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MEMORANDUM

DATE: March 15, 2016

TO: Habitat Committee

FROM: Habitat Plan Development Team

SUBJECT: **Recommended updates to deep-sea coral amendment alternatives**

This memo summarizes updates to coral management alternatives recommended by the Habitat Plan Development Team. The PDT met twice during December 2015 (see meeting summaries from December 4 and 15) to discuss updated data relevant to the amendment and develop recommendations. The recommendations were reviewed and finalized during a conference call on February 22. Additional information about data sources and how they were used, as well as a more detailed rationale for each recommendation, are provided in Appendix 1.

Currently, the draft amendment (http://s3.amazonaws.com/nefmc.org/5-150917_NEFMC_Coral_Amendment.pdf) includes the following range of alternatives:

1. Broad zone from the edge of the continental shelf to the Exclusive Economic Zone boundary. See section 4.1 of the amendment document. Under No Action, a broad zone would not be designated. There are three action alternatives based on landward boundaries at 300, 400, and 500 meter depth contours.
2. Discrete zones in specific locations overlapping and outside the broad zones. See section 4.2 of the amendment document. Under No Action, discrete zones would not be designated. Action alternatives propose discrete zones in twelve canyons, four seamounts, and two areas in the Gulf of Maine, with each zone as a separate alternative.
3. Management measures for the zones are described separately in section 4.3 of the amendment document, and include fishing restriction alternatives, provisions that would make coral zone changes frameworkable, and alternatives to allow special access program fishing, exploratory fishing, and to promote research in coral zones.

Updated recommendations are described below.

I. Broad zone recommendations

The proposed broad zones are large areas generally intended to freeze the footprint of fishing in the deep waters off New England beyond the continental shelf break. As currently conceived, the three landward boundaries are based on depth contours. Each successive increase in starting depth generates a progressively smaller zone that encompasses fewer corals but is likely to have less overlap with fishing activity.

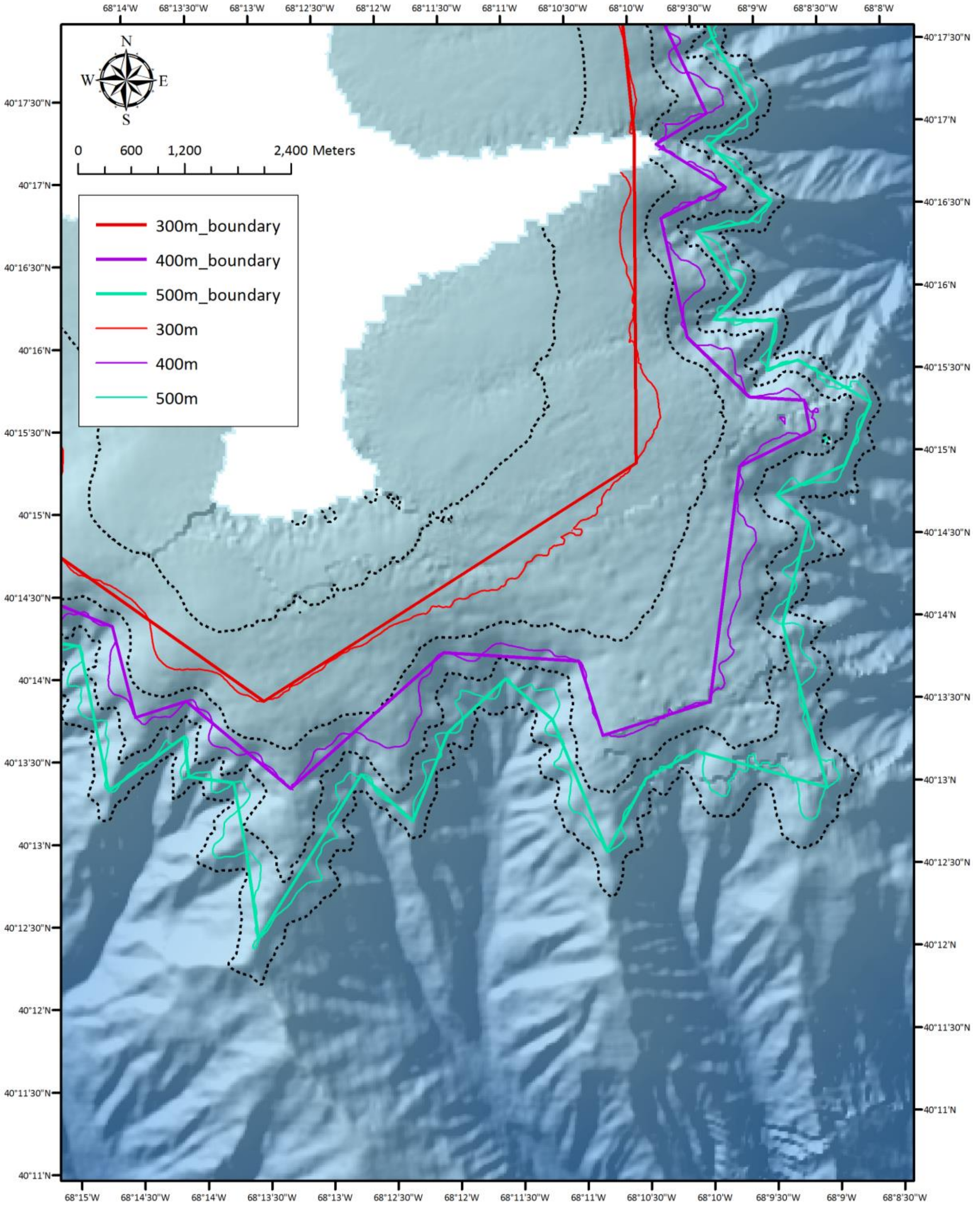
The Mid-Atlantic Fishery Management Council (MAFMC) experience is instructive here. Their process began with contour-based zones. However, a contour-based management area boundary is ambiguous, and it would be impossible for both fishermen and enforcement officers to know what side of a boundary a vessel was on. During final action, the MAFMC recommended a broad zone with a landward boundary approximating a depth of 450 meters, but defined using straight line segments. The resulting boundary uses the fewest number of segments possible while adhering to minimum (400 m) and maximum (500 m) depth criteria. While the MAFMC's approach for defining the broad zone boundary was specified during final action, the actual boundary was generated subsequently. Stakeholders commented that it would have been easier for them to comment on the broad zone proposal if a straight line boundary had been available earlier in the process.

