones. For example, distinctions might be made between whether or not exempted/exploratory fishing is authorized in broad zones, discrete zones based on coral data and habitat suitability, and/or discrete zones based on habitat suitability only.

Operational requirements: When fishing under an exploratory fishing permit in a coral area, vessel operators could be subject to requirements, similar to those for special access fisheries, above. The Regional Administrator would have the discretion to grant exempted permits as he or she saw fit, but the Council could provide guidance as to the types of activities that they would consider appropriate.

1. Gear requirements
2. Seasonal requirements (again, probably not necessary)
3. Total amount of effort permitted
4. Move-along provision if any corals are caught
5. Coral retention requirement
6. Reporting requirements:
    a. Vessel monitoring system if equipped
    b. Scientific personnel or NEFOP observer
    c. Enhanced documentation of fishing location and catch. For each tow of mobile gear or set of fixed gear:
        i. Start and end location and depth of all tows
        ii. Catch weights by species, including target and non-target fishes and invertebrates identified to the lowest taxonomic level possible

Permit requirements: An application for an exempted fishing permit to conduct market research/exploration could include the following elements. Additional details about these elements are provided above in the special access program section. The Regional Administrator would maintain final discretion regarding the approval of exempted fishing permits. Table 2 contains additional information about exempted fishing permits and other types of research documents. While exploratory fishing activities would not constitute scientific research, some of the requirements of an exempted fishing permit application are appropriate to an exploratory fishing program within deep-sea coral zones.

1. Vessel identifying information and point of contact.
2. Must be filed by the application deadline.
3. Target and incidental species expected to be harvested and discarded:
    a. Species regulated under a federal FMP
    b. Non-target/incidental species including corals and protected species
    c. For target exploratory species not regulated under a federal FMP, the application would need to summarize all available information about the distribution of the species, provide a brief rationale as to why the species is of exploratory fishing interest, and whether or not the species would be retained for sale.
4. The vessel would need to be in good standing
5. A description of any fishing gear to be used

3.6.3 Research activities

Finally, a third category of activities that might occur in corals zones is scientific research. This type of work would need to fall under the definition of scientific research (see below) and a letter of acknowledgement (distinct from a letter of authorization) would be required. A letter of acknowledgement would be useful to help NMFS and the Council keep track of research activities that may be occurring in coral zones, the results of which could benefit future management decisions.

Description of research-related documents currently issued

Presently, four types of documents are issued by the Northeast Regional Office to vessels participating in scientific research projects: an exempted fishing permit, a temporary possession permit, an exempted educational activity authorization, and/or a letter of acknowledgement (Table 2). Some or all of this information could be requested from special access program participants, exploratory fishing activities, or research activities.

Exemptions that are never granted in research context are exemptions from landing fish smaller than the minimum size limit, permit or reporting requirements, or quotas. Exemptions from these regulations would likely not be appropriate in coral areas, either. Also, exempted permits for research projects are not granted when the research objective is to develop a special access program within a closed area during specified peak spawning periods. This issue would not apply to exempted fishing in the coral zones. Finally, exemptions are never granted that would allow fishing by mobile bottom tending gear in a habitat closed area. An exemption program in coral areas would potentially need to be different in this regard.

In a research context, other types of exemptions are sometimes granted, but receive greater scrutiny. These include applications to fish in the parts of year round closed areas that are not habitat closures, outside of peak spawning periods; exemptions from DAS programs or limits; exemptions from trip or possession limits; exemptions from measures designed to reduce takes of protected species; and exemptions from landing but not selling fish below a minimum size. It doesn't seem that granting these types of exemptions would be necessary for vessels wishing to fish in coral zones.

Table 2 – Types of research documents issued by NERO. Summarized from Research Documentation: Exempted Fishing Permits, Temporary Possession Permits, Exempted Educational Activity Authorizations, and Letters of Acknowledgement. Updated 23 November 2010, available at http://www.nero.noaa.gov/permits/.

Exempted Fishing Permit: Authorizes a fishing vessel of the United States to conduct fishing activities that would be otherwise prohibited under the regulations at 50 CFR part 648 or part 697. Generally issued for activities in support of fisheries-related research, including seafood product development and/or market research, compensation fishing, and the collection of fish for public display. Anyone that intends to engage in an activity that does not meet the definition of scientific research but that would be otherwise prohibited under these regulations is required to obtain an EFP prior to commencing the activity.

Temporary Possession Permit: Temporary Possession Permits authorize a federally permitted fishing vessel that is accompanied by an eligible research technician to temporarily retain fish that are not compliant with applicable fishing regulations for the purpose of collecting catch data. Example regulations include minimum fish sizes, species under quota closures, and fish possession limits. All non-compliant fish are returned to the sea as soon as practicable following data collection.

Exempted Educational Activity Authorization: An EEAA is a permit issued to accredited educational institutions that authorize, for educational purposes, the target or incidental harvest of species managed under an FMP or fishery regulations that would otherwise be prohibited.

Letter of Acknowledgement: An LOA is a letter that acknowledges certain activities as scientific research conducted from a scientific research vessel. Scientific research activities are activities that would meet the definition of fishing under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), but for the statutory exemption provided for scientific research. Such activities are exempt from any and all regulations promulgated under the Magnuson-Stevens Act, provided they continue to meet the definition of scientific research activities conducted from a scientific research vessel. Although the LOA is not required for scientific research, obtaining an LOA serves as a convenience to the researcher, the vessel(s), NMFS, the NOAA Office of Law Enforcement, and the U.S. Coast Guard, to establish that the activity is indeed exempt from the provisions of the Magnuson-Stevens Act.

To meet the definition of a scientific research vessel, the vessel must be conducting a scientific research activity and be under the direction of an appropriate group, e.g. a government agency, university or accredited educational institution, etc.

Scientific research activity includes, but is not limited to sampling, collecting, observing, or surveying the fish or fishery resources within the EEZ. Research topics include taxonomy, biology, physiology, behavior, disease, aging, growth, mortality, migration, recruitment, distribution, abundance, ecology, stock structure, bycatch or other collateral effects of fishing, conservation engineering, and catch estimation of fish species considered to be a component of the fishery resources.

3.6.4 Allow changes to exemption fishery requirements via framework adjustment

This alternative would allow changes to exemption programs, such as permit and observer requirements, and move-along provisions, via framework adjustment.

4 Considered and rejected alternatives

In June 2015, the MAFMC approved coral management zones for their region through Amendment 16 to the Atlantic Mackerel/Squid/Butterfish FMP, and a proposed rule for this action was published in September 2016. Earlier versions of the NEFMC alternatives, developed prior to intiation of the MAFMC amendment, included areas with the MAFMC region. The NEFMC coral zone alternatives were modified to remove areas south of the NEFMC/MAFMC boundary, including the Mey-Lindenkohl slope, Baltimore Canyon, Norfolk Canyon, Emery Canyon, Hudson Canyon, Toms Canyon, Lindenkohl Canyon, Wilmington Canyon, Accomac Canyon, and Washington Canyon.

A broad coral zone with a landward boundary based on the 200 m depth contour was considered by the Habitat Committee and rejected, due to concerns about potential fishery impacts of a zone extending into these relatively shallower depths.

Larger discrete coral zones in the Gulf of Maine were not recommended for further analysis at the April 6, 2012 Committee meeting:

- An expanded version of the Mt Desert Rock zone that extended into similar depths and habitats, and also included some shallower areas within state waters
- Larger areas combining areas 1 and 2 and areas 3 and 4 in Western Jordan Basin, that would have encompassed a wider range of deeper and shallower habitat types

The PDT evaluated the following additional canyon and slope areas as possible discrete coral zones, but did not recommend zones in these areas to the Habitat Committee. The Committee concurred with the PDT's assessment and did not ask for further analysis of these options at their February 23, 2012 meeting. Note that some of these canyons are in the mid-Atlantic region, and were later evaluated by the MAFMC and their coral FMAT. Some were later reconsiderd by the PDT given additional coral exploratory survey data.

- Slope near U.S. – Canadian border
- Slope between Veatch and Hydrographer Canyons
- Slope west of Alvin and Atlantis Canyons
- Slope area between Baltimore and Accomac canyons
- Canyons not recommended based on GIS analysis: Chebacco, Filebottom, Sharpshooter, Dogbody, Shallop, Nantucket, Atlantis, Block, McMaster, Ryan Canyon, Uchupi, and Spencer Canyons
- Canyons not recommended, did not incise shelf enough to conduct GIS analysis: Clipper, South Wilmington, North Heys, South Vries, Warr, Phoenix, and Leonard Canyons

Between December 2015 and February 2016, the PDT evaluated updated data for the New England canyons and recommended adding some previously rejected areas to the list of discrete zones. These included Chebacco, Filebottom, Sharpshooter, Dogbody, Nantucket, and Atlantis Canyons. These recommendations were adopted by the Committee (March 2016) and Council (April 2016) for analysis. Shallop Canyon may have coral habitats, but is the only named canyon in the New England region that was not recently studied using ROV or towed camera to positively document coral presence. Therefore, the PDT did not recommend development of a Shallop Canyon coral zone. Shallop Canyon does lie within the broad zone alternatives. Slope areas between the discrete canyon zones, including those listed above are also encompassed within the broad zone alternatives. The Baltimore/Accomac slope in the Mid-Atlantic is part of the Mid-Atlantic Fishery Management Council's broad zone proposals.

5 Description of the affected environment

The purpose of this section is to provide background information that will inform analysis of impacts of the alterntaives proposed in this amendment.

5.1 Physical setting

These two sections describe the oceanographic and geological features of the Gulf of Maine, continental slope, canyons, and seamounts. These descriptions place coral habitats within these locations in context.

5.1.1 Gulf of Maine

The Gulf of Maine is an enclosed coastal sea, bounded on the east by Browns Bank, on the north by the Nova Scotian Shelf, on the west by the New England states, and on the south by Cape Cod and Georges Bank. The Gulf of Maine is glacially derived, and is characterized by a system of deep basins, moraines and rocky protrusions with limited access to the open ocean. This geomorphology influences complex oceanographic processes that in turn produce a rich biological community.

The Gulf of Maine's geologic features, when coupled with vertical variations in water properties, result in a great diversity of habitat types. There are twenty-one distinct basins separated by ridges, banks, and swells. The three largest basins are Wilkinson, Georges, and Jordan. Depths in the basins exceed 250 m, with a maximum depth of over 350 m in Georges Basin which is just north of Georges Bank. The Northeast Channel between Georges Bank and Browns Bank leads into Georges Basin, and is one of the primary avenues for exchange of water between the Gulf of Maine and the North Atlantic Ocean.

Four locations in the Gulf of Maine have been found to contain deep-sea coral habitats. These include rocky areas south of Mt. Desert Island, the Outer Schoodic Ridge, which runs southwest to northeast approximately 20 nm offshore the eastern Maine coast, various sites in Jordan Basin, and Lindenkohl Knoll along the western edge of Georges Basin.

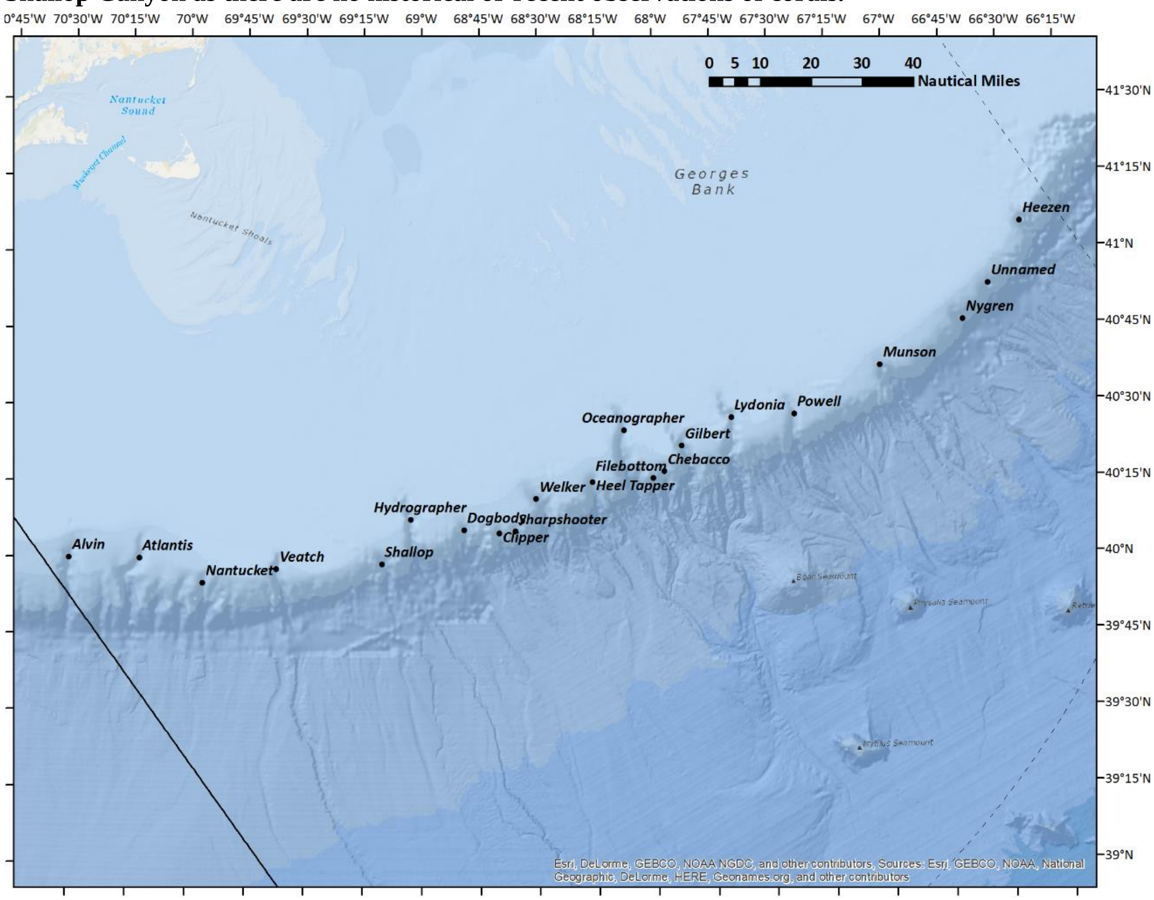
5.1.2 Continental slope, canyons, and seamounts

The continental slope extends from the continental shelf break, at depths between 60-200 m, eastward to a depth of 2000 m. The width of the slope varies from 10-50 km, with an average gradient of 3-6°; however, local gradients can be nearly vertical. The base of the slope is defined by a marked decrease in seafloor gradient where the continental rise begins. The morphology of the present continental slope appears largely to be a result of sedimentary processes that occurred during the Pleistocene, including, 1) slope upbuilding and progradation by deltaic sedimentation principally during sea-level low stands; 2) canyon cutting by sediment mass movements during and following sea-level low stands; and 3) sediment slumping.

Sediments become progressively finer with increasing depth and distance from land, although in some areas submarine canyons channel coarser sediments onto the continental slope and rise. A "mud line" occurs on the slope at a depth of 250-300 m, below which fine silt and clay-size particles predominate. Localized coarse sediments and rock outcrops are found in and near canyon walls, and occasional boulders occur on the slope because of glacial rafting. Sand pockets may also be formed because of downslope movements. Gravity induced downslope movement is the dominant sedimentary process on the slope, and includes slumps, slides, debris flows, and turbidity currents, in order from thick cohesive movement to relatively nonviscous flow. Slumps may involve localized, short, down-slope movements by blocks of sediment. However, turbidity currents can transport sediments thousands of kilometers.

The slope is cut by at least 70 large canyons between Georges Bank and Cape Hatteras and numerous smaller canyons and gullies, many of which may feed into the larger canyon systems. Map 36 shows the canyons in the New England region. Submarine canyons are not spaced evenly along the slope, but tend to decrease in areas of increasing slope gradient. Canyons form by erosion of the sediments and sedimentary rocks of the continental margin. They can be classed as high or low relief. Canyons with high relief that are deeply eroded into the continental margin may be U-shaped or V-shaped.

Map 36 – Canyons of the New England region. Note that a discrete zone is not recommended in Shallop Canyon as there are no historical or recent observations of corals.



Erosion by glaciers produces U-shaped canyons. These include canyons in Canadian waters in the glacially-eroded Northeast Channel that separates Georges Bank and the Scotian Shelf, but these areas are not under consideration for management in this action. Erosion by rivers, mass wasting, and turbidity currents produces V-shaped canyons.

These include the canyons on the southern margin of Georges Bank. These canyons did not experience direct glacial erosion because the glaciers terminated on the bank's northern margin. These V-shaped canyons contain the following sediment types:

- Gravel in canyons that was transported by floating ice
- Outcropping rocks exposed on canyon walls
- Rock rubble on canyon walls and floor from rock falls
- Stiff Pleistocene clay exposed on canyon walls; burrowed by crabs and fish to form "pueblo villages"; burrowed clay can collapse to form rubble on canyon walls and floors
- Veneer of modern sediment partly covering canyon walls
- Modern sediment covering canyon floors
- Modern sand transported onto the canyon floor from the shelf can be formed into bedforms by strong tidal currents in some canyons

Canyons shallowly eroded into the continental margin are produced by erosion/mass wasting events such as slumping or landslides. These types of shallow canyons are found on the shelf edge and upper slope of the southern margin of Georges Bank. Shallow canyons are less likely than deep canyons to have a well-defined canyon axis and floor, and because their walls are not steep, they are less likely than deep canyons to have outcropping rocks. They may contain the following sediment types:

- Gravel in canyons that was transported by floating ice
- Veneer of modern sediment covering canyon walls

Inter-canyon areas on the southern margin of Georges Bank are gently sloping seabed between canyons on the continental slope. They are characterized by both erosional (mass wasting) and depositional processes. Sediment types include:

- Gravel that was transported by floating ice
- Modern sediment

The continental shelf edge (shelf-slope break) represents a transition from a gently sloping shelf (1-2 degrees) to a somewhat steeper continental slope (3-6) degrees, and from coarser-grained shelf sediment to finer-grained upper slope sediment. Sediment types include:

- Modern sediment
- Gravel that was transported by floating ice
- Pebble gravel substrate in areas where sandy sediment has been eroded.

Canyons can alter the physical processes in the surrounding slope waters. Fluctuations in the velocities of the surface and internal tides can be large near the heads of the canyons, leading to enhanced mixing and sediment transport in the area. Shepard et al. (1979) concluded that the strong turbidity currents initiated in study canyons were responsible for enough sediment erosion and transport to maintain and modify those canyons. Since surface and internal tides are ubiquitous over the continental shelf and slope, it can be anticipated that these fluctuations are important for sedimentation processes in other canyons as well. In Lydonia Canyon, Butman et al. (1982) found that the dominant source of low frequency current variability was related to passage of warm core Gulf Stream rings rather than the atmospheric events that predominate on the shelf.

The water masses of the Atlantic continental slope and rise are essentially the same as those of the North American Basin. Worthington (1976) divided the water column of the slope into three vertical layers: deepwater (colder than 4°C), the thermocline (4 - 17°C), and surface water (warmer than 17°C). In the North American Basin, deepwater accounts for two-thirds of all the water, the thermocline for about one-quarter, and surface water the remainder. In the slope water north of Cape Hatteras, the only warm water occurs in the Gulf Stream and in seasonally influenced summer waters. The principal cold water mass in the region is the North Atlantic Deep Water. North Atlantic Deep Water is comprised of a mixture of five sources: Antarctic Bottom Water, Labrador Sea Water, Mediterranean Water, Denmark Strait Overflow Water, and Iceland-Scotland Overflow Water. The thermocline represents a straightforward water mass compared with either the deepwater or the surface water. Nearly 90% of all thermocline water comes from the water mass called the Western North Atlantic Water. This water mass is slightly less saline northeast of Cape Hatteras due to the influx of southward flowing Labrador Coastal Water. Seasonal variability in slope waters penetrates only the upper 200 m of the water column.

In the winter months, cold temperatures and storm activity create a well-mixed layer down to about 100-150 m, but summer warming creates a seasonal thermocline overlain by a surface layer of low density water. The seasonal thermocline, in combination with reduced storm activity in the summer, inhibits vertical mixing and reduces the upward transfer of nutrients into the photic zone.

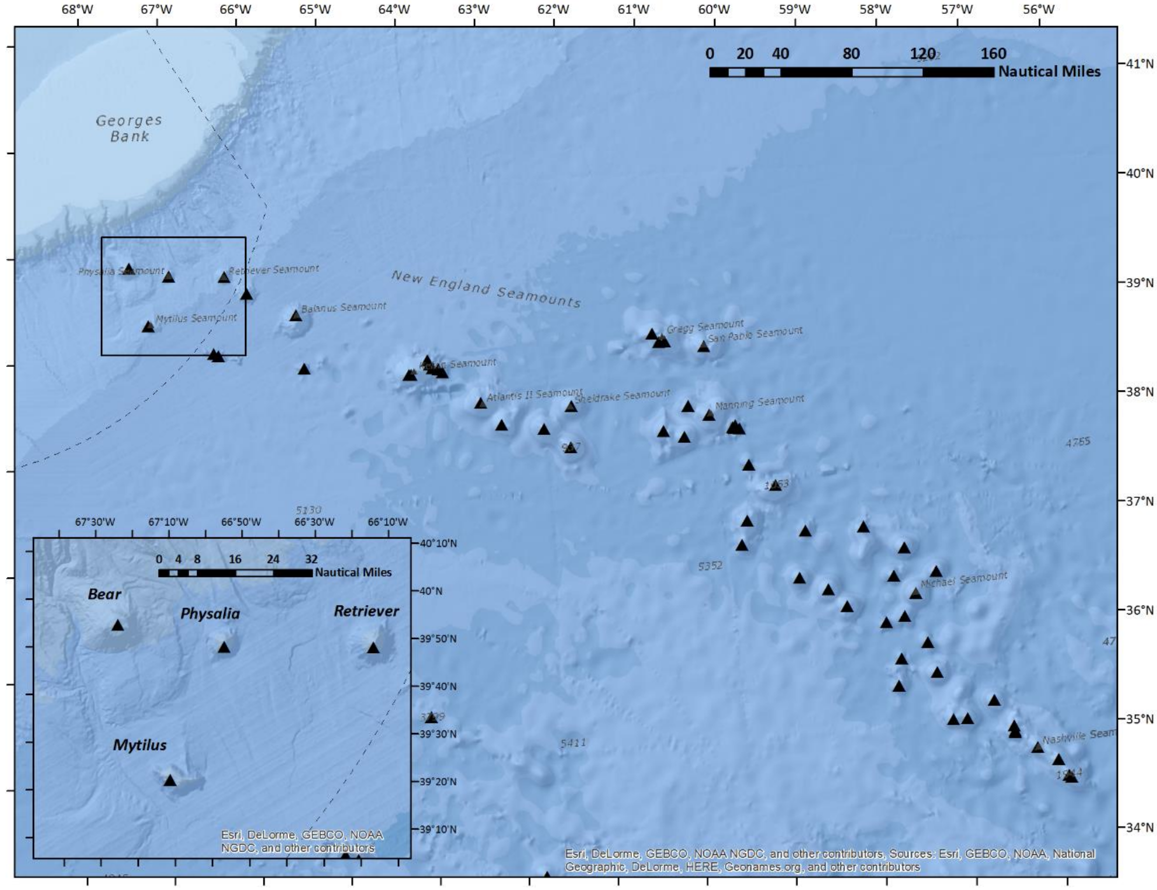
Two currents found on the slope, the Gulf Stream and Western Boundary Undercurrent, together represent one of the strongest low frequency horizontal flow systems in the world. Both currents have an important influence on slope waters. Warm and cold core rings that spin off the Gulf Stream are a persistent and ubiquitous feature of the northwest Atlantic Ocean. The Western Boundary Undercurrent flows to the southwest along the lower slope and continental rise in a stream about 50 km wide. The boundary current is associated with the spread of North Atlantic Deep Water, and it forms part of the generally westward flow found in slope water. North of Cape Hatteras it crosses under the Gulf Stream in a manner not yet completely understood.