Therefore, the PDT is recommending that the current NEFMC alternatives based on 300, 400, and 500 meter depths be updated with straight line boundaries. Using the MAFMC approach, straight line boundaries were generated that approximate the target depth, but have as few line segments as possible, while remaining within the adjacent contours (see Table 1). Briefly, these simplified boundaries were created by removing most of the vertices from the original contour, with a 500 meter tolerance for how far (distance over ground) the simplified boundary could deviate from the original contour. Because 500 meters is too large of a tolerance is some very steep areas where the contours are very closely spaced, some vertices were adjusted individually to ensure that the resulting boundary remained within the buffer contours. Map 1 compares the contours with the updated boundaries. While these boundaries remain complex, they have vastly fewer vertices than the original contours. The complexity of the simplified boundaries increases with depth because the topography becomes more complex and more line segments are required to remain within the buffer contours. The full extent of the three broad zones is shown on

Table 1 – Broad zone landward boundary criteria

Zone	Target depth of landward boundary	Minimum depth of landward boundary	Maximum depth of landward boundary
300 m	300 m	250 m	350 m
400 m	400 m	350 m	450 m
500 m	500 m	450 m	550 m

Map 1 – Broad coral zones on the western shoulder of Oceanographer canyon. Heavy colored lines indicate simplified boundaries, with finer lines of a corresponding color indicating the original contour. Buffer contours of 250, 350, 450, and 550 meters are shown in dotted black lines. Note that the less complex terrain associated with the shallower boundaries allows for lines with fewer vertices.



II. Discrete zone recommendations

Recommended changes to the discrete zone alternatives include additional discrete zones as well as boundary changes to some of the existing zones. All of the recommendations are based on additional data not available to the Council in April 2012 when the initial range of alternatives was approved for analysis. These data include higher resolution bathymetry and slope data that better reflect the true shape of the seafloor in the canyons as well as in two areas in the Gulf of Maine, the outputs of a coast-wide habitat suitability model, and numerous survey tows made using remotely operated vehicles and towed camera systems. The survey tow locations were selected using the new bathymetric data and suitability model outputs.

A. Canyons

In the canyons off Georges Bank and Southern New England, the existing discrete zone alternatives are based largely on historical presence/absence records of deep-sea corals, a small number of ROV dives, and the inference that canyon habitats suitable for corals are most likely to occur in areas of high slope. The existing canyon zone boundaries were drawn to encompass high slope areas, using a lower resolution slope data set than is presently available. At the time of initial coral zone development (2010 to early 2012), only a small number of the Georges Bank canyons had any appreciable amount of survey effort for corals. For canyons that were not well surveyed for corals prior to 2012 (i.e. the majority of canyons), the PDT recommended coral zones in a subset of canyons where the presence of suitable habitat types could be reasonably inferred based on the terrain. Specifically, zones were recommended for canyons that incised the shelf and had high vertical relief where the canyon crossed the shelf break. The PDT did not recommend coral zones in canyons that do not incise the shelf or had lower vertical relief at the shelf break, presuming that rock outcrop habitats would occur less frequently in these areas. Overall, combining the historical coral data set with available bathymetric and slope data, the original list of recommendations included twelve of the major Georges Bank and Southern New England canyons.

Recently collected data warrant a reconsideration of these recommendations. Based on data collected beginning in 2012 during towed camera and remotely operated vehicle (ROV) surveys, deep-sea corals occur throughout minor canyons not previously recommended, as well as in larger canyons previously recommended because they were likely to have suitable habitats, but where coral observations were previously scant or non-existent. Occurrence of corals was verified in all of the existing canyon zones, so none of these areas are recommended for removal. The PDT recommends adding eight new canyons where corals have been directly observed to the list of discrete canyon coral zones. Recommended changes are summarized in Table 2.

Various data sources guided dive site selection during recent surveys, and these data are also useful for developing coral zone boundaries. Site selection during the towed camera and ROV surveys was guided by a variety of considerations, including the historical coral records, the results of a habitat suitability model, and recently collected high resolution multibeam bathymetry data. Additional dive sites were chosen to investigate specific geologic phenomena and some dives were conducted in areas not predicted to be highly suitable for corals, to ground truth suitability model results. The PDT recommends updating existing discrete zone boundaries and generating new zone boundaries using the following sources of data:

- High resolution bathymetry and slope, in particular areas where slope exceeds 30 degrees
- Areas of high and very high predicted habitat suitability for soft corals
- Areas with documented presence of corals in the historical database, or according to the recent ROV and towed camera dives

Additional details about these data sources, the boundary development approach in general, and the characteristics of each discrete zone are provided in Appendix 1. Overall, the updated boundaries are more complex and better reflect the shape of the canyon as depicted in recently collected high-resolution terrain data.

Note that there are additional minor canyons on the southern margin of Georges Bank that have not been surveyed for corals. With the exception of Shallop Canyon, these canyons appear to be unnamed. Nonetheless, these canyons are clearly visible in the high-resolution bathymetric data. Using terrain data and Geographic Information System software, it would be possible to characterize these canyon in terms of their depth, slope, degree of continental shelf incision, vertical relief, etc., and compare these characteristics to areas where coral habitats have been positively identified. Many of these minor canyons have areas of high and very high likelihood of suitable habitat as predicted by the coral habitat suitability model. This type of terrain analysis, which would be similar to work previously done by the PDT in 2011, could lead to additional canyon zone recommendations that would be based on inference of suitable habitats. Alternatively, these canyons would to a large extent be encompassed within any of the broad zone alternatives. However, it is likely that the deeper broad zone alternatives would exclude some areas in the heads of these canyons as most of the discrete canyon zones have minimum depths around 300m (shelf-incising canyons) to 400m (slope confined canyons). The PDT requests Committee guidance as to whether or not such an analysis should be developed.

Table 2 – Recommended canyon coral zones, listed west to east.

Canyon	Current or newly recommended area	Boundary recommendation
Alvin	Current	Update
Atlantis	New	Update
Nantucket	New	Update
Veatch	Current	Update
Hydrographer	Current	Update
Dogbody	New	Update
Clipper	New	Update
Sharpshooter	New	Update
Welker	Current	Update
Heel Tapper	Current	Update
Oceanographer	Current	Update
Filebottom	New	Update
Chebacco	New	Update
Gilbert	Current	Update
Lydonia	Current	Update
Powell	Current	Update
Munson	Current	Update
Nygren	Current	Update
Unnamed canyon between Nygren and Heezen	New	Update
Heezen	Current	Update

B. Seamounts

The existing range of alternatives includes all four seamounts within the U.S. EEZ. Prior to 2012, ROV surveys had been conducted on Bear Seamount and Retriever Seamount, and the PDT inferred that the other two seamounts were likely to have coral habitats as well. Presently, all four seamounts within the EEZ have been surveyed for corals using ROV or AUV (autonomous underwater vehicle) technology. While the current suite of ROV and AUV dive results provides more robust support for these designations than the data used in 2012, the PDT is not recommending any changes to the draft management alternatives previously approved by the Council (Table 3). High-resolution multibeam bathymetry define the spatial extent of each seamount feature. These data were available during initial development of the seamount zones and remain the best available bathymetric data for the seamounts. Details for each discrete seamount zone are summarized in Appendix 1, including the locations and results of recent dives.