Shelf and slope waters of the northeast region are intermittently affected by the Gulf Stream. The Gulf Stream begins in the Gulf of Mexico and flows northeastward at an approximate rate of 1 m/s (2 knots), transporting warm waters north along the eastern coast of the United States, and then east towards the British Isles. Conditions and flow of the Gulf Stream are highly variable on time scales ranging from days to seasons. Intrusions from the Gulf Stream constitute the principal source of variability in slope waters off the northeastern shelf.

The location of the Gulf Stream's shoreward, western boundary is variable because of meanders and eddies. Gulf Stream eddies are formed when extended meanders enclose a parcel of seawater and pinch off. These eddies can be cyclonic, meaning they rotate counterclockwise and have a cold core formed by enclosed slope water (cold core ring), or anticyclonic, meaning they rotate clockwise and have a warm core of Sargasso Sea water (warm core ring). The rings are shaped like a funnel, wider at the top and narrower at the bottom, and can have depths of over 2000 m. They range in size from approximately 150 - 230 km in diameter. There are 35% more rings and meanders near Georges Bank than in the Mid-Atlantic region. A net transfer of water on and off the shelf may result from the interaction of rings and shelf waters. These warm or cold core rings maintain their identity for several months until they are reabsorbed by the Gulf Stream. The rings and the Gulf Stream itself have a great influence over oceanographic conditions all along the continental shelf.

Seamounts are topographic rises of the seabed that are typically conical in shape, with circular, elliptical, or elongate bases (Yesson et al. 2011). They vary in terms of elevation above the seafloor, with larger features have a relief of over 1000 m above the adjacent seabed. Large seamounts are often volcanic in origin. Using a criterion of at least 1000 m height above the seafloor, Yesson et al. (2011) identified over 33,000 seamounts globally based on an analysis of 30 arc-second bathymetry data. The New England seamount chain (Map 37) includes four seamounts within the U.S. EEZ, and additional seamounts further east. Yesson et al. classified seamounts with summits shallower than 1,500 meters as middle-depth seamounts, noting that these features can interact with zooplankton that migrate diurnally in the water column (the deep scattering layer). Bear Seamount fall into this category. Mytilus, Physalia, and Retreiver Seamounts were classified as deep seamounts, as they are below the influence of the deep-scattering layer.

Map 37 – The New England Seamount Chain. The four seamounts within the U.S. EEZ are shown in the inset. Seamount locations (triangles) are from a global seamount identification study (Yesson et al. 2011).



5.2 Coral species of the New England region

This section describes the data sources used to characterize the coral fauna of New England, lists coral types and known species found in the region, and summarizes the species richness in particular locations, based on sampling conducted to date.

5.2.1 Data sources

Sources of information on coral species richness and distribution in New England include historical (pre-2012) physical and visual samples, as well as recent (2013-2015) visual exploratory surveys conducted with remoted operated vehicles and towed camera systems.

5.2.1.1 Historical records (2012 and earlier)

The primary sources of historical deep-sea coral records and observations in this region are discussed and referenced in Packer et al. (2007). These include geo-referenced presence records and non-geo-referenced presence records (i.e., “observations”). There is also a small amount of deep-sea coral density or abundance data. The Northeast deep-sea coral database, based largely on historical geo-referenced presence records from the late

1800s to the present, was updated 2007-2013 by incorporating taxonomic changes and adding "new" presence records gleaned from museum collection databases (e.g., the Smithsonian Institution's National Museum of Natural History collection, which includes records of coral taxa collected from various research surveys, 1873 through the present), other data mining activities, and the literature, including new records from the NOAA-Ocean Explorer "Mountains in the Sea" expeditions to the New England Seamounts. Additional records of sea pens (especially *Pennatula aculeata*) collected from 1956-1984 were compiled from various sources (e.g., Langton et al. 1990). Records of new species of soft corals, mostly from Bear and Retriever seamounts with some from the submarine canyons off New England (e.g., *Thouarella grasshoffi* Cairns 2006 from Bear Seamount and Oceanographer Canyon) were obtained from recently published literature (Cairns et al. 2007, Thoma et al. 2009, Pante and Watling 2011, Watling et al. 2011); new records of antipatharians were also obtained from recently published seamount literature (Thoma et al. 2009). The major coral data sets covered by this database are summarized in Table 3.

Although the historical database has been thoroughly vetted, it should be viewed with caution as only presence data are shown (i.e., there is no absence data) as all areas were not surveyed and some specimens were not identified. In the past, very little density or abundance data was available for deep-sea corals and sponges in this region. Results from the recent 2012-2105 surveys will be added to this database in time, and will include data on relative abundance.

Unlike NOAA's fish-focused trawl surveys, the various coral surveys tend to be of limited spatial extent, and the regional coverage of coral-related investigations is rather patchy. Although recent dives, which will be described below, cover many additional areas, and are a much more comprehensive inventory of coral habitats, this statement about limited spatial coverage is still true to a certain extent. Many locations remain lightly sampled, and have not been visited repeatedly over time as is the case with continental shelf trawl or dredge surveys.

Table 3 – Deep-sea coral data sources for the Northeast Region

Data set	Citation
Deichmann, 1936	Deichmann, Elisabeth, 1936, The Alcyonaria of the western part of the Atlantic Ocean: Memoirs of the Museum of Comparative Zoology at Harvard College, v. 53, 317 p.
Hecker et al., 1980, 1983	These reports were prepared for Minerals Management Service in the early 1980s. Several canyons and slope areas were surveyed via submersible and towed camera sled. Hecker, B., Blechschmidt, G., and Gibson, P. 1980. Epifaunal zonation and community structure in three mid- and north Atlantic canyons—final report for the canyon assessment study in the mid- and north Atlantic areas of the U.S. outer continental shelf: U.S. Department of the Interior, Bureau of Land Management Monograph, 139 p. Hecker, B., et al. 1983. Final Report – Canyon and Slope Processes Study. Prepared for U.S. Department of the Interior, Minerals Management Service. Contains three volumes: Vol. I, Executive Summary; Vol. II, Physical Processes; and Vol. III, Biological

Data set	Citation
	Processes.
NEFSC HUDMAP	Records from 2001, 2002, and 2004 video samples taken near the head of Hudson Canyon between 100-200 m depth. Corals sampled include the sea pen *Stylatula elegans* and the stony coral *Dasmosmilia lymani*.
NEFSC Sea Pens	Records of sea pens compiled from various sources, including submersible surveys, trawl surveys, and towed camera surveys. Data collected between 1956 and 1984.
NES CR Dives	These data summarize dives locations of samples collected during NOAA Ocean Explorer "Mountains in the Sea" cruises to the New England seamounts during 2003 and 2004.
Smithsonian National Museum of Natural History	Records off all coral types from various research vessel surveys conducted from 1873 through present. Surveys conducted in GOM as well as along shelf/slope break on Georges Bank and in Mid-Atlantic Bight.
Theroux and Wigley	Theroux, Roger B. and Wigley, Roland L., 1998, Quantitative composition and distribution of the macrobenthic invertebrate fauna of the continental shelf ecosystems of the northeastern United States. NOAA Technical Report NMFS 140: 240.
US Fish Commission	Records for *Dasmosmilia lymani* off NJ/VA; collected in the 1880s
VIMS for BLM/MMS	Mostly *Dasmosmilia lymani* records; fewer records of *Stylatula elegans*; records from mid-late 1970s; collected for Minerals Management Service by Virginia Institute of Marine Science
Watling et al, 2003	Watling, L., Auster, P.J., Babb, I., Skinder, C., and Hecker, B., 2003, A geographic database of deepwater alcyonaceans of the northeastern U.S. continental shelf and slope: Groton, National Undersea Research Center, University of Connecticut, Version 1.0 CD-ROM.
Yale University Peabody Museum Collection	Yale University Peabody Museum Collection, Yale Invertebrate Zoology—Online Catalog: accessed July 2007 at http://peabody.research.yale.edu/COLLECTIONS/iz/

5.2.1.2 Recent exploratory surveys (2013-2015)

Recent survey work includes towed camera, remotely operated vehicle (ROV), and autonomous underwater vehicle (AUV) dives conducted from 2012 to 2015 (Table 4). Different survey gears have distinct capabilities and advantages (Kilgour et al 2012). For example, AUVs have fewer support vessel needs as compared to ROVs, may be easier to deploy and retrieve, and can be used to survey a larger area more quickly. While ROVs, towed camera sleds, and manned submersibles require additional vessel support and move more slowly than AUVs, they can be used to study areas at a very fine spatial scale and collect physical samples. With the exception of the 2012 cruise on Physalia Seamount, which used AUV technology, all of the recent cruises used either towed camera systems or ROVs. Because so much data is gathered during each dive, detailed analyses of many of these dives are still in progress, but high level classifications of geological and biological habitats are presently available[3] to inform management

[3] Initial analysis of cruise HB1402 (R/V Bigelow, ROPOS system) is still in progress.

decisions. Dive locations were often selected by identifying topographic features of interest on maps generated from high-resolution multibeam bathymetric maps or side-scan sonar data.

Table 4 – Recent deep-sea coral oriented cruises within the New England region

Year	Cruise Dates	Cruise Number	Research Vessel	Gear	Number of tows[4]	Locations
2012	5-6 Oct		Scarlett Isabella	REMUS 6000 AUV	2	Physalia Seamount
2012	7-17 Jul	HB1204	Bigelow	TowCam	11	Veatch Canyon (3), Gilbert Canyon (8)
2013	11-24 Jul	ISIS2_2013	Connecticut	ISIS2	40	Western Jordan Basin (18), Blue Hill Bay (3), Monhegan (5), Schoodic Ridges (9), Sommes Sound (4), test tow of tethering system
2013	9-23 Jun	HB1302	Bigelow	TowCam	16	Powell Canyon (6), Munson Canyon (7), minor Canyon between Powell and Munson (2), Munson-Powell intercanyon area (1)
2013	8-25 Jul	EX1304L1	Okeanos	D2	12	Alvin Canyon (2), Atlantis Canyon (2), Hydrographer Canyon (2), NE Seep2 (1), NE Seep3 (1), USGS Hazard 2 (1), USGS Hazard 4 (1), NE Seep (1), Veatch Seeps (1)
2013	31 Jul-16 Aug	EX1304L2	Okeanos	D2	14	Heezen Canyon (2), Lydonia Canyon (1), Lydonia-Powell intercanyon area (1), Mytilus Seamount (2), Nygren Canyon (2), Nygren-Heezen intercanyon (1), Oceanographer Canyon (2), Minor canyon next to Shallop Canyon (1), Welker Canyon (1), USGS Hazard 5 (1)
2014	23 Jul-6 Aug	K2_2014	Connecticut	Kraken 2	21	Outer Schoodic Ridge (8), western and central Jordan Basin (11), Stellwagen Bank (1), Wilkinson Basin (1)
2014	18 Jun-1 Jul	HB1402	Bigelow	ROPOS	7	Nygren Canyon (2), Heezen Canyon (3), minor Canyon btw Nygren and Heezen (1), Jordan Basin (1)
2014	23 Sep-6 Oct	EX1404L3	Okeanos	D2	4	Nantucket Canyon (1), Physalia Seamount (1), Retriever Seamount (1), unnamed canyon east of Veatch (1)

[4] Number of tows = number of tows in New England locations only; some cruises included tows in the Mid-Atlantic region or in Canadian waters

Year	Cruise Dates	Cruise Number	Research Vessel	Gear	Number of tows[4]	Locations
2015	1-10 Jul	ISIS2_2015	Connecticut	ISIS2	26	Outer Schoodic Ridge (4), Mount Desert Rock (4), Georges Basin and Lindenkohl Knoll (9), West Wilkinson Basin (5), Stellwagen Bank (1), Chandler Bay (3)
2015	27 Jul-7 Aug	HB1504	Bigelow	TowCam	23	Dogbody Canyon (3), Chebacco Canyon (5 – dives 4 and 5 repeated), Heel Tapper (3), Filebottom Canyon (4 – dive 8 repeated), Sharpshooter Canyon (2), Welker Canyon (4 – dive 15 repeated), Clipper Canyon (2)

Recent (2013-2015) surveys have greatly expanded our knowledge of coral species richness and distribution in both the New England and Mid-Atlantic. While some abundance data are collected during these efforts, these surveys should be considered exploratory, and are different in their design from surveys used to assess populations and generate biomass estimates. Despite the relatively large number of cruises and dives conducted, many areas of the canyons, seamounts, and Gulf of Maine remain unexplored. Thus, survey results, combined with terrain data and suitability model outputs, are the best way to understand the distribution of corals in the region.

In order to guide survey efforts, and better understand the seafloor terrain in the region, the Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) program was developed to generate integrated, coherent digital terrain model for the Atlantic shelf/slope region. Between February and August 2012, the research vessels *Ferdinand R. Hassler* and *Okeanos Explorer* collected high-resolution bathymetry data that was quickly processed into mapping products. The data from this project are used throughout this amendment in mapping and analysis.

The 2012 ACUMEN field efforts finished with a July survey aboard the *Henry B. Bigelow* (HB1204). Overall goals of the *Bigelow* mission were to survey and ground-truth known or suspected deep-sea coral habitats associated with the submarine canyons off the edge of the Northeastern U.S continental shelf/slope, and included (1) characterizing benthic habitats and identifying areas where deep-sea corals and sponges were present; (2) initial ground-truthing of areas predicted to be coral "hotspots" based on data and outputs provided from the deep-sea coral habitat suitability model; (3) ground-truthing newly collected high resolution (25-50 m) continental slope bathymetric maps created from the multibeam data collected during the ACUMEN cruises; and, (4) ground-truthing historical deep-sea coral records. Using the Woods Hole Oceanographic Institution's (WHOI) towed camera system (*TowCam*), three main canyon areas were targeted, including Veatch and Gilbert Canyons off New England and the rim of an un-named canyon northeast of Veatch. Gilbert Canyon in particular was identified as a deep-sea coral "hotspot" by the habitat suitability model; all three main canyon areas were either under-explored or unknown with regards to deep-sea coral and sponge occurrences.

There were 18 *TowCam* tows and over 38,600 high resolution photos that were taken at 10 second intervals during a dive along with concurrent sampling of environmental data (e.g. depth, temperature, salinity) to characterize benthic and deep-sea coral/sponge habitats. Each bottom image was visually screened for corals, sponges, and fish fauna. Presence/absence information was logged for each image using I-view Media Pro through which data catalogues indicating faunal occurrences were constructed.

These initial survey efforts were an important precursor to the 2013-2015 NOAA Deep Sea Coral Research and Technology Program (DSCRTP) Northeast fieldwork initiative. The overall purpose of the initiative was to locate, survey, and characterize deep-sea coral and sponge communities in this region. The work was guided by the Northeast Fieldwork Planning Team and implemented by NOAA scientists in collaboration with other NOAA line offices, other government agencies (including the Canadian Department of Fisheries and Oceans), and researchers from academic institutions. The major objectives included:

- Assisting resource managers by characterizing the deep-sea coral and sponge ecosystems and determining the distribution, abundance, and diversity of deep-sea corals/sponges in select areas of the continental slope, including the submarine canyons, the seamounts within the EEZ, and select areas of the Gulf of Maine where major structure forming corals/sponges may or were known to exist. Establishing the spatial extent of corals/sponges in these areas, their scales of patchiness, and correlation with substrate features.
- Collecting specimens, where possible, for taxonomic analyses, age and growth studies, genetic analyses, and reproduction studies.
- Using the deep-sea coral/sponge survey and distribution data to refine the next iterations of the Northeast's deep-sea coral habitat suitability model; conversely, the model would assist in choosing survey sites and thus be continuously "field tested" and ground-truthed.
- Continuing collaborative work with other NOAA line offices (OER, OCS) to obtain high resolution multibeam maps and data of the Northeast shelf, slope, and seamounts where corals/sponges are known to or may occur.
- Assisting the NEFSC groundfish and shellfish surveys and the Observer Program in better identifying and quantifying their deep-sea coral and sponge bycatch.

By combining DSCRTP resources with other partners within and outside of NOAA, leveraging funding, and employing a wide range of research tools, the initiative advanced deep-sea coral science and management through three major fieldwork projects.

1. Surveys and exploration of coral/sponge habitats in submarine canyons, slope areas, and seamounts off New England and the Mid-Atlantic.
2. Characterizations of seafloor communities in the U.S. and Canadian cross-boundary Gulf of Maine region and on the U.S. and Canadian continental margin.
3. Surveys of northern Gulf of Maine (U.S.) habitat areas for deep-sea corals and sponges. Includes collecting specimens of the common sea pen (*Pennatula aculeata*) to determine if they are being used by fish larvae (perhaps redfish,

Sebastes spp.) as nursery habitat, as has been observed in Canada (Baillon et al. 2012).

Surveys off New England and the Mid-Atlantic occurred every summer from 2013-2015, targeting areas in and around submarine canyons and on Mytilus seamount. Using the FSV *Bigelow* with the towed camera system *TowCam*, scientists collected still images from all major and some minor canyons not previously surveyed by the other recent expeditions. Because of the large amount of images collected during each dive, detailed analyses of most of the surveys are still in progress, although higher level classification of biological habitats are available.

Cruise HB 1302 (2013) covered Munson and Powell Canyons off New England. Also that summer, 31 ROV dives (494-3271 m) over two cruises were conducted from the NOAA Ship *Okeanos Explorer* (Cruise EX 1304, Legs 1 and 2). A variety of broad-scale habitat features, including 11 canyons in both the New England and Mid-Atlantic regions (Heezen, Nygren, Lydonia, Oceanographer, Welker, Hydrographer, Atlantis, Alvin, Block, two un-named canyons), open areas on the continental slope and intercanyon areas, Mytilus Seamount, and three cold seeps (1053–1484 m) were surveyed (Fig. 4, Table 1). The ROV transects ranged from 300 to 2200 m in length.

During September and October 2014, the NOAA R/V *Okeanos Explorer* surveyed two seamounts off New England and several canyons off both New England and the Mid-Atlantic (Cruise EX 1404, “Our Deepwater Backyard”). Sixteen ROV *Deep Discoverer* dives were conducted, and high-resolution multibeam sonar data covering 36,200 km^2 of seafloor was collected. Full descriptions of the dives can be found at: http://oceanexplorer.noaa.gov/okeanos/explorations/ex1404/welcome.html. The areas surveyed off New England included Physalia and Retriever Seamounts (see seamount section below), Nantucket Canyon, and an un-named, minor canyon east of Veatch Canyon. Cruise HB 1404 surveyed mid-Atlantic areas only. During Cruise HB 1504, seven New England minor canyons were surveyed; most had not been previously explored.

NOAA scientists collaborated with Canadian academic partners and Canada’s Department of Fisheries and Oceans to characterize coral communities in the cross-boundary Gulf of Maine region and continental margin in 2014. This international collaboration and information sharing enabled the U.S. and Canadian science teams, each with limited resources, to establish a better understanding of our shared waters in the Gulf of Maine and along the continental margin and slope. Using the Canadian ROV *ROPOS* aboard FSV *Bigelow*, the project team collected videos, photos, and coral samples from Nygren and Heezen canyons and a minor canyon between the two in U.S. waters; Corsair Canyon and the Northeast Channel Coral Conservation Area in Canada; and both sides of the international boundary (Hague Line) in Central Jordan Basin, Gulf of Maine. While analyses of the images and samples are still in progress, initial analyses of the videos and images show diverse and abundant corals in Nygren and Heezen Canyons. Given the significant deep-sea coral discoveries documented by ROV *Deep*

Discoverer in 2013, the objective here was to increase both geographic and bathymetric coverage within each canyon.

While much of the analysis of these cruises remains ongoing, the results of the 2013 Okeanos Explorer survey have been published (Quattrini et al. 2015). At least 58 taxa of deep-sea corals were noted, and at least 24 of these had not been documented in this region previously. The type of broad-scale habitat feature and high habitat heterogeneity in this region was an important factor that influenced coral assemblages. Quattrini et al. (2015) found no significant differences between deep-sea coral assemblages between the two different types of canyons (continental shelf-breaching canyons vs. canyons confined to the continental slope), but did find lower diversity and different faunal assemblages at cold seeps and soft bottom open slope sites. The canyons often had large patches of deep-sea coral habitat, which also included bivalves, anemones, and sponges. Stony (e.g., *Desmophyllum*, *Solenosmilia*, *Lophelia*) and soft corals were often abundant on long stretches of canyon walls and under and around overhangs. Coral communities were uncommon on the open slope, except on the channel floor of Veatch Canyon where sea pens and bamboo corals in soft sediments were frequently observed. Corals and sponges were also observed on boulders and outcrops in some open slope and intercanyon areas. At Veatch seeps and the canyon wall adjacent to the seep community in Nygren Canyon, soft corals and stony cup corals (*Desmophyllum*) were found attached to authigenic carbonates. Mytilus Seamount is discussed in the section below.

Quattrini et al. (2015) also found that depth was a significant factor influencing the coral assemblages. Although species richness did not change significantly with depth over the range explored by the surveys (494-3271 m), species composition changed at ~1600-1700 m. Species composition in the canyons and other areas with hard substrates were significantly dissimilar across this depth boundary. Stony and the soft corals *Anthothela* spp., *Keratoisis* sp. 1, and *Paragorgia arborea*, occurred at depths < 1700 m, whereas chrysogorgiids and sea pens were more common at depths >1700 m. Overall, depth, habitat, salinity and DO explained 71% of the total variation observed in coral assemblage structure (Quattrini et al. 2015).

Deep-sea corals in the Gulf of Maine have been reported since the 19th century, both as fisheries bycatch and from naturalist surveys. While at one time they may have been considered common on hard bottoms in the region, after a century of intensive fishing pressure using mobile bottom gear such as trawls and dredges as well as fixed gear such as lobster traps, substantial concentrations of deep-sea corals are now confined to small areas where the bottom topography makes them mostly inaccessible to these fisheries (Auster 2005; Watling and Auster 2005; Cogswell et al. 2009, Auster et al. 2013). Previous studies in the Gulf of Maine region, especially Canadian research, do show that deep-sea corals have a patchy distribution controlled by environmental factors such as slope, sediment, current, temperature and depth. Nevertheless, the information needed to assess their overall status in the U.S. Gulf of Maine has been lacking or incomplete, and there is inadequate information on deep-sea distribution in relation to habitat and landscape features, abundance, natural history, associated species, and human impacts.

Therefore, the goals of 2013-15 Gulf of Maine exploratory surveys, undertaken in partnership with the Universities of Connecticut and Maine, included:

- Delineating the spatial extent of deep-sea coral habitats at depths around 200 m in and around the proposed management areas;
- Characterizing deep-sea coral community structure and composition, including the abundance, density, size and size classes of coral;
- Documenting fauna found near or associated with the coral and their habitats, especially commercially important/federally managed fish and shellfish species;
- Collecting specimens for taxonomy, reproductive analyses, aging/growth, and genetics;
- Documenting anthropogenic impacts to these habitats;
- Using the survey results to directly inform the NEFMC deep-sea coral management alternatives process.

Previous deep-sea coral exploratory surveys and seafloor mapping in the region guided the selection of survey sites in 2013. Initial deep-sea coral surveys using ROVs in 2002 and 2003 documented a limited number of locations in Western Jordan Basin and around Mount Desert Rock with dense coral garden communities at around 200 m (Auster 2005, Watling and Auster 2005). Deep-sea corals were found on rocks, boulders, ridges and walls extending above the surrounding fine-grained sediments. During a cruise aboard the NOAA Ship *Ronald H. Brown* during 2005, preliminary multibeam bottom sonar data was collected in Western Jordan Basin and revealed that hard bottom in the immediate area around one of the sites surveyed for corals in 2002-2003 (known as "114 Bump") was more spatially extensive than previously suspected, thus implying more potential deep-sea coral habitat.

In 2013-2015, two different camera platforms on the R/V *Connecticut* were used to assess the presence and composition of coral communities in the Gulf of Maine: the towed camera sled ISIS2 (2013, 2015) and ROV Kraken 2 (2014); both systems had hi-definition still and video cameras, with the ROV having the additional ability to collect specimens. For the 2013 survey, using a bathymetric map created from the 2005 multibeam bottom sonar data and a detailed bathymetric chart of the Jordan Basin-Mount Desert Rock-Schoodic Ridge regions (Fisheries and Oceans Canada LC 4011), areas of steep topographies in depth ranges where corals were expected to occur (around 200 m) were selected for exploration. Thirty-five ISIS camera tows were conducted in four areas: Western Jordan Basin, near Mount Desert Rock, on Outer Schoodic Ridge, and off Monhegan Island.

High quality multibeam data were collected in the region after the initial 2013 survey. Maps of the two primary survey areas, Western Jordan Basin and Outer Schoodic Ridge, were produced during a collaborative effort with the Ecosystem Monitoring group of the NEFSC and NOAA's Office of Exploration and Research during the fall 2013 ecosystem monitoring cruise aboard the NOAA ship *Okeanos Explorer*. A map of a Central Jordan Basin dive site, next to the U.S.-Canada boundary, was also produced during the June 2014 joint U.S.-Canadian deep-sea coral cruise on the FSV *Bigelow*. Selection of ROV dive locations in 2014 was based on topographic features shown in these detailed maps. Based on these data, 18 ROV dives in 2014 re-explored areas in Western Jordan Basin and Outer Schoodic Ridge, along with one dive in Central Jordan Basin near and north of the U.S./Canadian dive site; collections of specimens were also made by the ROV.

For 2015, merged bathymetric data (combined regional hydrographic survey data and site specific multibeam coverages) for the larger Gulf of Maine region at a finer scale then available on bathymetric charts, along with resultant slope maps, facilitated exploration in areas beyond existing multibeam in Western Jordan Basin and Outer Schoodic Ridge regions. An area was also surveyed on the northern edge of Georges Bank, down into Georges Basin, where corals had been previously seen during a 1995 submersible survey of seafloor geology.

5.2.2 Species richness

Cold-water or deep-sea corals in the northwest Atlantic are a diverse assortment of two Anthozoan subclasses. The subclass Hexacorallia (Zoantharia) includes the hard or stony corals (order Scleractinia) and the black corals (order Antipatharia), and the subclass Octocorallia (Alcyonaria or octocorals) includes the true soft corals and gorgonians (order Alcyonacea) as well as the sea pens (order Pennatulacea). Some taxonomists have assigned the gorgonians to a separate order, Gorgonacea, but they are often combined, and that convention is adopted in this document (Bayer 1981, Daly et al. 2007; McFadden et al 2010). “Octocorals” is an umbrella term for the true soft corals, gorgonians, and sea pens, but is avoided here because the soft corals and gorgonians are generally distinct from the sea pens in terms of their habitat preferences, morphology, and their susceptibility to fishing gear impacts. Coral taxonomy is an active field of research, and continues to evolve as additional voucher specimens are collected and genetic analyses allow for discrimination between morphotypes.

The following four sections describe the species richness of corals in New England, grouped by taxonomic order. Some of these species are only recently known to occur in the region because of the recent exploratory surveys, while others are documented in the various historical datasets. Notes about taxonomy: in the tables below, the genus and species names are listed in italics. The abbreviation ‘sp.’ indicates that the listed coral belongs to the genus noted, but that the species is uncertain; “spp.” indicates it may be one of several species. Names following the species and genus refer to the author who first identified the species. When this name is in parentheses, the species name has been changed since the original identification. A question mark preceding the genus or species name indicates that the identification at this taxonomic level although uncertain, is probable. Species that thus far have only been found or described from the Mid-Atlantic region are not included in these tables.

5.2.2.1 True soft corals and gorgonians (Order Alcyonacea)

Along with the sea pens, which belong to a different taxonomic order and are discussed separately below, true soft corals and gorgonians are members of the subclass Octocorallia. The octocorals have polyps that are are subdivided into eight mesenteries, or spaces, each of which gives rise to a tentacle (Watling et al. 2011). Combining both types of corals together, eleven families are represented in New England: Acanthogorgiidae, Alcyoniidae, Anthothelidae, Chrysogorgiidae, Clavulariidae, Corallidae, Isididae, Nephtheidae, Paragorgiidae, Plexauridae, and Primnoidae. All of the species in these families are colonial (Watling et al. 2011). Table 5 lists true soft corals and gorgonians found in the New England region, by family affiliation. A more detailed version of this table that shows species in both the New England and Mid-Atlantic regions is found in Packer et al. (in review).

These corals exhibit a variety of forms. True soft corals in the family Clavulariidae grow from ribbon-like stolons, while those in the families Alcyoniidae and Nephtheidae are fleshy, and lack an axial skeleton. Many of their relatives are found in shallow reef environments. True soft corals in the families Anthothelidae, Corallidae, and Paragorgiidae have an axial skeleton composed of sclerites. Gorgonian corals in the families Acanthogorgiidae, and Plexauridae have a fan-like shape, with an organic central axis that has varying amounts of calcareous material, while those in the families Chrysogorgiidae, Isididae (bamboo corals), and Primnoidae are also fan-shaped, but have a solid axis comprised of large amounts of calcareous material.

Watling and Auster (2005) noted two distinct distributional patterns for alcyonaceans. Most are deepwater species that occur at depths > 500 m; these include corals in the genera *Acanthogorgia*, *Acanella*, *Anthomastus*, *Anthothela*, *Clavularia*, *Lepidisis*, *Radicipes*, and *Swiftia*. Others occur throughout shelf waters to the upper continental slope and include *Paragorgia arborea*, *Primnoa resedaeformis*, and species in the genus *Paramuricea*.

Table 5 – True soft corals and gorgonians (Order Alcyonacea) of the New England region.

Family	Species	References
Acanthogorgiidae	*Acanthogorgia armata* Verrill, 1878	Hecker and Blechschmidt 1980; Hecker et al. 1980; Opresko 1980; Malahoff et al. 1982; Watling and Auster 2005; Watling et al. 2011; Auster et al. 2013, 2014; Quattrini et al. 2015
Alcyoniidae	*Alcyonium digitatum* Linné, 1758	Watling and Auster 2005, Watling et al. 2011
	Anthomastus agassizii Verrill, 1922	Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Opresko 1980; Valentine et al. 1980; Maciolek et al. 1987a; Hecker 1990; Moore et al. 2003; Watling and Auster 2005, Watling et al. 2011
	Anthomastus grandiflorus Verrill, 1878	Hecker and Blechschmidt 1980; Hecker et al. 1980; Opresko 1980; Watling and Auster 2005, Watling et al. 2011
	Anthomastus (sp.?)	Quattrini et al. 2015
Anthothelidae	*Anthothela grandiflora* (Sars, 1856)	Hecker et al. 1980; Opresko 1980; Watling and Auster 2005

Family	Species	References
Chrysogorgiidae	*Chrysogorgia tricaulis* Pante and Watling, 2011	Thoma et al. 2009, Pante and Watling 2011
	Chrysogorgia sp.	Quattrini et al. 2015
	Metallogorgia melanotrichos (Wright and Studer, 1889)	Mosher and Watling 2009; Thoma et al. 2009; Watling et al. 2011; Quattrini et al. 2015
	Iridogorgia pourtalesii Verrill, 1883	Watling and Auster 2005
	Radicipes gracilis (Verrill, 1884)	Moore et al. 2004; Watling and Auster 2005; Thoma et al. 2009
Clavulariidae	Stoloniferan sp. 1 (yellow) [Family Clavulariidae?]	Quattrini et al. 2015
	Stoloniferan sp. 2 (white) [Family Clavulariidae?]	Quattrini et al. 2015
	Clavularia modesta (Verrill, 1874)	Watling and Auster 2005
	Clavularia rudis (Verrill, 1922)	Hecker and Blechschmidt 1980; Hecker et al. 1980; Opresko 1980; Watling and Auster 2005
Coralliidae	*Corallium ?bathyrubrum* Simpson and Watling 2010	Quattrini et al. 2015
	?Hericorallium Gray 1867	Quattrini et al. 2015
Isididae	*Acanella arbuscula* (Johnson, 1862)	Hecker and Blechschmidt 1980; Hecker et al 1980; Opresko 1980; Maciolek et al. 1987a, b; Hecker 1990; Theroux and Wigley 1998; Watling and Auster 2005; Thoma et al 2009
	Keratoisis grayi Wright, 1869	Watling and Auster 2005; Bear Seamount: Moore et al. 2004; Deep Atlantic Stepping Stones Science Team/IFE/URI/NOAA
	Keratoisis sp. 1	Quattrini et al. 2015
	Keratoisis sp. 2	Quattrini et al. 2015
	Keratoisis sp. 3	Quattrini et al. 2015
	Keratoisis sp. 4	Quattrini et al. 2015
	Keratoisis sp. 5	Quattrini et al. 2015
	Keratoisis spp.	Quattrini et al. 2015
	Lepidisis caryophyllia Verrill, 1883	Moore et al. 2003; Watling and Auster 2005
	Lepidisis sp. 1	Quattrini et al. 2015
	Lepidisis sp. 2	Quattrini et al. 2015
	?Eknomisis Watling and France, 2011	Quattrini et al. 2015
	Keratoisidinae (unbranched)	Quattrini et al. 2015
	Isidella Gray 1857	Quattrini et al. 2015

Family	Species	References
	Jasonisis Alderslade and McFadden, 2012	Quattrini et al. 2015
	Isididae unknown 1	Quattrini et al. 2015
Nephtheidae	*Duva* [= *Capnella*] *florida* (Rathke, 1806)	Hecker and Blechschmidt 1980; Hecker et al. 1980; Opresko 1980; Maciolek et al. 1987a; Hecker 1990; Watling and Auster 2005; Watling et al. 2011
	Capnella glomerata (Verrill, 1869)	Hecker et al. 1980; Opresko 1980; Watling and Auster 2005
	Gersemia fruticosa (Sars, 1860)	Hecker and Blechschmidt 1980; Opresko 1980; Watling and Auster 2005
	Gersemia rubriformis (Ehrenberg, 1934)	Watling and Auster 2005
	Nephtheidae Unidentified sp. 1	Quattrini et al. 2015
Paragorgiidae	*Paragorgia arborea* (Linné, 1758)	Wigley 1968; Hecker and Blechschmidt 1980; Hecker et al. 1980; Opresko 1980; Theroux and Grosslein 1987; Theroux and Wigley 1998; Moore et al. 2003; Watling and Auster 2005
	Paragorgia ?johnsoni Gray, 1862	Quattrini et al. 2015
	Paragorgia sp.	Quattrini et al. 2015
	Paragorgia/Sibogagorgia sp. 1	Quattrini et al. 2015
Plexauridae	*Paramuricea grandis* Verrill, 1883	Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Opresko 1980; Valentine et al. 1980; Watling and Auster 2005; Thoma et al 2009
	Paramuricea placomus (Linné, 1758)	Watling and Auster 2005
	Paramuricea n. sp.	Watling and Auster 2005
	Paramuricea spp.	Quattrini et al. 2015
	Paramuricea/Placogorgia sp. 1	Quattrini et al. 2015
	Swiftia casta (Verrill, 1883)	Moore et al. 2003; Watling and Auster 2005
	Swiftia ?pallida Madsen, 1970	Quattrini et al. 2015
	Plexauridae Unidentified sp. 1	Quattrini et al. 2015
	Narella laxa Deichmann, 1936	Watling and Auster 2005
Primnoidae	*Primnoa resedaeformis* Gunnerus, 1763)	Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Opresko 1980; Valentine et al. 1980; Theroux and Grosslein 1987; Theroux and Wigley 1998; Moore et al. 2003; Cairns and Bayer 2005; Watling and Auster 2005; Heikoop et al. 2002
	Thouarella grasshoffi Cairns, 2006	Watling and Auster 2005 = *Thouarella* n. sp.; Cairns 2006, 2007

Family	Species	References
	Parastenella atlantica Cairns, 2007	Cairns 2007, Watling et al. 2011
	Calyptrophora antilla Bayer, 2001	Cairns 2007, Watling et al. 2011
	Paranarella watlingi Cairns, 2007	Cairns 2007, Watling et al. 2011, Quattrini et al. 2015
	Convexella ?jungerseni (Madsen, 1944)	Quattrini et al. 2015
	Primnodidae Unidentified sp. 1	Quattrini et al. 2015

5.2.2.2 Sea pens (Order Pennatulacea)

Like the true soft corals and gorgonians, sea pens are also members of the subclass Octocorallia. Unlike their octocoral cousins which have some representatives in shallow reefs, almost all sea pens are deepwater species. Generally the sea pens are associated with soft sediments, and each colony is anchored to the seabed with a fleshy peduncle, or foot. In New England, the most widespread species are on the continental shelf and include the common sea pen *Pennatula aculeata* (Family Pennatulidae) and the white sea pen *Stylatula elegans* (family Virgulariidae). *P. aculeata* is common in the Gulf of Maine (Langton et al. 1990), and there are numerous records of *Pennatula* sp. on the outer continental shelf as far south as the Carolinas (Theroux and Wigley 1998). *S. elegans* is abundant on the Mid-Atlantic coast outer shelf (Theroux and Wigley 1998). Eight additional families are represented in New England: Anthoptilidae, Funiculinidae, Halipteridae, Kophobelemnidae, Ombellulidae, Protoptilidae, Renillidae, and Scleroptilidae.

Table 6 lists the sea pens that have been documented in New England waters. Some of these identifications are at the genus or even family level only. A more detailed version of this table that applies to both the New England and Mid-Atlantic regions is provided in Packer et al. (in review). Older records of sea pens are drawn from Smithsonian Institution collections and the Wigley and Theroux benthic database (Packer et al. 2007). Nearly all materials from the former source were collected either by the U.S. Fish Commission (1881-1887) or for the Bureau of Land Management (BLM) by the Virginia Institute of Marine Sciences (1975-1977) and Battelle (1983-1986). These latter collections heavily favor the continental slope fauna. The Wigley and Theroux collections (1955-1974) were made as part of a regional survey of all benthic species (Theroux and Wigley 1998), heavily favoring the continental shelf fauna.

Table 6 – Sea pens (Order Pennatulacea) of the New England region.

Family	Species	References
Anthoptilidae	*Anthoptilum grandiflorum*	US NMNH collection, OBIS; Hecker and Blechschmidt 1980; Opresko 1980, Quattrini et al. 2015
	Anthoptilum murrayi	US NMNH collection, OBIS
	Anthoptilum sp. 1	Quattrini et al. 2015

	Anthoptilum sp. 2	Quattrini et al. 2015
Funiculinidae	*Funinculina armata* Verrill, 1879	US NMNH collection
Halipteridae	*Halipteris (=Balticina) finmarchica* (Sars, 1851)	US NMNH collection as *Balticina*; Hecker and Blechschmidt 1980 and Opresko 1980 as *Balticina*; Quattrini et al. 2015
	?Halipteris Kölliker, 1880	Quattrini et al. 2015
Kophobelemnidae	*Kophobelemnon stelliferum*	US NMNH collection, OBIS; Hecker et al. 1980, 1983; Opresko 1980; Maciolek et al. 1987b
	Kophobelemnon scabrum	US NMNH collection
	Kophobelemnon tenue [may not be a valid species]	US NMNH collection
	Kophobelemnon sp. 1	Quattrini et al. 2015
	Kophobelemnon sp. 2	Quattrini et al. 2015
Ombellulidae (or Umbellulidae)	*Ombellula guntheri* Kölliker, 1880	US NMNH collection
	Ombellula lindahlii Kölliker, 1880	US NMNH collection, OBIS
	Umbellula (= Ombellula) Gray, 1870	Quattrini et al. 2015
Pennatulidae	*Pennatula aculeata*	US NMNH collection, OBIS. Hecker et al. 1980, 1983; Hecker and Blechschmidt 1980; Opresko 1980; Moore et al. 2004
	Pennatula grandis	US NMNH collection, OBIS; Hecker et al. 1983
	Pennatula borealis	US NMNH collection, OBIS
	Pennatula sp.	Quattrini et al. 2015
Protoptilidae	*Distichoptilum gracile*	US NMNH collection, OBIS; Hecker et al 1980, 1983; Opresko 1980; Maciolek et al. 1987a; Hecker 1990; Quattrini et al. 2015
	Protoptilum aberrans	US NMNH collection
	Protoptilum carpenteri	US NMNH collection, OBIS
Scleroptilidae	*Scleroptilum gracile*	US NMNH collection
Scleroptilidae	*Scleroptilum grandiflorum*	US NMNH collection, OBIS
Virgulariidae	*Stylatula elegans*	US NMNH collection, OBIS; Hecker et al. 1980, 1983; Opresko 1980; Pierdomenico et al. 2015

5.2.2.3 Hard (stony) corals (Order Scleractinia)

Hard or stony corals are in the subclass, Hexacorallia, and as their subclass name would suggest, the stony corals have a six part division, rather than eight like the octocorals (Pechenik 2000). Stony corals (and hexacorallians generally) commonly exhibit solitary body forms, although many are colonial as well (Pechenik 2000). As their common name indicates, these species have substantial hard exoskeletons made from calcium carbonate (sclero is Greek for hard, Pechenik 2000). Some stony corals form reefs or mounds over time, as new colonies overgrow old ones (Pechenik 2000). These reef builders are referred to as the hermatypic corals (Pechenik 2000). Most of the stony corals in New England are non-reef building or ahermatypic (e.g., solitary stony corals such as *Desmophyllum dianthus*), although *Lophelia pertusa* and *Solenosmilia variabilis* are notable exceptions. *L. pertusa* was only recently found in New England waters, but is more commonly known from the Southeastern U.S and Canada. The carbonate skeletons of stony corals are sensitive to changes in ocean chemistry. Assessing the resilience of these species to more acid and warmer waters is an active field of research.

Table 7 lists stony corals found in the New England region. Families with representatives in New England include the Caryophillidae, Dendrophylliidae, Flabellidae, Fungiacyathidae, and Rhizangiidae. A more detailed version of this table that applies to both the New England and Mid-Atlantic regions is provided in Packer et al. (in review).

Table 7 – Hard (stony) corals (Order Scleractinia) of the New England region

Family	Species	References
Caryophillidae	*Caryophyllia ambrosia ambrosia* Alcock, 1898	Cairns and Chapman 2001; Moore et al. 2003
	Caryophyllia ambrosia caribbeana Cairns, 1979	Cairns and Chapman 2001
	Dasmosmilia lymani (Pourtales, 1871)	Hecker 1980; Hecker et al. 1983; Maciolek et al. 1987a; Hecker 1990; Cairns and Chapman 2001
	Deltocyathus italicus (Michelotti, 1838)	Cairns and Chapman 2001
	Desmophyllum dianthus (Esper, 1794)	Hecker 1980; Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Malahoff et al. 1982; Cairns and Chapman 2001; Moore et al. 2003; Quattrini et al. 2015
	Lophelia pertusa (L, 1758)	Hecker 1980; Hecker and Blechschmidt 1980; Hecker et al. 1980; Cairns and Chapman 2001; Moore et al. 2003; Quattrini et al. 2015
	Solenosmilia variabilis Duncan, 1873	Hecker 1980; Hecker et al. 1983; Cairns and Chapman 2001; Moore et al. 2004; Quattrini et al. 2015
	Vaughanella margaritata (Jourdan, 1895)	Cairns and Chapman 2001; Moore et al. 2003
Dendrophylliidae	*Enallopsammia profunda* (Pourtales, 1867)	Cairns and Chapman 2001
	Enallopsammia rostrata (Pourtales, 1878)	Cairns and Chapman 2001; Moore et al. 2004
Flabellidae	*Flabellum alabastrum* Moseley, 1873	Hecker 1980; Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Maciolek et al. 1987a; Cairns and Chapman 2001; Moore et al. 2003, 2004
	Flabellum angulare Moseley, 1876	Hecker 1980; Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Cairns and Chapman 2001; Moore et al. 2003
	Flabellum macandrewi Gray, 1849	Hecker 1980; Hecker and Blechschmidt 1980; Hecker et al. 1980, 1983; Cairns and Chapman 2001; Moore et al. 2003
	Javania cailleti (Duch. and Mich., 1864)	Hecker 1980; Hecker et al. 1983; Cairns and Chapman 2001; Quattrini et al. 2015

Family	Species	References
Fungiacyathidae	*Fungiacyathus fragilis* Sars, 1872	Cairns and Chapman 2001
Rhizangiidae	*Astrangia poculata* (Ellis and Solander, 1786)	Theroux and Wigley 1998; Cairns and Chapman 2001

5.2.2.4 Black corals (Order Antipatharia)

Like the stony corals, black corals are also members of the subclass Hexacorallia. The black corals, however, are almost all deepwater species, occurring well below 50 m, often with increasing abundance with depth, perhaps to avoid competition with other coral types (Wagner et al. 2012). Black corals are very slow growing and long lived, and while they do not form reefs (ahermatypic), over time some can form dense aggregations or beds, and are therefore important habitat engineers for other invertebrate taxa (Wagner et al. 2012). In other parts of the world, black corals are culturally important, and may by harvested for medicinal purposes, or for making decorative objects such as jewelry (Wagner et al. 2012).

All black corals are colonial, but they have a wide array of body forms, from long, whip shapes to branching structures that may be bushy, feathery, fan like, or shaped like a bottle brush (Wagner et al. 2012). The majority of black corals attach to hard substrates by means of a basal plate, but a small number of species are adapted to anchor in soft sediments (Wagner et al. 2012). They are referred to as black corals because their underlying skeleton is brown to black, although this skeleton is covered by a layer of soft tissue, to which the polyps are attached (Wagner et al. 2012). The outer soft tissues come in a rainbow of colors.

Many of the black coral species occurring in New England, including all of the records in the canyons, are known from recent exploratory surveys conducted since 2013. Most are members of the family Schizopathidae, and are identified to the genus level only. A single Leiopathid species is known from Bear Seamount. This lack of taxonomic specificity is not surprising, as black corals are one of the less well studied coral types, and reference specimens are often lacking (Wagner et al. 2012). Prior to these recent explorations, black corals were thought to occur only on the seamounts, but now they are known to be more widespread. A more detailed version of this table that applies to both the New England and Mid-Atlantic regions is provided in Packer et al. (in review).

Table 8 – Black corals (Order Antipatharia) of the New England region.

Family	Species	References
Leiopathidae	*Leiopathes sp.*	Brugler 2005, Smithsonian Institution
Schizopathidae	*Bathypathes* sp.	Thoma et al. 2009
	Bathypathes sp. 1	Quattrini et al. 2015
	Bathypathes sp. 2	Quattrini et al. 2015

	Parantipathes sp.	Thoma et al. 2009
	Parantipathes sp. 1	Quattrini et al. 2015
	Parantipathes sp. 2 (branched)	Quattrini et al. 2015
	Telopathes magna MacIssac and Best, 2013	Quattrini et al. 2015
	Stauropathes sp. 1	Quattrini et al. 2015
	Unidentified *Schizopathidae* sp. 1	Quattrini et al. 2015

5.2.3 Geographic distribution

The following three sections describe the geographic distribution of corals in New England, based on both historical records and recent exploratory surveys. Information is presented by location and exploratory survey cruise in the sections below.

5.2.3.1 Canyons and slope

Some general patterns in deep-sea coral distribution on the continental slope and in the canyons can be discerned from the historical surveys. Deep-sea corals are generally more densely distributed and diverse in the canyons than on the adjacent slope. Some species, such as those restricted to hard substrates, are only found in the canyons, while other species that frequently occur on soft substrates, such as *Acanella arbuscula*, are found both in canyons and on the slope. The canyons, particularly the larger ones, have hard substrates along most of their axes and walls that support many deep-sea corals. The slope south of Georges Bank is mostly soft substrate, supporting mainly stony corals on the upper slope and sea pens deeper than about 1500 m, with some exceptions.