Table 3 – Recommended seamount coral zones, listed west to east.

Seamount	Current or newly recommended area	Boundary recommendation
Bear	Current	No change
Mytilus	Current	No change
Physalia	Current	No change
Retriever	Current	No change

C. Gulf of Maine

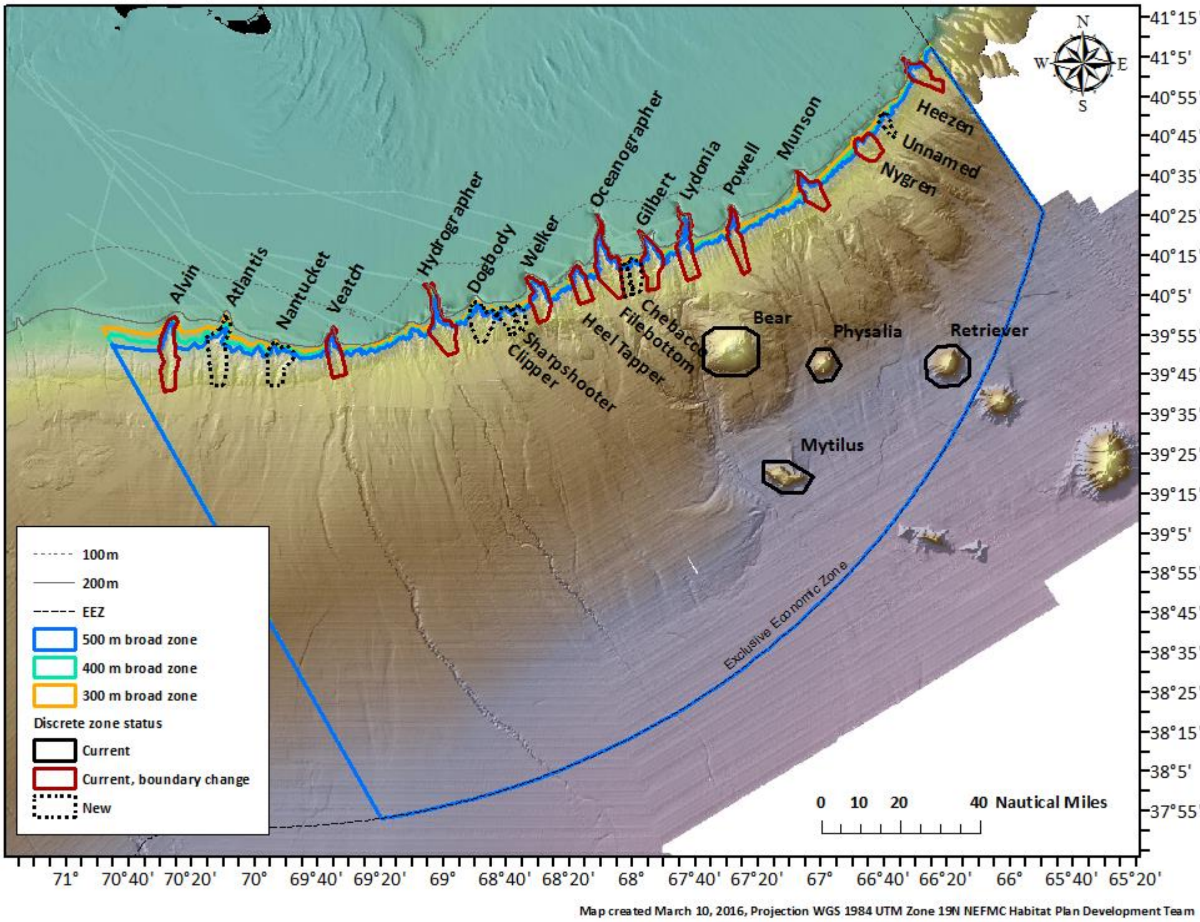
In the Gulf of Maine, the existing discrete zone alternatives near Mt. Desert Rock and in four sub-areas in Western Jordan Basin are based largely on occurrence of corals. Specifically, 2002 and 2003 ROV dives identified corals near Mt. Desert Rock and in three of the Western Jordan Basin sub-areas. The remaining Western Jordan Basin sub-area (Area 4) was recommended based on inference of suitable habitat. While Jordan Basin appears relatively featureless on nautical charts, recently collect high resolution data indicate areas of more complex terrain, and corals have been documented on these topographic highs.