The recent exploratory surveys provide a wealth of information on the distribution of corals in the canyons. It is important to note that these exploratory surveys only visited small sections of each canyon, and while attempts were generally made to investigate both walls, and various depths, the full array of species and habitat types present in each may not be represented in these samples.

There were two 2013 Okeanos coral survey tows in the **Alvin Canyon** area at depths ranging from 846 to 927 meters below sea level (Cruise EX1304L1, dives 9 and 10)[5]. Both the east and west walls were surveyed. Both dives traversed a range of soft sediment and rock wall/overhang habitats, and corals were observed on both dives, especially in rocky areas.

There have also been two recent tows in **Atlantis Canyon** on the Okeanos Explorer in 2013 (Cruise EX1304L1, dives 7 and 8), at depths ranging from 885 to 1,794 meters below sea level. Both the east and west walls were surveyed. Corals were observed during both dives. Dive 7 found colonial stony corals, soft corals, and black corals, plus cup corals, which are a solitary type of stony coral. Diverse types of stony, soft, and black corals were also found on Dive 8, in addition to sea pens.

[5] Do not have detailed logs for these dives.

In previously unexplored **Nantucket Canyon**, cruise EX 1404 (2014) visited the southwestern canyon wall at the mouth (1600-1900m). Corals observed on a debris field at 1875 m include the soft corals *Acanthogorgia* and *Anthomastus* and small *Distichoptilum* sea pens. The sea pen *Umbellula* was seen at 1870m. At 1861m, tall whip-like sea pens had large *Asteronyx* brittle stars clinging to them. At the base of the wall (~1825m) *Paramuricea* sea fans (with associated *Ophiocreas*) were noted. On the wall face were the soft corals *Anthomastus* and *Paramuricea* and the black coral *Bathypathes*. Overall, the wall was sparsely colonized. Other corals observed include bamboo corals (soft corals) *Keratoisis* (1783 m) *Lepidisis, Acanella*, and *Isidella*; the soft corals *Anthomastus* and *Clavularia* stoloniferous coral; *Parantipathes* black coral; and stony cup corals. *Paramuricea* sea fans and *Pennatula* sea pens were seen growing on the flat cap of the outcrop. *Chrysogorgia* soft coral colonies appeared at 1750m, some with a shrimp associate. *Eknomisis* bamboo coral were seen, as well as different morphs of hexactinellid sponges.

There were three *TowCam* dives in **Veatch Canyon** during cruise HB1204 (2012). During Dive 8, only stony and soft corals were observed, and in a smaller percentage of the collected images as compared to the other two dives. Dives 7 and 9, which were in deeper parts of the canyon, had larger percentages of images with corals, and stony, soft, and black corals and sea pens were observed. Overall, between 570-750m, the canyon has mostly sedimented habitats, with some draped chalky rocks. Between 1050-1250m there are hard bottom walls dominated by the soft coral *Acanthogorgia* and the stony corals *Solenosmilia* and *Desmophyllum*, all sparsely distributed. Between 1290-1424m, the seafloor is dominated by chalky rock bottom intermingled with flat, fully sedimented areas. On the hard substrate (rocks and walls) there is a diverse coral fauna, including the soft corals *Parmuricea*, *Anthomastus*, *Paragorgia*, *Swiftia*, *Clavularia*, *Acanthagorgia*, and bamboo corals; the stony coral *Desmophyllum*; and the black coral *Parantipathes*. On soft sediments at this deeper depth range, cerianthid anemones and the soft coral *Anthomastus* were noted. Overall, black coral abundance increased with depth, and none were observed between 569-751m. Stony and soft coral abundances were also low at the shallowest depths, and greatest at intermediate and deepest depths based on the percentages noted in the images; the highest abundances of stony coral were observed on vertical walls. Sea pen abundance was low throughout.

During cruise EX1404 (2014), the ROV explored a small mid-canyon cliff and the main canyon walls in an un-named, narrow **minor canyon east of Veatch Canyon** ("Okeanos Canyon"). Large debris boulders at the base of the cliff had a surprising density of corals, including the soft corals *Anthomastus*, *Paramuricea*, and *Swiftia*, and stony cup corals. Stony cup corals and the colonial *Solenosmilla* corals, black corals (?*Bathypathes*), bamboo coral (*Keratoisis*), and sponges were seen on the wall. Ascending the wall to about 1395 m, there were many patches of stony cup corals (*Desmophyllum*) and *Solenosmilia* colonies, the black coral *Parantipathes*, and the soft corals *Clavularia* and *Acanthogorgia*. At 1385 m, *Keratoisis* bamboo coral and *Paragorgia* ?*johnsoni* were observed. Other corals observed during the dive included the sea pens ?*Distichoptilum* and the black corals *Bathypathes* and *Telopathes*.

There have been two recent coral cruise tows in **Hydrographer Canyon** (Cruise EX1304L1, dives 5 and 6), where both the east and west walls of the canyon were surveyed. Dive 5 (1299-1418m) found stony, soft, and black corals of various species, including some smaller colonies noted as new recruits. Dive 6 (610-907m) found soft and stony corals, including *Lophelia pertusa*, which is a reef building species of stony coral.

Dogbody Canyon had eight historical observations of soft coral presence in the area. In 2015 (cruise HB1504), tow 1 (558-675 m) found sponges, but corals were uncommon. Tow 2 (894-1014 m) found abundant and diverse stony (*Desmophyllum*), soft (*Thouarella*, *Paramuricea*, *Acanthogorgia*, *Swiftia*) and black (*Telopathes*?) corals; during tow 3 (1461-1620), corals were rare with low diversity, and only soft (*Paramuricea*, *Radicipes*?) corals were observed.

Clipper Canyon had one historical observation of soft coral presence. In 2015 (cruise HB1504), sightings of corals were sparse, with soft corals seen during both tow 19 (495-571 m) (*Paragorgia*) and tow 20 (1216-1455 m) (*Paramuricea*).

During cruise HB1504 (2015), Tows 16 and 17 were conducted in **Sharpshooter Canyon**, in two of the larger contiguous areas of high slope. No corals were noted during the shallow tow 16 (800-901); tow 17 (1144-1168 m) found stony (*Solenosmilia*) and soft (*Paramuricea*) corals.

Welker Canyon had no historical records of coral presence. On dive 14 of Cruise EX1304L2 (1,377-1,445m), a wide diversity of corals were observed, including at least 17 species in all four major groupings. Three tows during cruise HB1504 (2015) surveyed the walls of the canyon. Tow 13 (559-778 m) found stony (*Solenosmilia, Desmophyllum*) and soft (*Acanthogorgia, Paragorgia*) corals; tow 14 (851-1156 m) found stony (*Solenosmilia*), soft (*Paramuricea*, *Thouarella*), and black (*Telopathes, Bathypathes*?) corals; tow 15 (1480-1650 m) found soft (*Paramuricea, Anthomastus*) and black (*Parantipathes, Bathypathes*?) corals.

There are no historical observations of coral presence in **Heel Tapper Canyon**. However, there have been recent ROV dives in the area, which include three tows on NOAA's Fisheries Survey Vessel Bigelow in 2015 (Cruise HB1504). These three ROV dives at depths ranging from 666 to 1,444 meters observed soft corals (*Thourella*, *Paramuricea*, and *Acanella*).

There are a relatively large number of historical observations (150+) within **Oceanographer Canyon**, including observations of soft corals and stony corals. Some additional areas to the west of the proposed zone have historical observations as well. In addition, there have been two recent Okeanos Coral Cruise tows within the proposed zone (EX1304L2), and both the eastern and western walls were surveyed. Dive 3 (983-1,239m) and Dive 13 (1,102-1,248m) both encountered diverse habitat types and at least 16 species of stony, soft, and black corals. The colonial stony coral *Lophelia* was observed during Dive 3.

Filebottom Canyon had one historical record of soft corals. There were a total of four tows there during the cruise HB1504 (2015). Tow 7 (664-887 m) and Tow 8 (1029-1077 m) recorded stony (*Solenosmilia, Desmophyllum*) and soft (*Paramuricea*, *Primnoa*?) corals. Heel Tapper Canyon had no historical observations. Three tows ranging from 666-1444 m found soft corals (*Thouarella*, *Paramuricea*, *Acanella*).

Chebacco Canyon had no historical records associated with it. During cruise HB1504 (2015), there were two tows on the east wall. Tow 4 (801-875 m) found stony corals (*Solenosmilia*, *Desmophyllum*) and Tow 5 (1133-1356 m) found soft (*Paramuricea, Swiftia, Acanthogorgia, Clavularia,* bamboo), stony (*Solenosmilia*), and black (*Parantipathes*?) corals. The deepest tow (6, 1909-2061) found soft corals (*Paramuricea*).

Gilbert Canyon is a hotspot of coral abundance and diversity. The tows during cruise HB1204 (2012) covered various locations throughout the canyon including an area near the head and on multiple walls and tributaries. All of the tows found soft corals, with the percentage of images with soft corals ranging from 2% to 54%. Other coral types were found in the canyon as well, including black corals, stony corals, and sea pens. Two tows of the eight revealed markedly high coral abundance and diversity. These tows were on the western wall between 1370-1679 m and in the canyon head between 640-820 m. The western canyon slopes had the greatest abundance and diversity of corals, with the hard bottom hosting solitary stony corals and a few colonial stony corals (*Solenosmilia*), mostly on rocky outcrops. Soft coral diversity (*Paramuricea*, *Acanella*, *Paragorgia*, etc.) was high in this canyon due to the diversity of habitats. Sea pen abundance was also high in the canyon. Soft corals in the head of the canyon (640-820 m) were highly abundant but dominated by a single type of coral (likely *Acanella*). Black corals (e.g., possibly *Plumapathes* and *Parantipathes*), were also noted in this canyon, and along with Veatch Canyon, these were the first new records for this order for the canyons in this region.

There are 105 historical observations of coral presence in **Lydonia Canyon**, including observations of soft corals, sea pens, and stony corals, making it one of the best studied prior to the recent exploratory surveys. There has also been one recent ROV dive within the proposed zone, onboard the R/V Okeanos Explorer, cruise EX1304L2, dive 12; 1,135-1,239m. A large number of species (at least 15) from all four coral groups were observed during the dive.

There were six tows in **Powell Canyon** during cruise HB1302 (2013). Tows 7 (753-1306 m) and 8 (905-1340 m) had high abundances and diversities of corals, while tow 9 (1302-1630 m) had abundant corals, and often with areas of high localized abundances, with some areas having widely dispersed corals or none at all. The remaining three deeper tows (1292-2053 m) have low abundances/low diversities of corals. Examples of species observed included the stony corals *Solenosmilia* and *Desmophyllum*; the soft corals *Paramuricea, Acanthogorgia, Anthomastus, Paragorgia, Primnoa, Radicipes, Thourella, Swiftia, Acanella*, *Chrysogorgia*, and bamboo corals; the black corals *Parantipathes, Bathypathes*, and ?*Telepathes*; and sea pens. In addition to these efforts within Powell Canyon, one tow surveyed a relatively shallow inter-canyon area (482-508 m) between

Munson and Powell; corals were rare, with low diversity, and only the soft coral *Acanthogorgia* was noted. Two tows surveyed a minor canyon between Munson and Powell (927-1273 m), corals were common and diverse and widely distributed, with some areas of high localized abundance or no corals at all. Stony corals found included *Solenosmilia* and *Desmophyllum*; soft corals included *Paramuricea, Anthomastus, Swiftia*, and bamboo corals; black corals included *Parantipathes*.

In **Munson Canyon**, seven *TowCam* tows were completed during cruise HB1302 (2013). In tows 14 (535-1040 m), 16 (983-1346 m), 17 (935-1455 m), 18 (1330-1941 m) and 24 (1084-1472 m), corals were abundant, often with areas of high localized abundances, with some areas having widely dispersed corals or none at all. Tow 19 (1283-1855 m) had fewer corals overall, while Tow15 (550-1089 m) had a low abundance and diversity of corals present. Examples of species observed included the stony corals *Solenosmilia* and *Desmophyllum*; the soft corals *Paramuricea, Acanthogorgia, Anthothela, Anthomastus, Paragorgia, Primnoa, Radicipes,* and bamboo corals; the black coral *Parantipathes,* and sea pens.

Relative to Munson Canyon, coral diversity in **Nygren Canyon** was higher, with few species occurring in high abundance locally as observed during the collaborative U.S./Canadian cruise conducted during 2014. One notable exception was a vertical wall covered with colonies of the stony coral *Solenosmilia variabilis*. Bamboo corals, *Paramuricea* sp. and the stony coral *Desmophyllum dianthus* were numerically dominant species. Sponges were diverse and abundant in Nygren Canyon. These 2014 observations were consistent with dives conducted during leg 2 of the 2013 Okeanos Explorer Cruise EX1304. Dive 6 (1310-1590m) traversed a diverse range of habitats, including soft sediments, a cold seep, and exposed rock faces. Corals found included soft corals (at least 17 species), black corals (three species), stony corals (three to four species), and sea pens (three species). Dive 8 (678-914m) traversed a shallower area of the canyon, with sediments ranging from soft sediment with large boulders to rugged steep terrain with sediment-draped rock. A diverse coral fauna was observed during this dive, as well as a diversity of fishes and other fauna.

There are no historical observations of coral presence in the **unamed canyon between Nygren and Heezen**. There was a 2013 ROV dive in the canyon (Okeanos Explorer Cruise EX1304 leg 2, dive 10, 497-824m). The dive track transited diverse habitat types and geological features, including soft sediments over rocky ledges, sediment with coral rubble, and a steeply sloping wall. The wall ledges harbored various coral types, including stony corals (solitary cup corals and colonial species) and soft corals. At the top of the slope the dive concluded on a sediment field with scattered rocks, colonized by attached organisms including soft corals (*Acanthogorgia*).

There are 67 historical records within **Heezen Canyon**, including observations of stony corals, soft corals, and sea pens. Two dives were completed in the area during the 2013 Okeanos Explorer Cruise EX1304, leg 2. Dive 7 (1615-1723m), traversed varied habitat types along the southwestern flank of the canyon. Various coral taxa were found, including soft corals (*Paramuricea*, *Acanella, Clavularia*, and *Radicipes*), stony corals (the colonial *Solenosmilia*), black corals (*Stichopathes*), and sea pens (*Umbellela*). Dive 9 (703-926m), was in a shallower portion of the canyon along the southwestern wall. Vertical rock faces traversed during the dive were inhabited by enormous soft coral (*Paragorgia*, *Primnoa*, and *Paramuricea*) colonies. Other coral taxa were also observed during the dive. In contrast to Nygren Canyon, the 2014 U.S./Canadian cruise suggested that Heezen Canyon had lower diversity of corals, but several species were locally abundant. For example, vertical canyon walls were populated with numerous, large colonies of the bubblegum coral *Paragorgia arborea* interspersed with *Primnoa resedaeformis* and *Paramuricea* sp. at depths of 569-668 m. In addition, true soft corals (Neptheidae) were commonly observed on the wall of Heezen Canyon. At deeper depths (1046-1133 m), the soft coral *Anthomastus* sp. was more abundant, often found co-occurring with the hard corals *D. dianthus* and *S. variabilis* and the soft coral *Anthothela grandiflora*.

5.2.3.2 Seamounts

The summit of **Bear Seamount** is approximately 1100m below sea level, and the base of the seamount is at over 3000m. Bear is the largest of the New England seamounts, and while it was not visited during recent (2012-2015) cruises, all four groups of corals (soft, stony, sea pens, and black corals) had been previously documented in the area.

Mytilus is the deepest of the four seamounts, with a minimum depth of approximately 2,400m and a maximum depth of over 4,000m. Mytilus Seamount was surveyed during leg 2 of the 2013 Okeanos Explorer cruise EX1304, dives 4 and 5. Dive 4 documented a diverse array of soft corals as well as two species of black coral. Sea pens, soft corals, and black corals were noted during Dive 5. A diversity of sponges were observed during both dives.

In October 2012, two Wiatt Institute REMUS 6000 AUVs were used to investigate deep-sea coral presence distribution on **Physalia Seamount** (summit depth approximately 1880 m), a previously unexplored member of the New England Seamount chain (Kilgour et al 2014). They collected 2956 color seafloor images as well as 120 kHz (low-frequency) and 420 kHz (high-frequency) sidescan sonar. Vehicle altitude of 8-10 m was necessary to maintain speeds of 3-4 kts and maximize area of coverage to locate coral aggregations. The presence of octocorals were confirmed from the images; sea pens were found in flat, soft sediments, but most other octocorals were found at either the ecotone of soft sediment and hard bottom, or on hard bottom features such as walls, ledges, and gravel/bedrock pavement (Kilgour et al. 2014).

The AUVs proved suitable for the rapid assessment of the presence and distribution of deep-sea corals, and this "high and fast" sampling strategy provided by the AUVs was appropriate for the spatial resolution of current management approaches that essentially propose broad geomorphic features (e.g., discrete submarine canyons, seamounts) as coral zone options. The geo-referenced images provided fine scale distribution information, but fine-scale taxonomic resolution and, of course, specimen collecting are not possible. But while manned submersibles and ROVs are excellent tools for surveys and studies where finer taxonomic resolution and small-scale sampling are required, the "low and slow" strategy, requiring low altitude and slow speed, is often not optimal for surveying the large areas required for tactical management needs (Kilgour et al. 2014). This project showed that AUVs could be an ideal tool for linking fine-scale spatial distribution of deep-sea corals to meso-scale patterns and variation in landscape features, flow regimes and other oceanographic attributes. Such information is of particular benefit for improved deep-sea coral habitat suitability modeling to predict distribution of deep-sea coral taxa across regional landscapes (Kilgour et al. 2014).

Retriever Seamount was surveyed by the Okeanos Explorer during 2013. Retriever Seamount is the farthest-offshore seamount within the US EEZ. It is about 2000 m high, 7 km in diameter, and has three main summits. The seamount harbors a diverse assemblage of taxa, including soft and especially black corals, and numerous hexactinellid sponges and demosponges. The corals observed (> 2600 m) were significantly different from those at other sites. Differences in species composition between Mytilus Seamount and other sites were primarily due to the presence/absence of numerous species. *Chrysogorgia* spp., *Convexella*? *jungerseni*, *Corallium*? *bathyrubrum*, *Paranarella*? *watlingi*, and *Paragorgia*/*Sibogagorgia* sp. 1 were observed on Mytilus Seamount, while *Acanthogorgia* spp., *Anthothela* spp., *Clavularia*? *rudis*, *P*. *arborea*, and *Paramuricea* spp. were not seen on Mytilus Seamount, but occurred at other sites. No stony corals were observed here; Quattrini et al. (2015) suggest that the deeper depths (2600 to 3200 m) are beyond the stony corals' bathymetric limits.

Cruise EX1404 (2014) returned to both of these seamounts. The ROV dive on Physalia Seamount took place on the upper flanks and ascended a steep slope on the southern side of the seamount. The maximum depth obtained was 2589 m. Corals were observed in low abundance and diversity, with the soft coral *Chrysogorgia* sp. and sea pen *Anthoptilum* sp. being seen most commonly; the latter were seen in typical sea pen habitats embedded in soft sediments but also on hard substrates. The occasional bamboo coral *Lepidisis* sp. was seen. Other corals include black corals *Telopathes* and *Bathypathes*, the soft coral *Anthomastus*, and stony cup coral.

On Retriever, the ROV was deployed to a depth of 2142 m and settled on a fairly monotonous sandy slope. Many sea pens colonies were seen in sedimented areas, with ?*Anthoptilum* sp. more common than *Pennatula* sp., as well as stony cup corals *Caryophyllia* sp. After transiting to an area of hard rock outcrop where soft coral *Metallogorgia melanotrichos* colonies were very abundant and several "sub-adult" colonies were observed, suggesting different bouts of recruitment to the area. The orientation of many of the coral colonies clearly pointed to a downslope current. Other corals observed on the outcrop included the soft corals *Corallium* ?*bathyrubrum* and *C.* ?*niobe*, *Paramuricea* sp., *Iridogorgia splendens* (at least one with shrimp associate) and *I. magnispiralis*, *Candidella imbricata* and an unidentified Primnoidae, bamboo corals *Lepidisis* sp. and *Acanella* sp., and the black corals *Parantipathes* (branched), *Stauropathes*, and seen further upslope on isolated rocks, *Bathypathes*.

5.2.3.3 Gulf of Maine

Results of the recent exploratory surveys revealed extensive coral at around 200-250 m in the five primary survey areas of western Jordan Basin, central Jordan Basin, near Mount Desert Rock, on Outer Schoodic Ridge, and on Lindenkohl Knoll in Georges Basin (Auster et al. 2013, 2014; Packer et al., unpublished data). Structure-forming corals on hard substrate at all sites were predominantly gorgonians, although scarce numbers of tiny, stony cup corals were seen on some dives, and sea pens were also observed. The sea pen *Pennatula aculeata*, which is common in the Gulf of Maine, was found in dense patches in the mud and gravel/mud habitats adjacent to hard-bottom habitats. The highest densities were observed in the Mount Desert Rock region.

Coral occurrences were classified as either coral present (sparse to medium density) or coral garden (high density patches). Coral gardens are defined as areas where soft corals are among the dominant fauna and occur at densities higher than surrounding patches (Bullimore et al. 2013). Dense and extensive coral gardens were seen in Western Jordan Basin, Outer Schoodic Ridge, and near Mount Desert Rock, especially in areas of high vertical relief. Outer Schoodic Ridge especially was a unique area, with of the topography reminiscent of narrow slot canyons on land (e.g., western U.S., in southern Utah). Based on preliminary analyses of 2013 images (Auster et al. 2013), these steeper areas had some of the highest densities, with about 16-39 colonies/m^2, well above the threshold of 0.1 colonies/m^2 used by ICES (2007) to define coral garden habitat. Central Jordan Basin and Georges Basin also contained coral communities, but were more patchy, less dense, and in lower relief environments than the aforementioned areas.

The dense corals on the steep vertical walls and cliffs of Outer Schoodic Ridge and Mount Desert Rock were primarily *Primnoa resedaeformis*, with lower abundances of *Paramuricea placomus* (in two color morphs of yellow and purple). On some of the tall, narrow canyon-like walls and cliffs of Outer Schoodic Ridge, *P. resedaeformis* colonies were so densely packed it was impossible to identify and count individual colonies; some were up to possibly one meter in size. Conversely, the major coral species found in Western and Central Jordan Basin and Georges Basin was *P. placomus*, with lower abundances of *P. resedaeformis* and *Acanthogorgia cf. armata* (Fig. 6c, d, e). *P. placomus* was found in higher densities on the steeper hard-bottom areas. Open areas adjacent to steeper features including muddy areas containing gravel, sand-gravel, and emergent rock outcrop features (with shallow expressions above the fine-grain sediment horizon) supported lower densities of coral, primarily *P. placomus*. This was true for Outer Schoodic Ridge and Mount Desert Rock also. Based on multivariate analyses of eight 2013 transects in Jordan Basin with coral garden habitat (Martin 2015), temperature, depth, sediment type, rock outcrop, and topographic rise were primary factors that correlated with coral distributions.

Of note were the first observations of the white coral *Anthothela* (*grandiflora*?) in the relatively shallow waters of the Gulf of Maine. A couple of colonies were seen at Outer Schoodic Ridge (e.g., dive 13 in 2014) around 200 m. This species has been observed off the Northeast Channel along the continental margin at depths deeper than 1400 m (Cogswell et al. 2009). However *Paragorgia arborea*, both pink and white forms, which was noted at 114 Bump in Western Jordan Basin during the 2003 survey, was not seen in the more recent surveys.