Updated data include three years of additional dives with ROVs and towed camera systems in western and central Jordan Basin, Outer Schoodic Ridge, the Lindenkohl Knoll area of Georges Basin, and west of Mount Desert Rock, plus new bathymetric maps for parts of Western Jordan Basin and Outer Schoodic Ridge. In addition, the Mount Desert Rock area was recently mapped at 1/3 arc second (roughly 10m) resolution. The PDT is recommending that some of the existing alternatives be retained as-is, that three new areas be added, and the fourth sub-area in Western Jordan Basin be removed. Recommended changes are summarized in Table 4. Unlike in the canyon and seamount regions, comprehensive high resolution bathymetric mapping is unavailable to fully delineate the spatial extent of seafloor features that might provide suitable habitat for deep-sea corals. Therefore, the recommended areas in the Gulf of Maine are closely tied to locations where corals have been directly observed, or in adjacent habitats near the dive sites where coral habitats can be reasonably inferred based on the terrain. This is consistent with the approach taken in 2012 for coral zones in the Gulf of Maine, where four of the five zones were recommended on the basis of ROV survey results. All of the areas currently recommended have at least one recent (since 2002) dive documenting the presence of deep-sea corals, and the Outer Schoodic Ridge and the 114 Bump area in Western Jordan Basin has been especially well characterized. Additional details for each discrete zone are provided in Appendix 1.

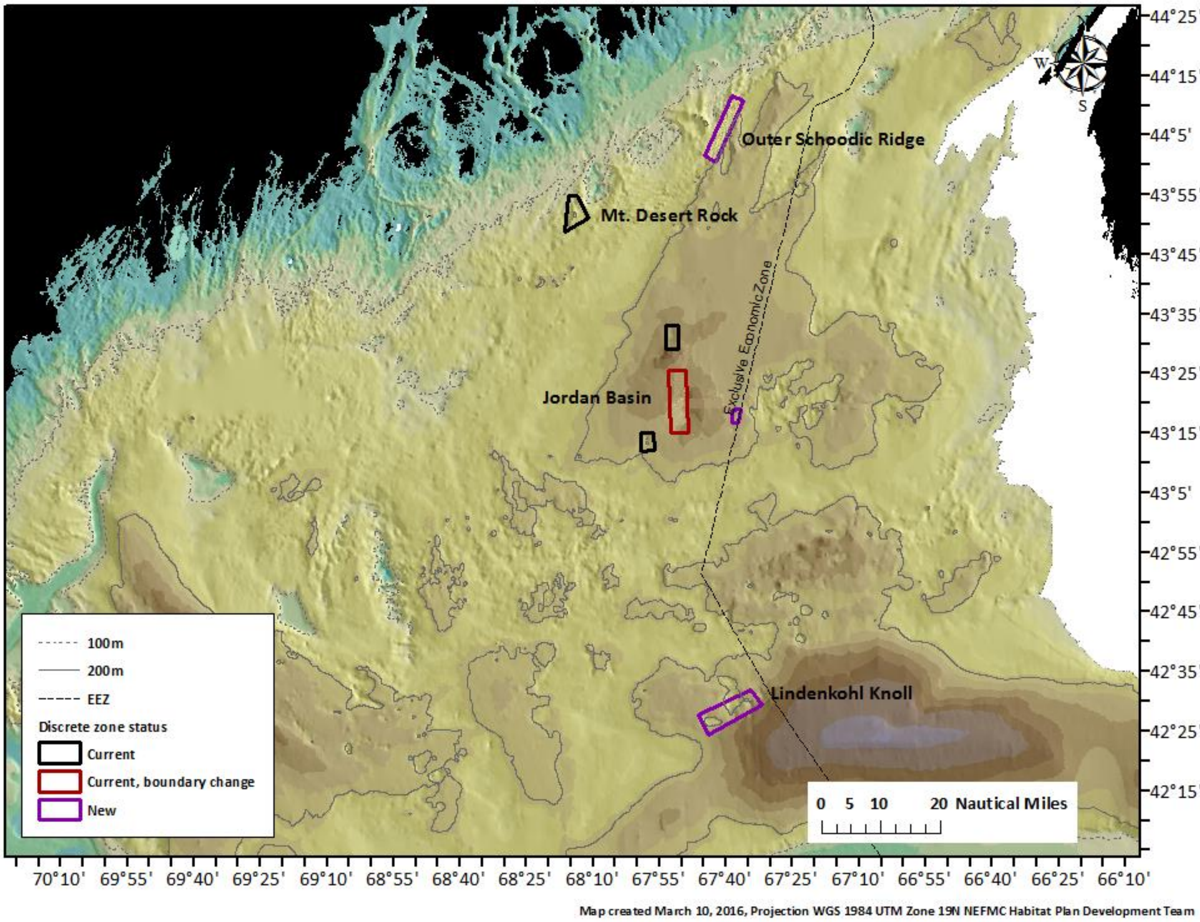
Table 4 – Recommended Gulf of Maine coral zones

Area	Current or newly recommended area	Boundary recommendation
Mount Desert Rock	Current	No change
Outer Schoodic Ridge	New	New
Western Jordan Basin 114 Fathom Bump	Current	Update
Western Jordan Basin 96 Fathom Bump	Current	No change
Western Jordan Basin 118 Fathom Bump	Current	No change
Western Jordan Basin Area 4	Current alternative, no longer recommended	Remove area
Central Jordan Basin	New	New
Lindenkohl Knoll	New	New

Map 2 – PDT recommendations for canyon and seamount deep-sea coral zones, including broad zones. Discrete zones are color-coded to indicate current alternatives, current alternatives where boundary changes are recommended, and newly recommended alternatives.



Map 3 – PDT recommendations for GOM coral zones. Discrete zones are color-coded to indicate current alternatives, current alternatives where boundary changes are recommended, and newly recommended alternatives.



Appendix I: PDT-recommended deep-sea coral management zones and boundaries

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II. Introduction

The New England Fishery Management Council's Omnibus Deep-Sea Coral Amendment currently includes management alternatives for discrete coral zone in twelve canyons, four seamounts, and five areas within the Gulf of Maine. Large amounts of recently collected data on corals and coral habitats, as well as the results of a habitat suitability model, warrant a reconsideration of these alternatives. The Habitat Plan Development Team has drafted a memo summarizing recommended discrete and broad zone updates. This appendix describes the data sources use to inform discussions about discrete coral zones in New England, and then provides specific recommendations and rationale for each zone. A slightly different boundary development approach was used for each category of coral zone (i.e. canyon, seamount, or Gulf of Maine), depending on the data available. These approaches are described at the beginning of each section. The broad zones and their boundaries are not described in this document.

III. Data sources

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 various coral types 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.

The historical database includes coral distribution records prior to 2012. The PDT relied on the Cold-Water Coral Geographic Database (CoWCoG) developed by the US Geological Survey and NOAA's Deep-Sea Coral Research and Technology Program (DSCRTP). A team at USGS compiled the first version of this database, and additional records were sourced and added by the staff at NOAA's DSCRTP with the assistance of the Northeast Fishery Science Center staff and others. The major coral data sets covered by this database are summarized in Table 1. These data sets constitute the bulk of the records in CoWCoG. In general, records vary in age from the 1850s through present, although most of the data were collected since the late 1970s. There is some degree of positional uncertainty with the older records.

Generally, the historical data indicates presence of corals only, and does not give absence or abundance information. Further, 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 1 – 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	One of the primary data sources describing the deep coral fauna of the northeastern U.S. are these reports, which 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 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/

Recent survey work includes towed camera, remotely operated vehicle (ROV), and autonomous underwater vehicle (AUV) dives conducted from 2012 to 2015 (Table 2). 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[1] to inform management decisions. As noted in the introduction to this section, 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 2 – Recent deep-sea coral oriented cruises within the New England region

Year	Cruise Dates	Cruise Number	Research Vessel	Gear	Number of tows[2]	Locations
2012	5-6 Oct			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)

[1] Initial analysis of cruise HB1402 (R/V Bigelow, ROPOS system) is still in progress.
[2] 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[2]	Locations
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)
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)

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 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 (Mount Desert Rock) is described in a 2011 report by Friday et al.