Detailed analyses of video and still images to determine coral and sponge distributions in relation to geology, associated species, and coral size structure are ongoing. Additionally, the 2014 Kraken 2 ROV dives in Outer Schoodic Ridge and western and central Jordan Basin also collected specimens of coral and other invertebrates for analysis for studies on deep-sea coral reproduction (Rhian Waller, University of Maine), population genetics, aging and growth studies, and taxonomy.

The extremely high densities observed for the large-sized, structure-forming gorgonians *P. resedaeformis* and *P. placomus* in the relatively shallow waters of the Gulf of Maine, as compared to the submarine canyons and seamounts, is unique in the Northeast. The proximity of these habitats so close to shore and their association with commercially important fish and shellfish increases the potential role of these habitats to function as EFH (e.g., Auster 2005). Finding these unique deep-sea coral habitats, especially the spectacular walls of corals at some sites, for the first time after 40-plus years of previous underwater surveys, illustrates how much remains to be discovered about the Gulf of Maine ecosystem in order to better conserve and protect its living marine resources.

The collaborative U.S./Canadian cruise in 2015 include a dive in U.S. waters in Central Jordan Basin. The Central Jordan Basin coral/sponge habitats fall under the definition of "coral gardens" as noted for other areas in the U.S. Gulf of Maine (see NECSI Project 3, below, for a detailed discussion of these habitats). Deep-sea corals in Central Jordan Basin were common to abundant. In areas of high abundance, corals were often a mix of the soft corals *Paramuricea placomus, Primnoa resedaeformis* and *Acanthogorgia* cf. *armata*. These are the three major soft coral species found in the Gulf of Maine, with *P. placomus* the most common species of coral observed. High abundances of sea pens (in soft sediments) and anemones, faunal assemblages typically found in the Gulf of Maine, were observed here as well. Additionally, marks on the bottom, presumably from bottom tending fishing gear, were observed in Central Jordan Basin, as well as in other deep-sea coral habitats in the Gulf of Maine.

5.3 Deep-sea coral habitat suitability model

Habitat suitability modeling examines the associations between the presence and/or absence of organisms and their relevant environmental or habitat variables. Because of the prohibitive costs and logistical difficulties of surveying the deep-sea, geo-referenced deep-sea coral location data is often limited, patchy, and mostly presence-only. Coral data in the New England region, in particular those data collected prior to 2012-2015 fieldwork, are no exception to these general rules. Predictive habitat modeling for deep-sea corals has therefore become a cost effective tool to identify potential locations of deep-sea corals and other benthic species, and aid managers in determining deep-sea coral management zones (Leverette and Metaxes 2005; Bryan and Metaxas 2007; Davies et al. 2008; Tittensor et al. 2009; Davies and Guinotte, 2011; Guinotte and Davies 2012; Yesson et al. 2012; Vierod et al. 2013).

NOAA's National Ocean Service (NOS) National Centers for Coastal Ocean Science (NCCOS), in partnership with the Northeast Fisheries Science Center (NEFSC), developed a deep-sea coral predictive habitat model for the Northeast region (Kinlan et al. 2013; Kinlan et al., in review). The spatial domain of the model is based on the footprint of the coastal relief digital elevation model, and thus includes the continental shelf and canyons in New England and the Mid-Atlantic, but not the seamounts. Results are reported on a 370 m grid, which was selected based on the resolution of the underlying bathymetry data, and is appropriate given that older coral presence records have some positional uncertainty.

A machine-learning technique called Maximum Entropy modeling, or MaxEnt, was used to predict suitability of unexplored habitats based on locations and environmental characteristics of known deep-sea coral presence (for more information on MaxEnt modeling, see Guinotte et al. 2016). The MaxEnt method was selected because it has performed well in previous deep-sea coral predictive habitat modeling studies using presence-only data, and outperformed other types of habitat suitability models, such as environmental niche factor analysis, in cross-validation studies (Tittensor et al. 2009, Davies and Guinotte 2011, Guinotte and Davies 2012, Yesson et al. 2012).

The MaxEnt model was run with selected predictor (environmental) variables and presence data for three groups of deep-sea corals in the Northeast historical (pre-2012) database (true soft corals and gorgonians, stony corals, and sea pens; see Table 9). These data are described further in section 5.2.1.1. There were insufficient data to include black corals in the model. These coral groups are described in section 5.2.2. Data included in the model were 1) coral presence records, 2) NOAA Coastal Relief Model bathymetry (NOAA 2011), and 3) environmental predictors (seafloor terrain statistics; physical, chemical, and biological oceanographic data, and sediment/substrate information). Only one coral record per taxonomic group was used per grid cell, and older records were dropped when there were multiple records in a grid. In areas of the region with fewer coral records, model outputs should still be predictive assuming that the ecological setting is similar to the areas where there are more coral records. Specifically, model outputs are applicable to Gulf of Maine despite fewer coral presence records in the version of the database used in the model.

Table 9 – Coral taxonomy used in the habitat suitability model

Group	Description	Code name
1	**Order Alcyonacea**	**ALCY**
1a	Gorgonian Alcyonacea (Suborders Calcaxonia, Holaxonia, Scleraxonia)	ALCY-GORG
1b	Non-Gorgonian Alcyonacea (Suborders Alcyoniina, Stolonifera)	ALCY-NONGORG
2	**Order Scleractinia**	**SCLER**
2a	Family Caryophylliidae	SCLER-CARYO
2b	Family Flabellidae	SCLER-FLAB
3	**Order Pennatulacea**	**PENN**
3a	Suborder Sessiliflorae	PENN-SESS
3b	Suborder Subsessiliflorae	PENN-SUBSESS

Habitat suitability maps and model evaluation methods predicted suitable habitat in the vicinity of known deep-sea coral presence locations, as well as in some areas without recorded presences. Some of these model outputs are better predictors of coral presence than others, due to different sample sizes of coral records of each type in the historical database. The combined output for gorgonians and true soft corals is the model with the best predictive ability for structure-forming deep-sea corals, as it is based on a sizeable number of data points from known structure-forming species. The model for scleractinians, on the other hand, is based on a smaller number of records of mostly solitary, soft-sediment dwelling cup corals (e.g., *Dasmosmilia* and *Desmophyllum*), and is likely to under-predict the likelihood of suitable habitat for this coral type. While numerous sea pens are documented in the historical database, most were records from the continental shelf and are either *Pennatula aculeata* from New England/Gulf of Maine or *Stylatula elegans* from the Mid-Atlantic; these animals occur in soft bottoms and are not considered to be structure-forming. Future incorporation of recent data for structure-forming scleractinians and black corals in the Northeast region will improve this model's predictive ability for these coral groups.

A large number of predictor variables were considered. These included variables describing seafloor terrain, including depth, slope, curvature (slope of slope), and rugosity, which is a measure of surface area to total area. These topographic variables were analyzed at multiple spatial scales to highlight large scale and finer features. Climatologic variables including bottom dissolved oxygen, temperature, and chlorophyll were also used. Bottom dissolved oxygen was taken from the World Ocean Database (https://www.nodc.noaa.gov/OC5/WOD/pr_wod.html) and NEFSC data. For some climatologic variables, seasonal data were used, while annual averages were used for others. In general, the maximum and minimum values are most predictive. Highly correlated predictor variables were removed to arrive at a set of 64 predictors. The final model (selection process described below) uses 22 predictor variables, out of a total of 64 variables (Table 10). For each predictor variable, response curves were generated to help users understand how that variable relates to coral distributions.

The model selection process relied on AUC and AIC combined with informed judgement of the analysts to identify a parsimonious suite of predictor variables. The model was fit to 70 percent of the coral data points for each taxa, and validated with the remaining 30 percent of the dataset. The model fit was evaluated using the area under the AU curve, and the gain, i.e. how well do the outputs fit the test data. For single variable response curves, peak suitability for each predictor variable is the highest point on the response curve. Multivariate response curves were also generated that indicate response to one varying predictor while others are held at their mean values.

Table 10 – Predictor variables retained in coral habitat suitability model. Table 2 in Kinlan, B.P., M. Poti, A.F. Drohan, D.B. Packer, D.S. Dorfman, and M.S. Nizinski (in review). Predictive Modeling of Suitable Habitat for Deep-Sea Corals Offshore of the Northeast United States.

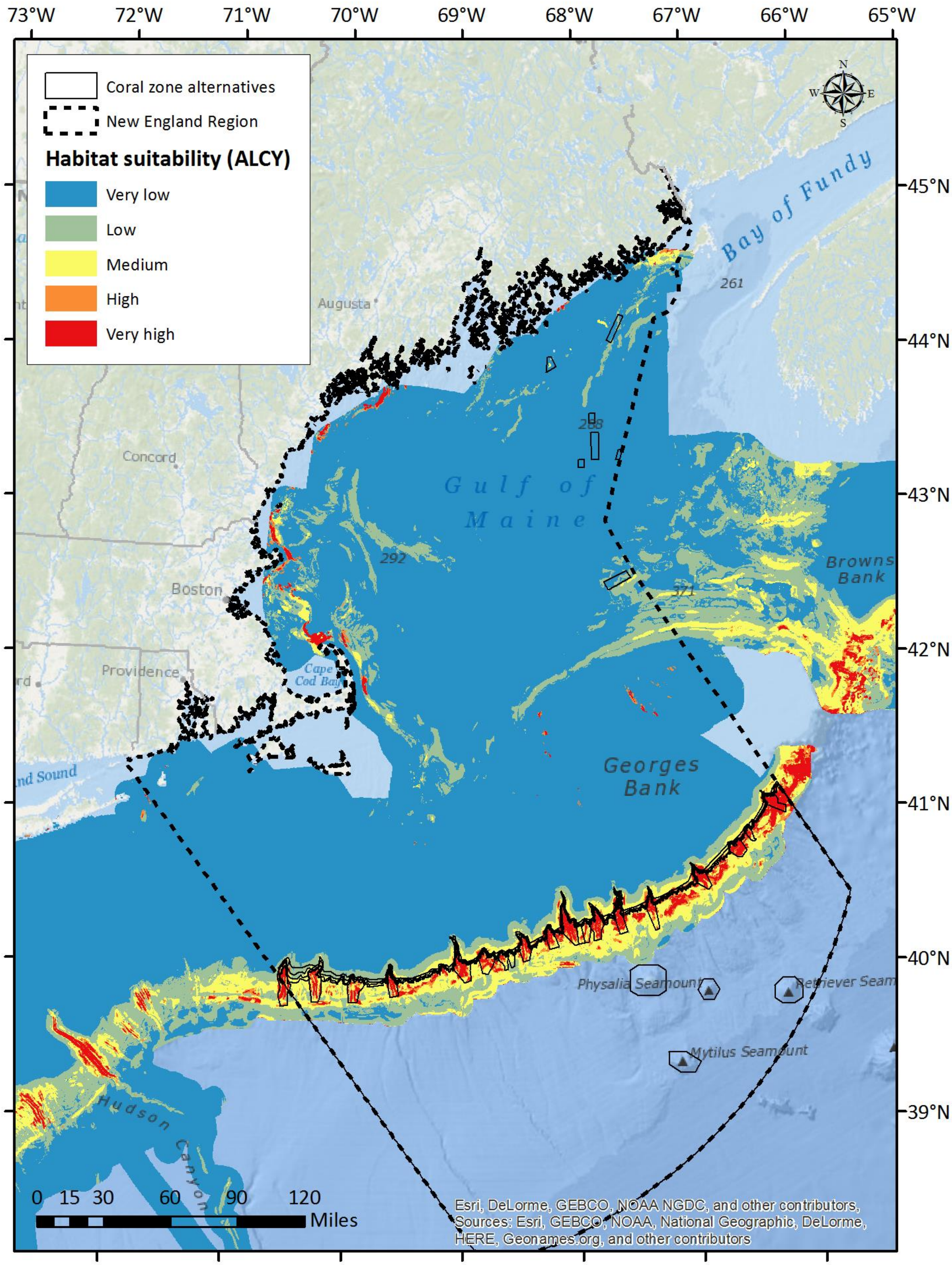
Predictor Variable	Code	Category
Aspect (derived at 1500 m scale)	asp1500m	Geomorphology
Aspect (derived at 5 km scale)	asp5km	Geomorphology

Predictor Variable	Code	Category
Depth	bathy	Geomorphology
Bathymetric Position Index (BPI) / Slope Index (derived at 20 km scale)	bpislp20km	Geomorphology
Predicted Mean Annual Bottom Salinity	bsalann	Oceanography
Predicted Mean Annual Bottom Temperature	btempann	Oceanography
Mean Annual Surface Chlorophyll-a	chlann	Oceanography
Predicted Mean Annual Bottom Dissolved Oxygen	doann	Oceanography
Predicted Surficial Sediment Percent Gravel	gravel	Substrate
Predicted Surficial Sediment Mean Grain Size	meanphi	Substrate
Plan Curvature / Slope Index (derived at 1500 m scale)	plcurslp1500m	Geomorphology
Plan Curvature / Slope Index (derived at 5 km scale)	plcurslp5km	Geomorphology
Profile Curvature / Slope Index (derived at 1500 m scale)	prcurslp1500m	Geomorphology
Profile Curvature / Slope Index (derived at 5 km scale)	prcurslp5km	Geomorphology
Rugosity (derived at 370 m scale)	rug370m	Geomorphology
Rugosity (derived at 1500 m scale)	rug1500m	Geomorphology
Predicted Surficial Sediment Percent Sand	sand	Geomorphology
Slope (derived at 370 m scale)	slp370m	Geomorphology
Slope (derived at 5 km scale)	slp5km	Geomorphology
Slope of Slope (derived at 1500 m scale)	slpslp1500m	Geomorphology
Slope of Slope (derived at 5 km scale)	slpslp5km	Geomorphology
Mean Annual Turbidity	turann	Oceanography

When using the results, it is important to consider the underlying data quality and resolution. The model grid resolution was selected to accommodate the positional uncertainty associated with the underlying coral data, but the canyon areas in particular have complex terrain such that the model outputs should be considered a somewhat coarse predictor of suitable habitat. In addition, the taxonomic resolution is also fairly coarse, to the order or sub-order level, and there is considerable diversity of coral species within each of these groupings.

The model does not predict abundance, density, or diversity, rather, it is indicating the likelihood of finding corals of a particular type in a particular area. The basic suitability outputs are generated on 0 to 1 scale, but they are not probabilities and cannot be compared across taxonomic groupings. Thresholded outputs were developed to allow comparisons between taxonomic groupings (these were the outputs used by MAFMC in their analysis). The thresholded model outputs for Alcyonaceans are shown below (Map 38).

Map 38 – Habitat suitability model outputs for Alcyonacean corals. Source: Kinlan et al. 2013.



The deep-sea coral habitat suitability model was qualitatively validated during later visual surveys, including the 2014 Okeanos Explorer canyon and seamount cruise. All sites observed to be hotspots of coral abundance and diversity (e.g., Gilbert Canyon) were predicted hotspots based on the regional model. Each model validation attempt indicated that the habitat suitability model performs well in predicting areas of likely deep-sea coral habitat, as well as predicting areas where corals are unlikely to occur. However, the exact location of deep-sea coral hotspots often depends on fine-scale seabed features (e.g., ridges or ledges of exposed hard substrate) that are smoothed over in this regional-scale model. The current resolution of the model is grid cells of approximately 370 m^2 (although there are plans to improve the model by increasing resolution to 25 m^2, as well as incorporate more recent coral observations). Habitat suitability maps based on this model should be viewed as representing only the general locations of predicted suitable coral habitat (within approximately 350-740 m, or approximately two model grid cells). For this reason, the total area of high/very high habitat suitability is an approximation using the best available data. In addition, model predictions are of the likelihood of coral presence, and high likelihood of presence will not necessarily correlate with high abundance.

5.4 Coral vulnerability to fishing impacts

The biological characteristics of deep-sea corals influence their vulnerability to physical disturbance. While deep-sea corals are threatened by various human activities, fishing with bottom-tending gears, particularly bottom trawls, has impacted coral habitats worldwide. The studies and reviews summarized below have assessed the impacts of commercial fishing on deep-sea corals and coral reefs, addressing a range of gear types as well as study locations. While other activities such as mining or energy exploration can threaten deep-sea corals, fishing restircitons are within the purview of the Council and are the subject of this action. This section concludes with a summary of the data on recent interactions between corals and fishing gears in New England.

5.4.1 Coral vulnerability and recovery potential

Many types of deep-sea corals tend to be very sensitive to physical disturbance given that they are sessile, fragile, and extend above the seafloor in a manner that makes interactions with fishing gear more likely. The ability of deep-sea corals to recover from injury, their rates of growth, and their ability to reproduce and colonize new sites is directly related to their resilience in the face of direct impacts from fishing or other mechanical disturbance, as well as their resilience to longer-term environmental change, specifically warming and increasingly acidic waters. This section describes these biological characteristics.

When bottom-tending gear interacts physically with corals, mechanical impacts can include removal of entire colonies, branches, or polyps, fracture, abrasion, crushing or burial. Severe mechanical impacts could cause immediate mortality, or sub-lethal effects might result from wounds in the tissue and possible microbial infection (Fosså et al. 2002), or to increased predation (Malecha and Stone 2009). Bottom trawling can also suspend sediments, which can impact coral feeding and may suppress growth and recovery of colonies. Because black coral polyps do not retract, these species are particularly sensitive to physical abrasion from sediments (Wagner et al. 2012). On the other hand, some types of scleractinian corals appear to be able to shed sediment, and may be able to cope with sediment suspension (Fosså et al. 2002; Clark et al. 2015). Sediment layer disturbance can also alter the physical or chemical composition of the sediment, particularly in the more stable waters of the deep sea (Clark et al. 2015), potentially impacting suitable habitat for corals.

The effects of mechanical disturbance and trauma to the soft coral *Gersemia rubiformis* (collected from the Bay of Fundy) were examined in a lab setting (Henry et al. 2003). In the study, eight colonies of soft coral, four control and four experimental, were set up in separate aquariums to determine damage and recovery rate of the organisms. The experimental colonies were rolled over and crushed every two weeks to simulate bottom contact trawling, with observations recorded four days and then one week after disturbance. Crushing the corals caused retraction of the entire colony. Damaged tissue was repaired and healed between 18 and 21 days.

The effect the crushing had on coral reproduction was surprising to the researchers. Thirteen days after the initial disturbance, daughter colonies were seen forming at the base of the corals, and by the end of the experiment 100% of the corals had daughter colonies. The mortality rate of the juveniles was 100%, however, and none of these daughter colonies survived past the polyp stage. Upon further testing, it was determined that these colonies were sexually derived, and since the individual colonies had been separated for the experiment, it is assumed that the corals were brooding when collected, as they were not visibly fertile prior when the experiment commenced. However, the control group did not have any daughter colonies during the experiment, and only after experimental crushing did daughter colonies appear. The authors guessed that the reason for daughter colony development and subsequent mortality was the expulsion of premature larvae, due to stress placed on the coral and the need to allocate resources to repair damaged tissue. While adult *G. rubiformis* were able to withstand the mechanical rolling and crushing, such physical disturbance could have negative long-term effects on the fitness of impacted corals, if they are less likely to produce surviving offspring during periods of tissue repair (Henry et al. 2003).

The approximate growth rates of different deep-sea corals have been calculated in several studies. Off Atlantic Canada, Risk et al. (2002) examined the growth rates for *Primnoa resedaeformis*. The corals were found at approximately 200-600m and were dated to 2600-2920 years old ± 50-60 years using ^{14}C dating techniques. Using the dated age and size of the colony (~0.5-0.75m in height) the average radial growth at the base of the coral was found to be 0.44 mm/yr and tip extension growth rates were around 1.5-2.5 mm per year (Risk et al. 2002). Another study of *P. resedaeformis* and *Paragorgia arborea*, found that the height of colonies ranged from 5-180cm for *P. arborea* (averaging 57cm) and 5-80cm for *P. resedaeformis* (averaging 29.5cm). The maximum age of samples collected was 61y (found by counting annual growth rings under a dissecting microscope and x-ray examination). It estimated that the rate of growth for the first 30 years was around 1.8-2.2 cm/yr. After the coral began to age (>30 years), growth slowed to 0.3-0.7 cm/yr. This shows that initially the coral grows at a speed concurrent with the first study, and then dramatically slows to only a few millimeters a year, suggested by the second study (Mortensen and Buhl-Mortensen 2005).

Deep-sea coral reproduction is a subject that has not been the topic of research until recently. While the physiology of reproduction in corals has been studied, little is known about the process of timing involved and the survival of resulting offspring. Studies have, however, shown that many of the deep-sea corals have separate sexes (Brooke and Stone 2007; Roberts et al. 2006; Waller et al. 2002; Waller et al. 2005). Brooke and Stone (2007) collected samples of corals (*Stylaster, Errinopora, Distichopora, Cyclohelia, and Crypthelia*) around the Aleutian Islands and discovered that the collection held a mix of females containing mature eggs, developing embryos, and planulae, males producing spermatozoa, and organisms with no reproductive material. As was pointed out the gametes within the collection were not synchronized which indicates that reproduction is either continuous, or prolonged during a certain season of the year (Brook and Stone 2007).

Waller et al. (2002) also found *Fungiacyathus marenzelleri* (collected from the Northeast Atlantic at 2200m) to be gonochoric (separate sexes), with a sex ratio of near 1:1. The mean diameter of oocytes did not vary significantly from month to month and all levels of sperm development were noted in the collection. The coral was thus considered a quasi-continuous reproducer. An interesting finding of the study was that while *F. marenzelleri* has separate sexes, it can also undergo asexual reproduction, and budding was present during the study. However, this was limited to no more than one bud found on any individual and no more than two individuals were found to bud at the same time (Waller et al. 2002), not nearly the kind of reproductive rate to sustain a population in highly disturbed areas.

Fecundity and reproductive traits for three other corals collected in the Northeast Atlantic were also determined in a study by Waller et al. (2005). *Caryophyllia ambrosia* (collected from 1100-1300m), *C. cornuformis* (from 435-2000m), and *C. seguenzae* (from 960-1900m) were all found to be cyclical hermaphrodites. The corals possessed both sexes but only one sex was dominant at a time; corals transitioning between sexes were seen in the study and labeled as “intermediates”. The fecundity of the corals was calculated at 200-2750 oocytes per polyp for *C. ambrosia*, 52-940 oocytes per polyp for *C. seguenzae* and no data due to insufficient samples of *C. cornuformis*. As with the other studies, there was no significant difference in the average number of oocytes per month and continuous reproduction is assumed for both *C. ambrosia* and *C. cornuformis* (Waller et al. 2005).

While the physiology of these corals has been recently studied, more research is needed to determine the ability of corals to recolonize disturbed areas. Brooke and Stone (2007) concluded that a lightly impacted area would be able to recover via colony growth alone. However, heavily impacted areas, where the seafloor has been scoured and stripped of cover would require coral larvae to be dispersed via currents and settle the area again, which could be a slow, timely process.

5.4.2 Gear interaction studies

Research on gear impacts to deep-sea corals specifically within the New England Council region is extremely limited; thus, studies reviewed here include a range of different study locations worldwide. While the study sites cover a variety of locations, the impacts of commercial fishing on the local corals and seafloor are virtually identical throughout the literature. The conclusions drawn by these studies are that commercial fishing gear can damage or destroy deep-sea corals and associated fauna. Trawling, specifically, is very detrimental to coral and the seafloor. Several studies have concluded that deep-sea corals are especially fragile and the greatest disturbance and destruction occurs at depths targeted by commercial fishing (Heifetz et al. 2009, Hall-Spencer et al. 2002). Disturbances to deep sea corals range from scarring left by fishing gear to complete destruction of coral and stripping of the seafloor to underlying rock or sediment. The substrates of areas heavily fished with bottom-tending gear have been observed stripped to bare rock or reduced to coral rubble and sand, whereas unfished and lightly fished areas typically do not see such degradation (Grehan et al. 2005).

Most of the relevant research has involved study sites that were observed using some form of photographic or continuous video transects. Several studies mapped the area using sidescan sonar (Wheeler et al. 2005, Fosså et al. 2002) or multibeam sonar in conjunction with a deep camera system (Althaus et al. 2009, Grehan et al. 2005). This technique allows for determination of damage caused by dragging gear over the seafloor. The logs of fishing trips, reports from fishermen, and other literature on fishing activities at each of the areas, have also been utilized by several studies in different regions (Althaus et al. 2009, Koslow et al. 2001, Heifetz et al. 2009, Fosså et al. 2002, Cryer et al. 2002). Anecdotal reports acted as a guide to further research areas, as well as providing information about to the history of fishing and practices in the area (Fosså et al. 2002).

Potential gear impacts to corals depend on many factors, such as the configuration and weight of the gear, towing speed, sediment type, the strength of tides and currents, and the frequency of disturbance (Jones 1992; Clark et al. 2015). It should be noted that in many studies reviewed, there was frequently a lack of adequate descriptions of the gear used, so generalizations should be made with caution. A few studies were successful at providing gear descriptions, but the dimensions of gear size can vary and a universal description and size should not be assumed for all fishing effort with each gear type. Nevertheless, general conclusions were similar among various studies using different configurations of gear.

Passive or static gear types, such as pots, traps, or longlines, have been demonstrated to impact localized area of corals, though they have not been observed to be as destructive as bottom trawls and dredges. Several studies have described passive gear interactions with benthic habitat, commonly in the form of observed entanglements of coral with fishing gear (Fosså et al. 2002, Ross et al. 2015). Despite these gear types having a smaller footprint compared to a trawl, in certain conditions these gear types may drag across the seafloor, potentially entangling corals or stirring up sediments (Clark et al. 2015). Longline impacts on corals and sponges have been observed where corals have been broken by longline weights or by the mainline cutting through them during fishing or hauling. A Canadian report (DFO 2010) concluded that traps can crush and entangle sponges and corals and cited a number of factors that can affect their habitat impacts, including the type of bottom, their weight, size, and construction material, the type of rope (floatline or sinkline), retrieval methods and weather conditions, soak time, the number of traps on a string, and the use of anchors.

In Alaska, Heifetz et al. (2009) and Stone (2006) conducted studies in commercially fished areas in the Aleutian Islands using a ROV and a research submersible and Krieger (2001) made direct observations inside and outside the paths of two research trawl paths in the Gulf of Alaska from a submersible. Stone found that disturbance attributable to longline gear was observed on 76% of transects, but was very localized, occurring on only 5% of the observed seafloor. Damage attributed to trawling, on the other hand, was observed in 28% of the transects, but affected about 33% of the observed seafloor, indicating a relatively greater impact of trawls. Overall, 22 of the 25 transects showed disturbance to the seafloor and approximately 39% of the total observed area showed signs of disturbance.

The second study in this region (Heifetz et al. 2009) was conducted over a broader area and greater depth range and provided additional evidence of trawling impacts, as indicated by uniform parallel striations in the seafloor, seen on several dives. The proportion of damaged corals was significantly lower in areas with little or no bottom trawl fishing than in areas with medium and high intensity bottom trawling activity. There was also a general tendency for coral damage to be greater in areas fished with crab pots, fish pots, and longlines, but due to high variability, there were no statistically significant differences in the proportion of damaged corals between the fished and unfished areas. Both studies observed that the most damage done to corals occurred at depths where commercial fishing intensity was the highest (100-200 m), with higher population densities occurring at 200-300 m. All damage deeper than 700 m was attributed to longlines and pots, since those were the only two gear types used at those depths.

Observations made by Krieger (2001) in the Gulf of Alaska revealed severe impacts to *Primnoa* spp. along two paths of a research trawl. At one site in an un-fished area, a 30 minute trawl tow (2.72 km) had removed a metric ton of coral colonies seven years before the in situ observations were made. The path of the net was identified by displaced boulders, broken corals, and pieces of net twine. Thirty-one coral colonies were observed over a distance of 0.68 km. Almost all of the branches were removed from 5 of 13 large colonies and 80% of the polyps were missing from two smaller colonies. Damage was attributed primarily to corals that were attached to boulders that had become entangled in the net, causing the boulders to tip or be moved. Large patches of bare rock on boulders showed where the trawl had removed entire colonies. No damage was observed outside the trawl path, including areas within 10 m of the net path that had been swept by the net bridles. No young colonies were seen in the trawl path, indicating that corals had not recolonized the bottom during the seven year time period.

In a more recent study in the eastern Gulf of Alaska, Stone et al. (2014) attributed most of the damage to red tree corals (*Primnoa pacifica*) to fishing gear rather than predation. Study sites were located in an area that was closed to trawling in 1998 where large catches of red tree corals have been observed as bycatch in groundfish surveys. The area was virtually untrawled for ten years prior to the closure. Small longline fisheries still occur in or near the study sites. At one site, 90.7% of the observed damage was attributed to fishing gear. A total of 24 derelict longlines were seen at the two study sites on 13 of 19 transects. Damaged corals and sponges were observed in the immediate vicinity of all derelict longlines and anchor drag furrows were seen in soft sediment areas. Larger colonies were much more susceptible to damage at both sites.

Studies conducted in the Northeast Atlantic Ocean have resulted in similar conclusions to those conducted in the Aleutian Islands. Fosså et al. (2002) found that damage to *Lophelia pertusa* reefs off Norway was most severe at shallower depths where commercial fishing primarily took place. The various study sites presented a range of disturbance due to fishing. While the deeper water corals were intact and living at one site, almost all corals were crushed or dead at another. A third demonstrated multiple stages of coral degradation, from living to dead and crushed, as well as the base aggregate the reefs often form and grow on being crushed and spread out. The percent of damage to the area was correlated with the number of reports by the fishermen of fishing activity, bycatch, and corals in the area; ranging from 5-52% damaged. The continental shelf, at approximately 200-400m (below the highest levels of fishing), had the highest abundance of corals. These corals were intact and developed, whereas the shallower sites contained crushed coral and coral rubble, where damages were estimated at 30-50%.

Hall-Spencer et al. (2002), in a study focused on the West Ireland continental shelf break, found scars from trawl doors (indicated by parallel marks or furrows on the sea floor) that were up to 4km long, as well as coral rubble on trawled areas. Locations lacking observable trawl scars contain living, unbroken, *L. pertusa*. Similar findings were observed at a site off the northern coast of Ireland (Wheeler et al. 2005). Trawl marks were located on side scan sonar records, and video showed parallel marks left by trawl doors, as well as the net and ground line gear, on the seafloor. The amount of dead coral and coral rubble increased at sites that were obviously trawled.

Althaus et al. (2009) and Koslow et al. (2001) conducted studies on seamounts in Tasmania. Areas that had never been trawled, or were lightly fished (determined via trip logs), were dominated by the stony coral *Solenosmilia variabilis*, making up 89-99% of coral cover in never trawled areas (Althaus et al. 2009) as well as seamounts peaking below 1400m (Koslow et al. 2001). These studies found that active trawling at sites removed most, or all, of the coral and associated substrate, leaving bare rock in heavily trawled areas, and coral rubble and sand at the lower limits of fishing activity (Koslow et al. 2001). This was supported by photographic transects by Althaus et al. (2009) showing coral in less than 2% of trawled areas. “Trawling ceased” areas, where trawling had effectively stopped five to ten years earlier, showed coral in approximately 21% of transects. This study also found a higher abundance of the faster growing hydroids colonizing cleared areas, smaller corals and octocorals, as well as noting whip-like chrysogorgiid corals, which were flexible and could presumably bend and pass under the trawls.

While several studies reported that much of the coral on fishing grounds was damaged or destroyed, there were areas that avoided contact. The surviving coral in fished areas was often located on undesirable fishing terrain, or at depths not targeted by fishermen. Corals growing on steep slopes have a natural protection from commercial fishing gear, as a slope greater than about 20 degrees cannot be trawled. Areas of higher three-dimensional complexity were also relatively untouched, as these were avoided by the fishermen for fear of damage and loss of their gear. The effect of seafloor topography on fishing and the resulting impact on corals was observed in a study site west of Ireland (Grehan et al. 2005). While evidence of active trawling was seen, indicated by trawl scars in mud and non-coral habitat, there was no fishing-related damage to corals on mounds having slopes greater than 20 degrees. Here, the terrain is too steep to trawl and the corals were naturally protected from the gear and relatively undamaged. Hall-Spencer et al. (2002) also noted that fishermen avoided uneven ground due to the loss of time and money from resulting gear upkeep of tangled and damaged gear. Areas of large coral bycatch were avoided in the future, as known trouble areas for the fishermen. Because of this only five of the 229 trawls in the study contained large amounts of coral bycatch. Thus, the areas where corals were present and undamaged tended to have a higher topographic complexity of the seafloor.

5.4.3 Fishing gear interactions with corals in the New England region

Overall, the fishery independent trawl surveys are not particularly useful in terms of characterizing the distribution of corals in the region. Several years ago, the NEFSC's fishery independent survey and Northeast Fishery Observer Program (NEFOP) databases were searched for coral bycatch records (Packer at al. 2007). Historically, observers aboard NEFSC research vessels and commercial fishing vessels loosely described and quantified any substrate (rock, shell, etc.) or non-coded invertebrate species that were retained in the gear and were not trained to recognize corals. Although this bycatch information could possibly be useful as presence/absence data, since deep-sea corals are not the focus of the bottom trawl surveys, these data should be used with caution (John Galbraith, NOAA Fisheries Service, NEFSC, Woods Hole Laboratory, Woods Hole, MA, pers. comm.).

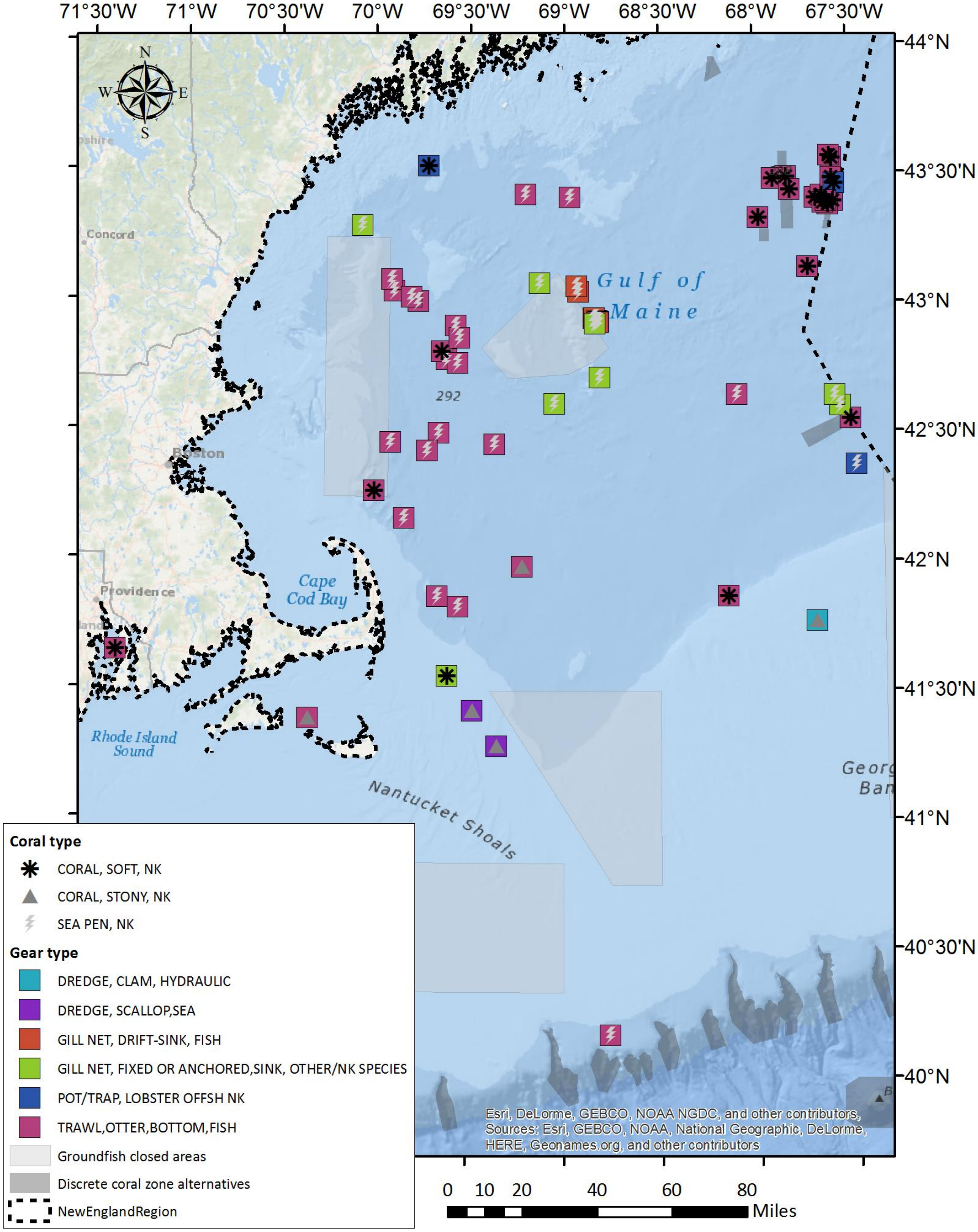
Outside of the Gulf of Maine, the general lack of deep-sea coral in both the NEFSC spring/fall groundfish trawl and scallop dredge surveys may be a function of the surveys fishing in waters shallower than where the larger deep-sea coral species are likely to occur (e.g., nearly all the scallop surveys fish < 100 m and all are < 140 m). Alternatively, these larger corals (e.g., *Paragorgia*, *Primnoa*) may have already been "fished out" in the survey areas during the 19th and 20th centuries (Packer et al. 2007). Anecdotal accounts from the period before the groundfish survey began (1950's or early 60's) reference an area on Georges Bank called "The Trees" where large corals existed in shallower water before being eventually cleared out, supposedly by foreign trawling vessels. In Canadian waters near the Northeast Channel, but within the survey region, there is a deep-sea coral protection area that is closed to fishing. John Galbraith (NEFSC, pers. comm.) stated that this was the only area he could remember where any amount of coral was encountered during the survey.

The fishery dependent deep-sea coral bycatch data collected by observers aboard commercial fishing vessels used to suffer many of the same problems (i.e. coral catches were poorly characterized). A small NEFOP database of coral bycatch collected form 1994-2009 was examined and showed to only include 39 confirmed coral entries (Packer et al. 2007). Two of these entries were labeled *Astrangia* (a genus of stony coral) and 10 additional entries were labeled as "stony corals." Basic information about the haul (gear type, year, month, depth, and geographic coordinates) was included. Gear used included otter trawls, scallop dredges, and gill nets, at depths from 5.5-253 m (depths were taken at the beginning of a trawl). Estimated or actual weights for the coral in a given haul ranged from 0.05-22.7 kg. No specimens or photographs were included.

In 2013, the NEFOP training curriculum and associated sampling protocols were significantly upgraded to improve deep-sea coral bycatch identification, retention, enumeration, and documentation (Lewandowski et al. 2016). This included the development of a Northeast deep-sea coral identification guide for the onboard observers, and standardized recording, sampling, and preservation procedures. Since the new protocols were implemented, although deep-sea coral bycatch is still low, the number of recorded and verified samples has increased, and photographic records and samples are being stored using the NEFOP Species Verification Program (Lewandowski et al. 2016). Specimens collected at sea were recently examined and classified by Northeast deep-sea coral experts, and several species of structure-forming soft corals and sea pens were identified. Improved NEFOP fishery dependent deep-sea coral bycatch data will lead to a better understanding of fisheries and deep-sea coral interactions and impacts, and guide conservation efforts of deep-sea corals habitats in the Northeast.

Since 2013, the NEFOP program has documented coral catches during 63 hauls occurring within the New England Fishery Management Council region (Map 39). Just over half (N=36) were identified as sea pens, 22 were identified as soft corals, and five were identified as stony corals. Just under half of the 63 records (N=28) have been identified to species. Documented taxa include the sea pens *Pennatula aculeata* and *Halipteris finmarchica*, the soft corals *Paramuricea placomus* and *Primnoa resedaeformis*, and one record of the stony coral *Astrangia poculata*. With a small number of exceptions, these catch records are concentrated in the Gulf of Maine. Catches occur in a variety of gears, mainly bottom trawl (N=40), and gillnet (N=17), but also pot/trap, sea scallop dredge, and clam dredge. The three dredge records were in shallow waters on Georges Bank and in the Great South Channel and captured stony corals.

Map 39 – Observed fishery interactions with deep-sea corals in the New England region, 2013-present. Data from the Northeast Fishery Observer Program.



The spatial patterns of coral bycatch by species are consistent with known distributions of corals in the Gulf of Maine. There are relatively large number of observed catches of sea pens in Wilkson Basin and surrounding Cashes Ledge. The catches in Wilkinson Basin (N=15) were taken with bottom trawls targeting plaice, pollock, and other unspecified groundfish. The catches around Cashes (N=13) were taken with gillnets, targeting pollock and other unspecified groundfish.

A relatively large number of the catch records (N=15) occur in Jordan Basin, and all of these records are of soft corals, including *P. placomus* and *P. resedaeformis*, which are the most common soft coral taxa in the Gulf of Maine. With the exception of a single lobster trap record, the Jordan Basin catches occurred in bottom trawls targeting species such as white hake, plaice, and other unspecified groundfish. Assuming straight line tow paths between haul start and end positions, it is possible that a few of these catches occurred within proposed coral management zones, but most appear to be outside them as the tow paths do not intersect the proposed management areas. Four of the observed catches (three sea pen, one soft coral) occurred in Georges Basin, but outside the Lindenkohl Knoll zone. The remaining 16 records were scattered throughout the region, roughly half in the Gulf of Maine and half outside it.

It is not possible to extrapolate from these data to estimate the annual number of interactions between fishing gear and deep-sea corals. The percentage of fishing effort that is observed ranges from around 10-40%, depending on the fishery, and a grand average may be somewhere around 10%. Observer coverage rates by gear type and fishery are designed to estimate bycatch of specific managed resources, and are not intended to accurately assess bycatch rates of corals. However, given the large number of observed fishing events, and the low number of documented interactions, it is probably fair to say that a relatively small number of trips interact with deep-sea corals.

In addition to these observed catches, evidence of fishing gear damage has been noted in recent camera surveys. Areas exhibiting direct impacts from fishing activities were observed at sites in the Gulf of Maine in Western and Central Jordan Basin, Outer Schoodic Ridge, and Georges Basin. In steep areas, paths or tracks, consistent with the setting or recovery of trap gear, were denuded of corals and associated fauna. The peaks of some ridges and nearly horizontal sections of wider rock outcrops were also denuded. Tracks observed here were consistent with impacts from mobile fishing gear. Some coral patches exhibited damage in the form of live colonies with disjunct size class structure, suggesting past impacts. In areas such as Georges Basin, colonies of *Paramuricea placomus* and associated species were often small and virtually all occurred in physical refuges such as cracks and crevices of outcrops and along the sediment-rock interface of large cobbles and boulders. Of note is that the sea star *Hippasteria phrygiana* was observed eating or preying on *P. resedaeformis* colonies at the Outer Schoodic Ridge site. These were seen on living coral colonies that had been detached from rock walls and were laying on the seafloor, possibly due to fishing activity, as one was seen next to an abandoned fishing net. Opportunistic predation by *H. phrygiana* has also been noted in Alaska on *Primnoa pacifica* that had been injured or detached by fishing gear (Stone et al. 2015). This may indicate that coral damaged by fishing gear interactions are at an increased risk of predation by sea stars, thus further reducing the chances that a coral colony will recover from gear-related injuries and impacts.

In 2011, NMFS granted the Maine Department of Marine Resources an exempted fishing permit for redfish to conduct a baseline catch and bycatch evaluation in and around Wilkinson Basin in the central Gulf of Maine. Redfish are currently harvested in this area, but many smaller individuals escape from the 6.5 in mesh nets currently in use. The experimental fishing used nets with smaller, 4.5 in mesh liners in the cod end and targeted schools of redfish that congregate on "bumps" or pinnacles that occur in the normally deep, muddy areas in the central Gulf of Maine. Since redfish seek shelter near structure-forming organisms such as deep-sea corals and sponges, as well as boulder reefs (Packer et al. 2007), concerns were raised by NMFS that the smaller mesh nets would increase the probability of increased bycatch of deep-sea corals. NMFS determined that the project could have an adverse effect on EFH, particularly on any deep-sea corals found there. Therefore, they requested that deep-sea coral bycatch be carefully monitored to enhance the understanding of deep-sea coral distribution in the Gulf of Maine and the potential effects of an expanded redfish fishery on deep-sea corals. However, by the end of the project the only coral by-catch was that of a single specimen of the common sea pen, *Pennatula aculeata*, which is ubiquitous in muddy areas of the Gulf of Maine.

5.5 Deep-sea coral associates and ecological interactions

Deep-sea coral communities exhibit a high diversity of deep-sea corals, fishes, and invertebrates relative to other communities in the deep ocean (Foley et al. 2010). Deep-sea corals have also been shown to have high microbial diversity, even among different colonies of the same species separated over a short distance (Gray et al. 2011).

TO BE DEVELOPED: Describe deep-sea biological communities with a focus on taxa other than corals (other invertebrates, fishes).

Deep-sea coral aggregations have been noted to have higher associated concentrations of fish than surrounding areas, and are believed to serve as nursery grounds and provide habitat for many species of fish and invertebrates at various life stages, including commercially important fish species (Costello et al. 2005; Auster 2007; Foley et al. 2010). There is recent evidence that deep sea corals play an important role in the early life history of some fish and shark species, providing nursery grounds and habitat for protection, reproduction, and feeding (Costello et al. 2015; Armstrong et al. 2014). Numerous types of fish have been noted to co-occur with three-dimensional deep sea coral habitat, including, for example, redfish (*Sebastes sp.*), rabbit fish (*Chimaera monstrosa*), cusk (*Brosme brosme*), cod (*Gadhus morhua*), morid cods (*Laemonema sp.*), slimeheads (e.g., *Hoplostethus sp.*), American anglerfish (*Lophius americanus*), cusk eels (e.g., *Benthocometes robustus*), cutthroat eels (e.g., *Dysommina rugosa*), and various deep water sharks (see Costello et al. 2005; Auster 2007; Henry et al. 2013; Ross et al. 2015). Fish associating with corals and other three-dimension habitat types may be seeking cover from predators, and/or sites for enhanced capture of prey (Costello et al. 2005; Auster 2007).

Many invertebrate species are directly associated with deep-sea corals. Brittle stars, sea stars, and feathery crinoids live directly on coral colonies, and smaller animals burrow into coral the skeletons (Foley et al. 2010). Recent studies in the Northeast U.S. highlight relationships of symbionts and their octocoral hosts at deep-sea coral habitats on the seamounts (Watling et al. 2011). In an extreme case of host fidelity, Mosher and Watling (2009) showed that the ophiuroid *Ophiocreas oedipus* was found only on the gorgonian *Metallogorgia melanotrichos*. *O. oedipus* is an obligate associate of *M. melanotrichos*, with young brittle stars settling on young corals and the two species then remain together for life. The brittle star may receive some refuge and feeding benefits from the coral, but the coral's relationship to the brittle star appears to be neutral. Within the EEZ, these two species were collected from Bear Seamount at 1491 and 1559 m. Another ophiuroid, *Asteroschema clavigera*, has a close relationship with *Paramurecia* sp. and *Paragorgia* sp. on both the seamounts and continental slope (Cho and Shank 2010; this was also noted in images from the 2012 Bigelow/TowCam canyon cruise). The shrimp *Bathypalaemonella serratipalma* as well as the egg cases of an unknown octopus were found on *Chrysogorgia tricaulis* on the seamounts (Pante and Watling 2011). Additionally, older colonies of *Acanella arbuscula* collected from the seamounts were host to a scale worm (Watling et al. 2011). See Watling et al. (2011) for reviews and lists of known invertebrate symbionts and their octocoral hosts worldwide.