- Lower resolution 250 meter bathymetry 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 hillshaded bathymetry, which allows for the share of the seafloor to be visualized more easily. Hillshaded 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. In the canyons (ACUMEN data), high slope areas (greater than 30 degrees) were highly likely to contain deep-sea corals during recent ROV and towed camera surveys, and areas with slopes above 36 degrees nearly always contained corals. 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

As noted above, 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 spatial domain of the model includes the continental shelf and canyons in New England and the Mid-Atlantic, but not the seamounts, as it is based on the footprint of the coastal relief DEM which does not include the seamounts. In the canyons, habitat suitability model outputs were used in conjunction with terrain data to define boundaries around areas with a high or very high likelihood of habitats suitable for deep-sea corals. Data are available from NOAA NOS.[3]

The historical distribution of deep sea corals in the Northeast is the dependent variable in the model. Twenty-two environmental predictor variables were used to estimate areas of suitable deep-sea coral habitat. Notable predictor variables includes depth, slope, slope of slope, and surficial sediment grain size. The modeling takes a maximum entropy (MaxEnt) approach, which is appropriate when absence information is not available, as is the case with the coral data. The model output is based on the relationships between historical coral distributions for each taxonomic grouping and the twenty-two environmental predictor variables. The model outputs are likelihoods of suitable habitat occurrence for different types of corals, including stony corals, soft corals, and sea pens. The outputs are not intended to reflect predicted abundance, density, or diversity of corals.

Habitat suitability outputs for different types of corals were thresholded to allow for comparison between coral types. The reason for this procedure is that MaxEnt logistic values cannot be directly compared from one model (i.e. one coral group) to another. The thresholded logistic outputs were generated through a cross-validation/tuning process in which logistic predictions were confronted with coral presence data that had been left out of model fitting (i.e., test data). At each cross-validation iteration, these test data were used to find the optimal threshold to discriminate between presence points and background. The optimal threshold depends on the relative cost of false positive errors vs. false negative errors. For example, if false positives are deemed ten times more costly than false negatives (a 10:1 FP:FN cost ratio), then the optimal threshold will be larger (more conservative), and result in a smaller area of only very high likelihood suitable habitat being identified. If false positives and false negatives are given equal weight, a much broader and less conservative area of suitable habitat will be identified. Likelihood classes were defined by FP:FN cost ratios as follows: Low (<1:1), Medium-Low (1:1 to 2:1), Medium (2:1 to 5:1), High (5:1 to 10:1), and Very High (>10:1). The results of the cross-validation "tuning" process area likelihood classes that mean the same thing (in terms of likelihood of correct habitat classification) for all modeled coral groups. This allowed the model developers to merge together results from three separate soft coral (Alcyonacean) models: Alcyonacea, Gorgonian Alcyonacea, and Non-gorgonian Alcyonacea.

The combined high and very high suitability areas for the Gorgonian Alcyonacea and non-gorgonian Alcyonacea were used to develop the canyon zones. Although models were developed for sea pens and stony corals, the results are not presented here. The Alcyonacea model is expected to have 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. While numerous sea pens are documented in the historical database, these animals are solitary and are not considered structure-forming. Compared to sea pens, fewer stony coral records are present in the historical

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[3] Kinlan BP, Poti M, Drohan A, Packer DB, Nizinski M, Dorfman D, Caldow C. 2013. Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch and NOAA National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC). Released August 2013.

database, and many of these records represent species that are not considered structure-forming. Black corals were not included in the modeling study due to insufficient data on their distribution when the study commenced. However, the recent ROV and towed camera dives have documented black corals in many of the canyons, as well as a variety of structure-forming stony corals.

IV. Canyon coral zones and boundaries

The PDT is recommending coral zones 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. Those that are underlined are not part of the current range of canyon zone alternatives and are new recommendations.

The PDT is recommending boundary updates for all of the existing canyon zones, based on the most up to date information on coral observations, high resolution terrain data, and habitat suitability model results. The same boundary development approach is used for newly recommended zones as well. 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 the abyssal plain. 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). Overlaps between each discrete zone and the historical data are summarized in Table 4. These data should be viewed as indicators of both coral presence and survey effort. An absence of historical records for a particular area is more likely to reflect an absence of scientific surveys than it is to reflect an absence of corals.