During the *Okeanos Explorer* 2013 slope/canyon/seamount surveys, Quattrini et al. (2015) noted that the presence of certain deep-sea coral species may influence crustacean assemblage patterns. For example, the squat lobster *Uroptychus* sp. was only observed on the black coral *Parantipathes* sp. In contrast, the squat lobster *Munidopsis* spp. utilized a variety of different coral species as habitat, particularly those with structurally complex morphologies. Other observations suggesting associations between deep-sea corals and other invertebrates are documented in the dive logs from recent exploratory surveys.

A cause and effect relationship between coral/sponge presence and fish populations is hard to determine, and our understanding of relationships between deep-sea corals and fishes is speculative (e.g., Baker et al. 2012), particularly in seamount habitats (Auster 2007). Nevertheless, it has been shown, for example, that false boarfish, *Neocyttus helgae*, were associated with basalt habitats featuring gorgonian corals and sponges (on both nearly horizontal basalt sheets and steep cliffs) on Bear and other seamounts (Moore et al. 2008). Dead coral on seamounts could also be habitat for juveniles of deep-sea fish, but observations have been limited (Moore and Auster 2009).

There is also some new information from the recent exploratory surveys regarding the functional role deep-sea corals play in fish life history and ecology. As part of the BOEM Southern Mid-Atlantic Canyon Surveys 2012-2013, Baltimore and Norfolk canyons were surveyed to determine demersal fish distributions and habitat associations, including the influence of deep-sea corals and sponges (Ross et al. 2015). Although it was determined that deep-sea coral and sponge presence did not statistically influence fish assemblages in the two canyons, deep-sea coral and sponges did increase habitat complexity, which is an important factor governing the distribution of deep-sea fishes (Ross et al. 2015), and some of the fishes were closely associated with the corals. Quattrini et al. (2015) found that deep-sea coral species richness was an important variable in explaining demersal fish assemblage structure. They speculated that the corals may increase fish diversity because the fish use the corals as habitat, among other reasons.

In all areas surveyed in the Gulf of Maine, sponges (e.g., *Polymastia*, *Iophon, Phakellia/Axinella*) and anemones (e.g., *Urticina*) often occurred in high density patches amongst the more extensive corals on walls and on steep features without corals. Crustaceans such as shrimp, amphipods, aggregations of krill (*Meganyctiphanes norvegica*), and king crab (*Lithodes maja*) were commonly associated with coral communities along steep walls, and were seen foraging amongst structure-forming organisms, including corals, on the seafloor. In mud and gravel-mud habitats adjacent to hard-bottom habitats, other structure forming and non-structure forming attached and mobile invertebrates were found including brachiopods, attached anemones, the large burrowing anemone (*Cerianthus borealis*), sponges, sea stars, and the ubiquitous and abundant brittle stars.

At the Gulf of Maine sites, commercially important fish and shellfish species were observed in coral habitats, including Acadian redfish (juveniles, adults, and pregnant females), haddock, pollock, cusk, monkfish, cod, silver hake, Atlantic herring, spiny dogfish, squid, and lobster. The fish were observed searching for and catching prey that were also found among the coral, including shrimp, amphipods, krill, and other small fish. The corals seemed to provide refuge from the strong, tidally generated bottom currents.

Baillon et al. (2012) collected sea pens as trawl bycatch during routine multispecies research surveys, and found convincing evidence that several species of sea pens, including *Pennatula aculeata*, *Anthoptilum grandiflorum*, *Pennatula grandis*, and *Halipteris finmarchica*, are being directly utilized as shelter by fish larvae, mainly by those of redfish (*Sebastes* spp.). *Anthoptilum grandiflorum* appeared to be of particular importance to redfish larvae in that study. Although Baillon et al. collected sea pens from the Laurentian Channel and southern Grand Banks, because the same species of redfish and sea pens co-occur in the Gulf of Maine, similar associations could be occurring in New England.

The U.S. Gulf of Maine surveys collected relatively small numbers of *P. aculeata* via ROV from different sites during the 2014 cruise; the specimens were examined for fish larvae, and none were found. *P. aculeata* were then collected as bycatch from the 2015 NEFSC Gulf of Maine northern shrimp survey aboard the R/V *Gloria Michelle*. Eight stations on the shrimp survey generated sea pen bycatch and 186 individual *P. aculeata* were subsequently examined in the laboratory. Redfish larvae were found on *P. aculeata* at four stations, either adhering to the exterior of the colony, or entrapped within the arms or polyps (Dean et al. 2016). Because both these sea pens and those collected by Baillon et al were trawl survey bycatch, this introduces the possibility that fish larvae were extruded by viviparous ripe and running redfish during capture, and then the larvae then subsequently adhered to the sea pens. Baillon et al. (2012) reported the presence of adult redfish in all but one of their hauls; however, they found no correlation between the number of adult redfish and yield of fish larvae per sea pen colony. For this Gulf of Maine study, it was observed that there were instances of redfish extruding larvae in the checker on deck, but at other times adult redfish were noted in the catch but were not spawning. Thus, while these current results confirm some general co-occurrence and possible association between these two species in the Gulf of Maine, the strength of the relationship cannot be determined without taking the state of the co-occurring redfish in the trawls into account.

In June 2016, a two day cruise in the Gulf of Maine, again aboard the R/V *Gloria Michelle* resampled some of the previous stations where a positive association had been found between redfish larvae and *P. aculeata*, only this time a small beam trawl was used as the sampling gear, with the hope that it would only capture sea pens without adult redfish, thus eliminating the potential cross contamination described above. Over 1400 sea pens were collected over two days of beam trawling at depths around 150-180 m over soft bottoms. No larval redfish were found associated with the sea pens, but that may be because ~80 to 85% of the sea pens collected were quite small, < 25-50 mm total length (adults are upwards of 200-250 mm), suggesting a recent recruitment event, and are therefore probably too small to be used as possible nursery habitat for larval redfish. Very few of the larger sea pens were captured, and those that were caught were generally tangled in the chain rather than caught in the net, suggesting that the beam trawl may not have dug deep enough into the sediment to dislodge the animals. Thus, the role of *P. aculeata* as possible nursery habitat for larval redfish in the Gulf of Maine remains uncertain. Meanwhile, collecting of *P. aculeata* specimens to further evaluate the relationship with larval fish will continue, again through bycatch from future NEFSC Gulf of Maine northern shrimp surveys as well as Northeast Fisheries Observer Program (NEFOP) bycatch from commercial fishing vessels.

In Norway, Foley et al. (2010) applied a production function approach to estimate the link between deep-sea corals and redfish (*Sebastes* spp.) in Norway. Both the carrying capacity and growth rate of the redfish were indeed found to be functions of deep-sear coral habitat and thus they conclude that deep-sea corals can be considered as essential fish habitat; they also estimate a facultative relationship between deep-sea coral and *Sebastes* stocks.

Deep-sea corals also support other key ecosystem processes. Given the contribution of anthropogenic carbon dioxide (CO_2) to global climate change, the deep sea may provide ecosystem services in the form of CO_2 sequestration, thus removing CO_2 from the atmosphere (Foley et al. 2010), though this idea has become more controversial recently (Armstrong et al. 2014). Microorganisms associated with corals may provide other ecosystem functions in addition to cycling carbon, such as fixing nitrogen, chelating iron, producing protective antibiotics, and other beneficial activities (Gray et al. 2011). Deep-sea corals have also offered opportunities for pharmaceutical and engineering research. Some species have been used in clinical trials for cancer research or bone grafting (Foley et al. 2010).

Deep-sea corals also have cultural value, including non-use benefits such as existence value (Foley et al. 2010). The public has seen increasing opportunities in recent years to view and appreciate deep-sea ecosystems by engaging virtually in deep-sea exploration streamed via the internet.

5.6 Managed resources, fisheries, and associated human communities

The managed resources described here are those that may be impacted by the coral zone alternatives under consideration, whose fisheries use bottom-tending gear in areas overlapping the alternatives. The resources of interest were identified through the economic analysis of recent vessel trips that overlap the deep-sea coral zones under consideration. The potentially impacted fisheries, and the human communities linked to those fisheries, are also described. Some of these resources and fisheries occur exclusively in areas overlapping the Gulf of Maine or deep-sea coral zones, while others occur in both (Table 11).

Table 11 – General distribution of managed resources and their fisheries relative to coral zone alternatives under consideration

Fishery and species	Managed by	Canyon and seamount zones	Gulf of Maine zones
Northeast multispecies, large mesh	NEFMC	GB haddock, white hake	GOM cod, GOM haddock, American plaice, witch flounder, white hake, GOM winter flounder, pollock, Acadian redfish
Northeast multispecies, small mesh	NEFMC	Silver and offshore hake along shelf break, particularly in eastern canyons	Silver and red hake occur in these areas, but the fishery is precluded.
Longfin squid, butterfish	MAFMC	Longfin squid and butterfish along shelf break	No overlap noted
Monkfish	NEFMC, MAFMC	Along the shelf break in western canyons	Offshore zones (Jordan Basin, Lindenkohl)
Golden tilefish	MAFMC	Along shelf break in western canyons	No overlap noted
Deep-sea red crab	NEFMC	Along shelf break in all canyons	No overlap noted
Lobster	ASMFC	Along shelf break in all canyons	Fishery overlaps all zones; distinct fisheries inshore vs. offshore
Jonah crab	ASMFC	All shelf break particularly in western canyons	No overlap noted

5.6.1 Managed species and their associated fisheries

These sections outline pertinent aspects of the biology and status of managed fishery resources that overlap the coral zones, and describe major elements of the fisheries that target them.

5.6.1.1 Northeast Multispecies

There are 13 species managed under the Northeast Multispecies Fishery Management Plan (FMP) as large mesh (groundfish) species, based on fish size and type of gear used to harvest the fish: American plaice, Atlantic cod, Atlantic halibut, Atlantic wolffish, haddock, pollock, redfish, ocean pout, yellowtail flounder, white hake, windowpane flounder, winter flounder, and witch flounder. Several large mesh species are managed as two or more stocks based on geographic region. Three species — offshore hake, red hake, and silver hake (whiting) — are managed under a separate small mesh multispecies FMP (per Amendment 12).

5.6.1.1.1 Large mesh (groundfish) multispecies

Groundfish stocks have been managed under the Magnuson-Stevens Act (MSA) beginning with the adoption of a groundfish plan for cod, haddock, and yellowtail flounder in 1977. This plan first relied on hard quotas, but the quota system ended in 1982 with the adoption of the Interim Groundfish Plan, which controlled fishing mortality with minimum fish sizes and codend mesh regulations. The Northeast Multispecies FMP replaced this plan in 1986, initially continuing to control fishing mortality with gear restrictions and minimum mesh size, and used biological targets based on a percentage of maximum spawning potential. The FMP has had many revisions in subsequent years. Since 2010, the vast majority of the fishery has been managed with a catch share program, in which self-selected groups of commercial fishermen (i.e., sectors) are allocated a portion of the available catch.

The groundfish fishery has recently targeted the following stocks within the areas that overlap with the coral management zones under consideration:

- Canyon and seamount zones: GB haddock, white hake
- Gulf of Maine zones: GOM haddock, GOM cod, American plaice, witch flounder, white hake, GOM winter flounder, pollock, and Acadian redfish.

Framework 55 to the Northeast Multispecies FMP summarizes the status of all groundfish stocks and the groundfish fishery (NEFMC, 2016). Of the nine stocks with fisheries that potentially overlap the alternatives under consideration, two are considered overfished and overfishing is occurring (Table 12).

Table 12 – Status of selected Northeast groundfish stocks for FY2015. Source: NEFMC 2016.

	Previous Assessment		**2015 Assessments**	
Stock	Overfishing?	Overfished?	Overfishing?	Overfished?
Gulf of Maine cod	Yes	Yes	Yes	Yes
Georges Bank haddock	No	No	No	No
Gulf of Maine haddock	No	No	No	No
American plaice	No	No	No	No
Witch flounder	Yes	Yes	Yes	Yes
Gulf of Maine winter flounder	No	Unknown	No	Unknown
Acadian redfish	No	No	No	No
White hake	No	No	No	No
Pollock	No	No	No	No

The overall trend since the start of sector management through 2013 has been a decline in groundfish landings (42.3M lbs in FY2013), revenue ($58.7M in FY2013), the number of vessels with a limited access groundfish permit (1,119 in FY2013), and the number of vessels with revenue from at least one groundfish trip (316 in FY2013). The groundfish fishery has had a diverse fleet of vessels sizes and gear types. Over the years, as vessels entered and exited the fishery, the typical characteristics defining the fleet changed as well. The decline in active vessels has occurred across all vessel size categories. Since FY2009, the 30’ to < 50’ vessel size category, which has the largest number of active groundfish vessels, experienced a 38% decline (305 - 159 active vessels). The <30’ vessel size category, containing the least number of active groundfish vessels, experienced the largest (50%) reduction since FY2009 (34 - 17 vessels). The vessels in the largest (≥75’) vessel size category experienced the least reduction (30%) since FY2009 (Murphy et al 2013).

5.6.1.1.2 Small mesh multispecies

The silver, red, and offshore hake trawl fishery, commonly referred to as the “whiting” fishery, and is managed by the NEFMC under the Small Mesh Multispecies FMP. Silver hake is the primary target species. There is little to no separation of silver and offshore species in the market, and both are generally sold under the name "whiting."

Silver hake (*Merluccius bilinearis*) occur throughout the Gulf of Maine and in moderate to deeper depths on Georges Bank and in the Mid-Atlantic Bight. In the NEFSC trawl survey, larger and older fish are found further north and in deeper waters, and smaller younger fish are found in relatively shallow waters. Depth appears to be a more important determinant of silver hake distribution than temperature (NEFSC 2006). The 2013 assessment update concluded that both the northern and southern stocks were found to be not overfished and overfishing was not occurring (NEFMC 2013).

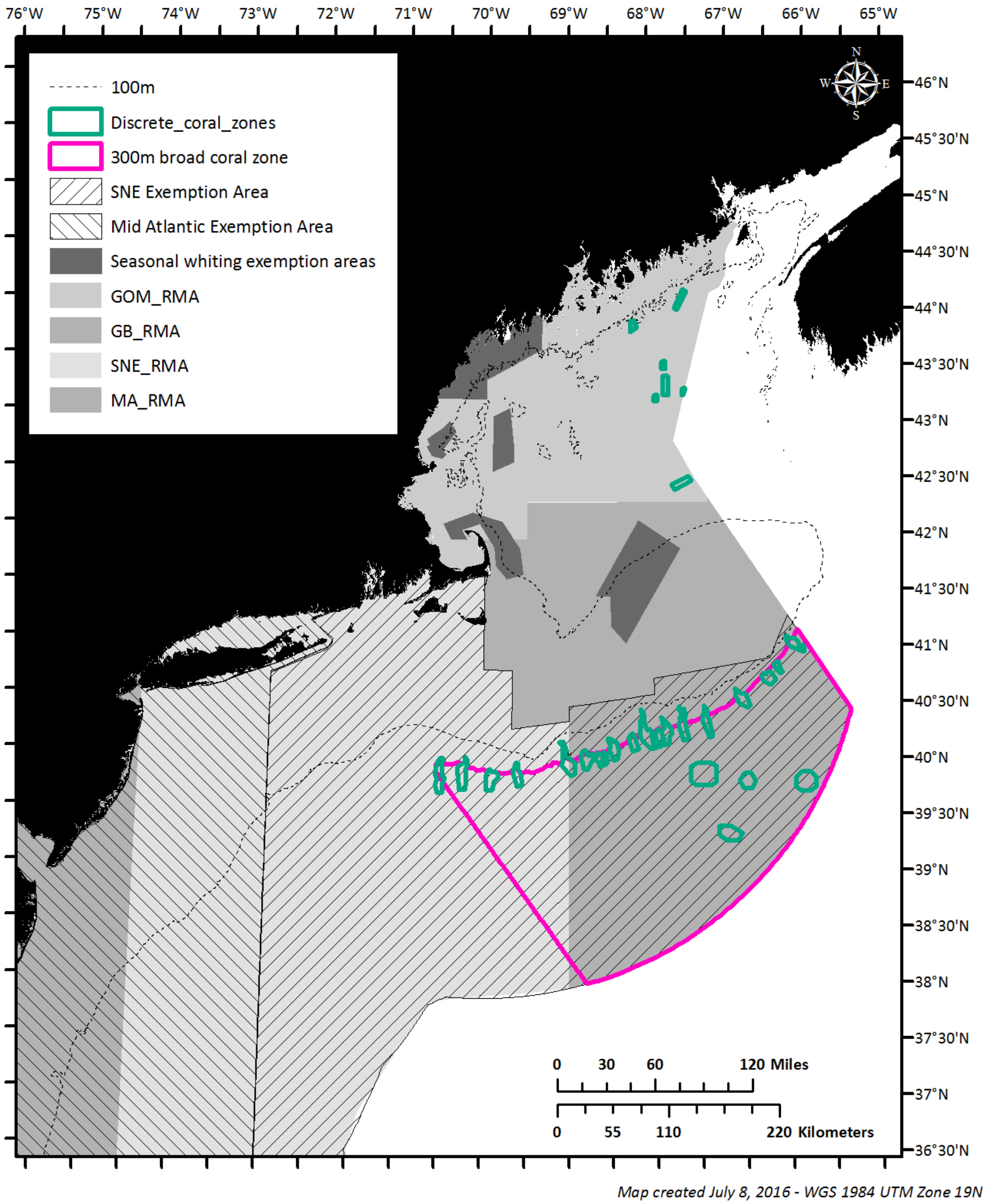
Red hake (*Urophycis chuss*) occur throughout the Gulf of Maine, on Georges Bank, and in the Mid-Atlantic Bight. They occur at a wide range of depths throughout the year, the juveniles in particular making seasonal migrations to follow preferred temperature ranges. I the Mid-Atlantic Bight, the juveniles move into deeper waters in the fall, while on Georges Bank, they are found in shallower waters in fall and nearly absent in the spring, when they occur mostly on the northern edge. Overall, juveniles have a shallower distribution in the NEFSC trawl surveys, 0-30 m in spring and 40-80 m in fall, while adults occur between 60-300 m in spring, and 50-160 m in the fall. The 2015 assessment update concluded that both northern and southern stocks of red hake were not overfished and overfishing was not occurring. Northern red hake had previously experienced overfishing (NEFMC 2015).

Offshore hake (*Merluccius albidus*) occur along the shelf/slope break. Their distribution in the Northeast U.S. extends from the southeastern flank of Georges Bank to Cape Hatteras. At night, juveniles and adults occur in the water column. During the day, both occur in mud, mud/sand, and sand habitats. As their common name implies, offshore hake have the deepest distribution of any of the hake species managed by NEFMC. There is little information available on the reproductive biology of offshore hake. Spawning appears to occur over a protracted period or even continually throughout the year from the Scotian Shelf through the Mid-Atlantic Bight. Offshore hake feed on pelagic invertebrates, e.g. euphausiids and other shrimps, and pelagic fish, including conspecifics. There is no accepted assessment of offshore hake.

Fishery. The whiting fishery is managed under the Northeast Multispecies FMP via a series of exemptions to the regulations for large mesh stocks, including a 6.5 inch codend mesh size requirement that limits catch of undersized groundfish. This exemption requires that a fishery should routinely catch under 5% of regulated multispecies (i.e., large mesh species and ocean pout). The whiting fishery also has possession limits and area restrictions on small-mesh use. Seasonally, the whiting fishery can operate within spatially-discrete exemption areas within the Gulf of Maine and Georges Bank regulated mesh areas (RMAs). Year-round, the fishery can also operate throughout the southern portion of the Georges Bank RMA, as well as throughout the Southern New England and Mid-Atlantic RMAs. The deep-sea canyons and slope are part of the Southern New England/Southern GB exemption area. The Gulf of Maine coral zones are outside the discrete exemption areas and therefore are not accessible to the whiting fishery.

Landings and revenues of silver hake in the northern and southern area have been increasing since 2006. Landings of northern silver hake have been over 1,000 mt per year ($1.2 – 2.3M annual revenue). Landings of southern silver hake have been higher, between 2,600 mt to 13,000 mt er year ($7.6 – 15.5M annual revenue). Most of the high landings trips targeting whiting are made by vessels fishing along the Mid-Atlantic continental shelf edge and along the southern edge and eastern portion of Georges Bank. Almost all trips landing over 12.7 mt and targeting whiting occurred in the Southern New England Exemption Area. Other trips targeting whiting are more broadly distributed along the Southern New England shelf edge and within statistical area 537. There is an increasing trend of trips targeting whiting in the southern stock area and landing closer to 13.6 mt per trip.

Map 40 – Deep-sea coral zones and whiting exemption areas.



5.6.1.2 Longfin inshore squid and butterfish

Longfin inshore squid (*Loligo pealeii*) is distributed primarily in continental shelf waters located between Newfoundland and the Gulf of Venezuela (Cohen 1976; Roper et al. 1984). In the northwest Atlantic Ocean, longfin squid are most abundant in the waters between Georges Bank and Cape Hatteras, where the species is commercially exploited. The stock area extends from the Gulf of Maine to Cape Hatteras. Distribution varies seasonally. North of Cape Hatteras, squid migrate offshore during late autumn to overwinter in warmer waters along the shelf edge and slope, and then return inshore during the spring where they remain until late autumn (Jacobson 2005). The species lives for about nine months, grows rapidly, and spawns year-round with peaks during late spring and autumn. Individuals hatched in summer grow more rapidly than those hatched in winter and males grow faster and attain larger sizes than females (Brodziak & Macy III 1996). At the latest assessment in 2011, overfishing was not occurring, and the overfished status could not be determined, as there is no biomass reference point (NEFSC 2011a).

Butterfish *(Peprilus tricanthus)* is a semi-pelagic/semi-demersal schooling fish, primarily distributed between Nova Scotia and Florida, but are most abundant between the Gulf of Maine and Cape Hatteras. Butterfish are fast-growing, short-lived, pelagic fishes that form loose schools, often near the surface. They winter near the edge of the continental shelf in the Middle Atlantic Bight and migrate inshore in the spring into southern New England and Gulf of Maine waters. During the summer, butterfish occur over the entire mid-Atlantic shelf from sheltered bays and estuaries out to about 200 m. In late fall, butterfish move southward and offshore in response to falling water temperatures (Cross et al. 1999, and references therein). At the latest assessment in 2014, butterfish was not overfished and overfishing was not occurring (NEFSC 2014).
Butterfish are also managed as a single stock. The most recent assessment in 2010 questioned the 2004 reference points, and while it was agreed that overfishing was not likely to be occurring, the overfished status of butterfish was classified as unknown. A benchmark assessment of the stock is ongoing.

Fishery. Longfin squid and butterfish have been managed by the MAFMC under the Atlantic Mackerel, Squid, and Butterfish FMP since 1983. The domestic longfin fishery occurs primarily in Southern New England and Mid-Atlantic waters, but some fishing also occurs along the edge of Georges Bank. Fishing patterns reflect seasonal longfin distribution patterns and effort is generally directed offshore during October through April and inshore during May through September. The fishery is dominated by small-mesh otter trawlers, but near-shore pound net and fish trap fisheries occur during spring and summer. Since 1984, annual offshore landings have generally been three-fold greater than inshore landings. Management measures for the *L. pealeii* stock include annual TACs, which have been partitioned into seasonal quotas since 2000 (trimesters in 2000 and quarterly thereafter), a moratorium on fishery permits, and a minimum codend mesh size of 1 7/8 inches.

The directed longfin squid fishery is managed via trimester quota allocations and the directed fishery is closed when 90% of the trimester quota allocations or 9% of the total domestic harvest is projected to be landed. There is also a cap on butterfish discards in the longfin squid fishery that is allocated by trimester, and closes the longfin squid fishery to directed harvest once it has been exceeded. Finally, butterfish is managed using a phased system. The system triggers butterfish possession limit reductions at different points to ensure quota is available for directed harvest throughout the fishing year. During closures of the directed longfin squid or butterfish fisheries, incidental catch fisheries for these species are permitted.

Although 1.5 percent of butterfish landed from 2007-2011 were reported as caught with gillnets, and trace amounts of these species were reported as caught with a variety of fishing gears, more than 98 percent of reported landings of all four species during this period were caught with otter trawls (midwater and bottom). Management measures implemented under the FMP restrict only the commercial fishing sectors, although there is a recreational fishery for Atlantic mackerel. Fishing for Atlantic mackerel occurs year-round, although most fishing activity occurs from January through April. Butterfish are landed year-round, with no apparent seasonal patterns.

Butterfish had been landed domestically from the late 1800s, and in the 1960s and 1970s there was a substantial increase in catch, mostly by foreign vessels. After extended jurisdiction was implemented, domestic landings expanded but then declined in the 1990s due to lower abundance and market conditions. As of January 2013, a limited domestic fishery has been reestablished, although landings have been low so far. In general discards represent a significant fraction of the catch.

5.6.1.3 Monkfish

Juvenile and adult monkfish (*Lophius americanus*, i.e., "goosefish") are common in mud habitats and occur in U.S. waters from the Hague Line to Cape Hatteras, North Carolina, in depths of at least 900 m. Monkfish undergo seasonal onshore-offshore migrations, which may relate to spawning or possibly to food availability. Female monkfish begin to mature at age 4 with 50% of females maturing by age 5 (~17 in [43 cm]). Males generally mature at slightly younger ages and smaller sizes (50% maturity at age 4.2 or 14 in [36 cm]). Spawning takes place from spring through early autumn. It progresses from south to north, with most spawning occurring during the spring and early summer. Females lay a buoyant egg raft or veil that can be as large as 39 ft (12 m) long and 5 ft (1.5 m) wide, and only a few mm thick. The larvae hatch after 1 - 3 weeks, depending on water temperature. The larvae and juveniles spend several months in a pelagic phase before settling to a benthic existence at a size of ~3 in (8 cm; NEFSC 2011).

The Monkfish FMP defines two management areas for monkfish (northern and southern), divided roughly by an east-west line bisecting Georges Bank. As of 2013 data, monkfish in both management areas are not overfished and overfishing is not occurring (NEFSC 2013c), although the 2013 stock assessment emphasized a high degree of uncertainty: "due to cumulative effects of under-reported landings, unknown discards during the 1980s, uncertainty in survey indices, and incomplete understanding of key biological parameters such as age and growth, longevity, natural mortality and stock structure contributing to retrospective patterns primarily in the northern management area." (NEFSC 2013c).

Since 1999, the monkfish fishery has been jointly managed by the NEFMC and MAFMC in two management units, a Northern Management Area in the Gulf of Maine, the Great South Channel, and most of Georges Bank, and a Southern Management Area covering the southwest part of Georges Bank, Southern New England, and Mid-Atlantic waters. Monkfish have a large, bony head and are harvested for their livers and the tender meat in their tails. During the early 1990s, fishermen and dealers in the monkfish fishery approached both Councils with concerns about the increasing amount of small fish being landed, the increasing frequency of gear conflicts between monkfish vessels and those in other fisheries, and the expanding directed trawl fishery. Since the implementation of the FMP, vessels are more commonly landing large, whole monkfish for export to Asian markets.

The Northern Management Area monkfish fishery is closely integrated with the northeast multispecies fishery, and is primarily a trawl fishery, while the Southern Management Area fishery is primarily a gillnet fishery targeting monkfish almost exclusively. These differences have resulted in some differences in management measures, such as trip limits and DAS allocations, between the two areas.

The fishery is primarily managed through the issuance of limited access permits, as well as days-at-sea (DAS) allocations, landing limits, and gear restrictions that differ in each fishery management area. Limited access monkfish vessels having a limited access groundfish permit are also required to comply with applicable Multispecies DAS and sector provisions or common pool regulations, depending on the vessel's enrollment for a given fishing year. Mesh size regulations for trawls and gillnets are set to prevent the fishery from targeting small monkfish and catching groundfish when not on a Multispecies DAS. As a measure to reduce habitat impacts, regulations promulgated under Monkfish Amendment 2 require trawl vessels in the SFMA to use nets with roller gear with a diameter no larger than 6-inches[6]. Vessels in the western Gulf of Maine may not use roller gear with a diameter larger than 12-inches.

Monkfish are harvested primarily with bottom trawls and gillnets. Scallop dredges also catch monkfish, but in much smaller amounts. No other gear types account for more than trace landings of monkfish, and there is no recreational component to this fishery. Revenues have generally increased since the mid-1980s, peaking in 1999 and 2000, before declining through 2010. Vessels using trawls typically target monkfish along the continental shelf edge, next to canyons and in deeper water than vessels fishing with gillnets.

Landings for both areas combined have generally decreased since 1999, with a peak in 2003 (26, 353 mt), and have been under 10,000 mt since 2009. Revenue was just under $20M in 2014. In 2014, there were 637 monkfish limited access permits, of which 282 were Category C permits holding limited access permits in either the multispecies (52%) or scallop (59%) fisheries, and 264 were Category D permits, primarily (98%) holding limited access multispecies permits (NEFMC 2016a).

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[6] See Section 4.1.8.1 in Monkfish Amendment 2, http://www.nefmc.org/monk/planamen/final_planamen2.html)

5.6.1.4 Golden tilefish

The golden tilefish (*Lopholatilus chamaeleonticeps*) is the largest and longest lived of all the tilefish species, and in U.S. waters ranges from Georges Bank to Key West, Florida, and throughout the Gulf of Mexico. In the SNE/MA area, golden tilefish generally occur at depths of 76-366m along the outer continental shelf and are most abundant in depths of 100-240m. Temperature may also constrain their range, as they are most abundant near the 15° C isotherm. Although golden tilefish occupies a variety of habitats, it is somewhat unique in that it creates and modies existing vertical burrows in the sediment as its dominant habitat in U.S. waters. The most recent stock assessment, SAW 58, determined that tilefish is not overfished and overfishing is not occurring (NEFSC 2014).

The MAFMC has managed golden tilefish fishery within the Tilefish FMP since 2001. for the fishery that occurs north of the Virginia/North Carolina border. An original intent was to address the overfished status of the species (the stock was considered rebuilt in 2014). Amendment 1 to the Tilefish FMP, implemented in 2009, adopted an IFQ program, initially with 13 quota holders, based primarily on historical participation in the fishery. Since then, the IFQ fishery has been allocated 95% of the annual quota. The open access incidental fishery, under a 500lb. trip limit, is allocated the remainder. (MAFMC 2016).

During 2001-2015, golden tilefish landings have averaged 1.9 million pounds, ranging from 1.3 (2015) to 2.5 (2004) million pounds. Based on dealer data from 2011 through 2015, the bulk of the golden tilefish landings are taken by longline gear (98%) followed by bottom trawl gear (~1%). No other gear had any significant commercial landings. Minimal catches were also recorded for hand line and gillnets (MAFMC 2016). There is a minimal recreational fishery for this species, with less than 8,300 lb. landed annually for the last 30 years. In 2015, just 4% of landings were from Statistical Area 526 and 525 on Georges Bank, with all other landings from areas to the west and south (MAFMC 2016).

5.6.1.5 Deep-sea red crab

Deep-sea red crab is a data poor stock. Red crab inhabit deep water, are rarely caught in the trawl survey, and there is little information about their life history. In U.S. waters, deep-sea red crab (*Chaceon quinquidens*) occurs in the Gulf of Maine, along the continental slope from Georges Bank to the Gulf of Mexico, and on the seamounts. The stock status for deep-sea red crab is unknown.

There is limited information about red crab spawning locations and times. Erdman et al. (1991) suggested that the egg brooding period may be about nine months, at least for the Gulf of Mexico population, and larvae are hatched in the early spring there. There is no evidence of any restricted seasonality in spawning activity in any geographic region of the population, although a mid-winter peak is suggested as larval releases are reported to extend from January to June (Wigley et al. 1975; Haefner 1977; Lux et al. 1982; Erdman et al. 1991; Biesiot and Perry 1995).

Based on laboratory observations, larvae probably consume zooplankton. Juveniles and adults are opportunistic feeders. Post-larval, benthic red crabs eat a wide variety of infaunal and epifaunal benthic invertebrates (e.g. bivalves) that they find in the silty sediment or pick off the seabed surface. Smaller red crabs eat sponges, hydroids, mollusks (gastropods and scaphopods), small polychaetes and crustaceans, and possibly tunicates. Larger crabs eat similar small benthic fauna and larger prey, such as demersal and mid-water fish (*Nezumia* and myctophids), squid, and the relatively large, epibenthic, quill worm (*Hyalinoecia artifex*). They can also scavenge deadfalls (e.g., trawl discards) of fish and squid, as they are readily caught in traps with these as bait and eat them when held in aquaria.

Only male red crabs are landed in the trap fishery, which is managed via the Atlantic Deep-Sea Red Crab FMP, implemented in 2002. The species is managed as a single stock, and red crabs in the Gulf of Maine are not included in reference point, biomass, or management calculations. Additional details are provided in the 2008 Data Poor Stocks Working Group Report (NEFSC 2009), which found that as of 2008, the stock status was unknown.

The NEFMC has managed the deep-sea red crab fishery under a FMP since 2002. In 1999, members of the red crab fishing industry requested that the Council development a FMP to prevent overfishing of the red crab resource and address a threat of overcapitalization of the red crab fishery. There had been a small, directed fishery off the coast of New England and in the Mid-Atlantic since the early 1970s. Though the size and intensity of this fishery has fluctuated, it has remained small relative to more prominent fisheries (e.g., groundfish, sea scallops, and lobster).

The FMP established a limited access permit program for qualifying vessels with documented history in the fishery, days-at-sea limits, trip limits, gear restrictions, and at-sea processing limits. The directed, limited access red crab fishery is a male-only fishery. In 2011, Amendment 3 implemented Annual Catch Limits (i.e., the fishery is closed when the quota is reached) and accountability measures and revised the management measures by eliminating DAS and the vessel trip limit. Although there is an open access permit category, and 1,295 such permits were issued in 2016 (NMFS, 2016), the small possession limit (500 pounds per trip) has kept this fishery component very small. The directed fishery is limited to using parlor-less crab pots, and is considered to have little, if any, incidental catch of other species. There is no known recreational fishery for deep-sea red crab.

The catch limit has been stable since 2002 at 1,775 mt and landings have fluctuated between about 1,000-1,700 during this time. The red crab fishery is a small, market-driven fishery, and landings are very closely tied to market demand. When landings are low, it is often because the demand for red crabs has decreased and the fleet has targeted other more profitable species. Catch is attributed to three regions: Georges Bank/Southern New England, New Jersey, and Delmarva. The GB/SNE area encompsses the area the canyon and/or seamount deep-sea coral zone areas considered in this action. Through 2007, the largest proportion of landings was attributed to the GB/SNE area.

Since 2013, had the largest proportion has been attributed to New Jersey (NEMFC 2016b).

Since at least 2014, limited access red crab permits have been issued to six vessels. Fishery revenue since 2002 has averaged $3.0M per year (NEFMC 2016b). The fishery occurrs out of New Bedford, MA, where a red crab processing plant has been in operations since 2009 (NEFMC 2011; www.atlanticredcrab.com).

5.6.1.6 American lobster

American lobsters (*Homarus americanus*) are benthic crustaceans found in U.S. waters from Maine to New Jersey inshore and Maine to North Carolina offshore. Lobsters tend to be solitary, territorial, and exhibit a relatively small home range of 5-10 square kilometers, although large mature lobsters living in offshore areas may migrate inshore seasonally to reproduce, and southern inshore lobsters may move to deeper areas to seek cooler temperatures on a seasonal or permanent basis.

The 2009 lobster stock assessment assumed three distinct stocks, Gulf of Maine, Georges Bank, and Southern New England. However, the 2015 lobster stock assessment combined the Gulf of Maine and Georges Bank stocks to more effectively model recruitment size compositions and seasonal variations in the location of large females (ASMFC 2015). The 2015 lobster stock assessment concluded that the SNE stock is depleted (at record low levels), while the GOM/GB stock is at record abundance. While the assessment concluded that neither the GOM/GB stock nor the SNE stock is experiencing overfishing, the overfishing determination for SNE may be misleading and unreliable, because the methods used to estimate fishing mortality are not designed for such low biomass situations (ASMFC 2015).

The lobster fishery is one of the top fisheries on the U.S. Atlantic coast (>$461M total revenue in 2013). It is managed by the Atlantic States Marine Fisheries Commission in state waters (0-3 nm from shore) and by NMFS in federal waters (3-200 mi from shore). The fishery occurs within the three stock units: Gulf of Maine, Georges Bank, and Southern New England, each with an inshore and offshore component. The management areas most relevant to this action are Area 1 (inshore Gulf of Maine) and Area 3 (offshore Gulf of Maine, Georges Bank, and Mid-Atlantic Bight to the EEZ).

The fishery is managed using minimum and maximum lobster sizes; limits on the number and configuration of traps; possession prohibitions on egg-bearing females and v-notched lobsters, lobster meat, or lobster parts; prohibitions on spearing lobsters; and limits on non-trap landings. Between 1981 and 2013, 96% of all lobster was harvested using traps (ASMFC 2015).

The Gulf of Maine stock supports the largest portion of the fishery (average of 79% of the U.S. landings between 1981 and 2013; over 90% since 2009; 95% in 2013). The fishery is prosecuted mainly with small, 22-42’ vessels that conduct day trips within about 12 miles of shore. Some larger vessels fish offshore in the Gulf of Maine. Maine vessels account for most of the fishing effort, and the number of traps fished increased substantially between 1993 and 2002, and has remained at over 3.5 million since then. Trap efforts in New Hampshire and Massachusetts are much smaller in magnitude compared to Maine; since 1989, effort in New Hampshire has increased and Gulf of Maine effort in Massachusetts has declined.

For Georges Bank, the offshore fishery dominates, however inshore Georges Bank catch from statistical area 521 has increased in recent years. On Georges Bank, most of the effort is on multi-day trips taken using larger, 55-75' vessels. There is day trip fishery in the Outer Cape Cod area. According to the 2009 stock assessment, the number of traps fishing on Georges Bank is "not well characterized, due to a lack of mandatory reporting, and/or a lack of appropriate resolution in the reporting system" (ASMFC 2009, p 42). Data from Massachusetts, which constitutes a large fraction of the Georges Bank fishery, indicate that the number of traps remained relatively stable between 1994 and 2007.

In Southern New England, the offshore fishery has dominated total catch since the late 1990s, due to dramatic declines in the catch from inshore SNE (attributed to waters increasingly exceeding the lobster thermal stress threshold of 20° C). Southern New England has been the second largest fishery (average of 22% of the U.S. landings between 1981 and 2001), but recent declines in SNE landings (≤9% since 2002) make this component more on par with the Georges Bank fishery (5% from 1981 to 2013). In Southern New England, there is a nearshore, small vessel day boat fleet as well as an offshore fleet that takes multi-day trips to the canyons along the edge of the continental shelf.

An average of 11,396 vessels were issued commercial lobster permits each year between 2009 and 2013, including permits issued by each state (n=7) from Maine to New Jersey for fishing in their respective state waters (73%) and by NMFS (27%) for the federal fishery (Table 13). The State of Maine is the jurisdiction that has issued the largest number of permits (45%). Vessels with Federal lobster permits in 2013 had homeports in 15 states, 48% from Maine and 28% from Massachusetts (NMFS 2016).

Table 13 – Commercial lobster licenses issued by jurisdiction, 2009-2013. Source: ASMFC 2015

Year	ME	NH	MA	RI	CT	NY	NJ	NMFS	Total
2009	5,376	365	1,314	979	220	375	109	3,176	11,914
2010	5,226	347	1,278	948	206	360	109	3,141	11,615
2011	5,155	333	1,245	922	180	344	109	3,119	11,407
2012	5,079	334	1,214	905	161	334	109	3,003	11,139
2013	4,979	322	1,188	874	142	326	109	2,963	10,903
Average	**5,163**	**340**	**1,248**	**926**	**182**	**348**	**109**	**3,080**	**11,396**

Lobster landings have generally increased over time, from about 5,000 mt in the 1920s to an average of about 59,000 mt between 2009 and 2013 (Table 14). Given that the Gulf of Maine supports the largest portion of the fishery and Maine is the state with the most permitted vessels, it follows that Maine has the largest portion of landings, about 83% between 2009 and 2013 (ASMFC 2015a).

Table 14 – Total lobster landings (mt) by state, 2009-2013. Source ASMFC 2015.

	ME	NH	MA	RI	CT	NY	NJ + south	Total
2009	36,828	1,354	5,929	1,289	187	331	388	**46,306**
2010	43,654	1,654	6,094	1,328	201	369	366	**53,666**
2011	47,590	1,777	6,333	1,249	90	156	341	**57,536**
2012	57,446	1,905	6,753	1,219	110	125	450	**68,008**
2013	57,797	1,729	6,894	978	58	112	359	**67,927**
Average	**48,663**	**1,684**	**6,401**	**1,213**	**129**	**219**	**381**	**58,689**

In 2016, the ASMFC sent mail surveys to 97 commercial lobster permit holders with a trap allocation in Area 3. Of the 34 permit holders who returned surveys, 19 had fished in the area the canyon and/or seamount deep-sea coral zone areas considered in this action (Whitmore, 2016).

5.6.1.7 Jonah crab

Jonah crab (*Cancer borealis*) are distributed in the waters of the Northwest Atlantic Ocean primarily from Newfoundland, Canada to Florida. The Jonah crab life cycle is poorly understood; what is known is largely compiled from a patchwork of studies that have both targeted and incidentally documented the species. Female crabs (and likely some males) move inshore during the late spring and summer. Motivations for this migration are unknown, but could be due to maturation, spawning, and molting. It is also widely accepted that migrating crab move back offshore in the fall and winter. Due to the lack of a widespread and well-developed aging method for crustaceans, the age, growth, and maturity of Jonah crab is poorly described. The status of the Jonah crab resource is unknown, as no range-wide stock assessment has been conducted (ASMFC 2015b).

The ASMFC instituted a Jonah crab FMP in 2015, prompted by the American Lobster Board's concern for potential impacts to the status of the Jonah crab resource given the recent and rapid increase in landings. Jonah crab has long been lobster fishery bycatch, but in recent years, there has been increasing targeted fishing pressure and growing market demand for crab. Over time, a mixed crustacean fishery has emerged that can target both lobster or crab or both at different times of year.

Commercial Jonah crab landings were two to three million pounds throughout the 1990s, but steadily rose to over 17 million pounds in 2014. A similar increase occurred in the value of fishery, as ex-vessel values grew from roughly $1.5 million in the 1990s to an estimated $12.7 million in 2013. Landings in 2014 predominately came from Massachusetts (70%), followed by Rhode Island (24%). The practice of declawing the Jonah crab while fishing lobster traps and pots occurs in the mid-Atlantic and constitutes less than 1% of the total Jonah crab fishery. The magnitude of recreational landings is unknown, but is likely minimal (ASMFC 2015b).

5.6.2 Human Communities

This section describes the human communities that could be affected by the alternatives under consideration in this amendment.

5.6.2.1 Defining affected communities

This amendment considers and evaluates the impact management alternatives may have on people's economy, way of life, traditions, and community. These social and economic impacts may come from changes in fishery flexibility, opportunity, stability, certainty, safety, and/or other factors. While individuals alone could experience these impacts, it is likely that community impacts would also occur.

The alternatives under consideration could affect communities throughout the Northeast. Consideration of the social impacts on these communities from proposed fishery regulations is required as part of the National Environmental Policy Act (NEPA) of 1969 and the Magnuson Stevens Fishery Conservation and Management Act (Magnuson Stevens Act) of 1976. A "fishing community" is defined in the Magnuson-Stevens Act, as amended in 1996, as "a community which is substantially dependent on or substantially engaged in the harvesting or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and United States fish processors that are based in such community" (16 U.S.C. § 1802(17)). For detailed descriptions of the affected human communities and fisheries affected by the Omnibus Amendment refer to the respective FMPs available from the New England and Mid-Atlantic Councils and the Atlantic States Marine Fisheries Commission.

Given the geographic scope of this action, and the fact that it will influence fishing with various gear types, these alternatives will impact numerous fishing communities. Identifying specific communities that will be impacted is can be difficult and uncertain. In part this reflects challenges with the confidential nature of the information used to narrow the focus to individual communities in the analysis of fishing dependence. Data must be presented so that proprietary information such as landings or revenue cannot be attributed to an individual vessel or a small group of vessels. This is particularly difficult when presenting information on small ports and communities that may only have a small number of vessels, such that information can easily be attributed to a particular vessel or individual.

The communities that are likely to experience significant impacts from the alternatives under consideration include those that support fishing that would be prohibited by this action (e.g., excluded from certain coral zones). The specific communities of interest were identified through the economic analysis of recent vessel trips that overlap the deep-sea coral zones under consideration. It is important to note that this is not an exhaustive list of communities that could be impacted. It is necessary to consider the impacts of the proposed alternatives across all communities, particularly those identified as communities of interest in their respective FMPs.

Community characteristics are described in other publications. Brief snapshots of the Human Communities and Fisheries of the Northeast with the most recent data available for key indicators for Northeastern fishing communities related to dependence on fisheries and other economic and demographic characteristics can be found at http://www.nefsc.noaa.gov/read/socialsci/communitySnapshots.php . More detailed profiles providing in-depth information regarding the historic, demographic, cultural, and economic context for understanding a community's involvement in fishing can be found at http://www.nefsc.noaa.gov/read/socialsci/communityProfiles.html.

5.6.2.2 Specific communities of interest

Communities of interest were identified through the economic analysis of recent (2010-2015) vessel trips that overlap the deep-sea coral zones under consideration and were using bottom-tending fishing gear (see Habitat PDT report: "Fishing Activity in Coral Zones"). The economic analysis used fishing trips as reported through VTRs. However, only a small portion of the GOM lobster fishery operates with a federal VTR requirement. Thus, the fishery participation reported using VTR alone is likely an underestimate. Other data sources will be used as appropriate.

Between 2010-2015, there were at least 90 communities between Maine and North Carolina that landed species, with bottom-tending fishing gear, from the areas under consideration in this action (not including the No Action alternative).

TO BE DEVELOPED: Describe the fishing communities and their involvement in the fisheries that overlap these areas, considering data confidentiality restrictions.

5.7 Essential Fish Habitat

TO BE DEVELOPED: Describe EFH designations along shelf/slope break and on seamounts, as well as overlapping coral areas in GOM. Base on pending OHA2 designations.

5.8 Protected resources

TO BE DEVELOPED.

6 Environmental impacts of the alternatives

TO BE DEVELOPED.

6.1 Physical habitat and EFH

TO BE DEVELOPED.

6.2 Deep-sea corals

See separate document for preliminary analysis.

6.3 Fisheries and human communities

See separate document for preliminary analysis.

6.4 Protected resources

TO BE DEVELOPED.

7 Cumulative effects analysis

TO BE DEVELOPED.

8 Compliance with the Magnuson Stevens Fishery Conservation and Management Act

TO BE DEVELOPED.

9 Compliance with the National Environmental Policy Act

TO BE DEVELOPED.

10 Relationship to other applicable laws

TO BE DEVELOPED.

11 References

11.1 Glossary

TO BE DEVELOPED.

11.2 Literature cited

Note: this list is a work in progress and is missing some citations referenced in the text.

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