The maps also depict depth, hillshaded 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 hillshaded 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. Depth statistics for each canyon zone including the minimum, maximum, mean, and median depths, in meters, are described in the text and summarized in Table 3. These values will of course change if the zone boundaries are edited. A particular minimum does not indicate that a large fraction of the zone by area falls at that depth. However, what can be taken from the minimum depth information is that the various canyons that incise the shelf tend to have shallower minimum depths than those canyons which are slope confined.

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

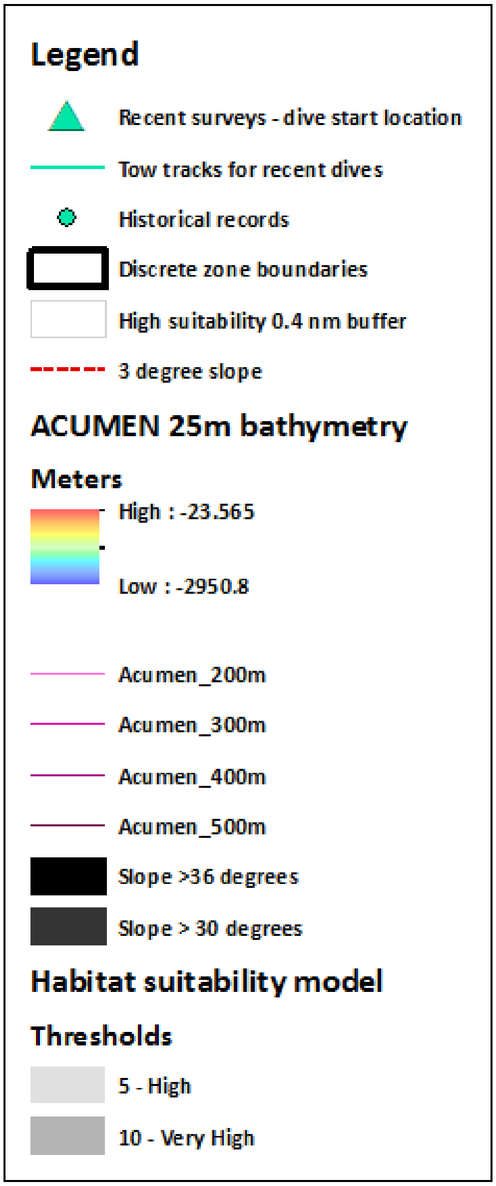


Table 3 – Depth statistics for proposed canyon zones

Canyon name	Area (km^2)	Minimum depth (meters)	Maximum depth (meters)	Mean depth (meters)
Alvin	208	-298	-2,002	-1,008

Atlantis	218	-280	-2,052	-947
Nantucket	176	-281	-1,956	-970
Veatch	128	-150	-1,821	-888
Hydrographer	212	-119	-1,989	-960
Dogbody	150	-234	-1,897	-1,012
Clipper	65	-363	-1,838	-994
Sharpshooter	47	-348	-1,994	-1,031
Welker	144	-265	-2,094	-922
Heel Tapper	105	-271	-1,792	-969
Oceanographer	235	-259	-2,068	-991
Filebottom	56	-371	-1,995	-1,297
Chebacco	84	-340	-1,963	-1,141
Gilbert	163	-256	-2,143	-1,041
Lydonia	223	-143	-1,870	-862
Powell	190	-260	-2,267	-1,161
Munson	117	-256	-2,097	-959
Nygren	109	-358	-2,030	-1,151
Unnamed btwn Nygren and Heezen	45	-345	-1,878	-1,016
Heezen	124	-160	-2,270	-1,167

Note: results were calculated from the ACUMEN raster file, using the Zonal Statistics tool in ArcGIS Spatial Analyst

Table 4 – Number of historical (pre-2012) records of corals in the canyon zones

Canyon Name	Alcyonacea	Antipatharia	Pennatulacea	Scleractinia	Grand Total
Alvin	2		5	4	11
Atlantis			1	1	2
Nantucket				7	7
Veatch					0
Hydrographer	2				2
Dogbody	8				8
Clipper	1				1
Sharpshooter					0
Welker					0
Heel Tapper					0
Oceanographer	148			18	166
Filebottom	1				1
Chebacco					0
Gilbert					0
Lydonia	92		4	7	105
Powell					0
Munson	1				1
Nygren					0
Unnamed Canyon btw Nygren and Heezen					0
Heezen	42		12	13	67

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 fairly closely with the 3° slope contour. Based on the ACUMEN bathymetric data, the area has a depth range of 298 to 2,002 meters below sea level.

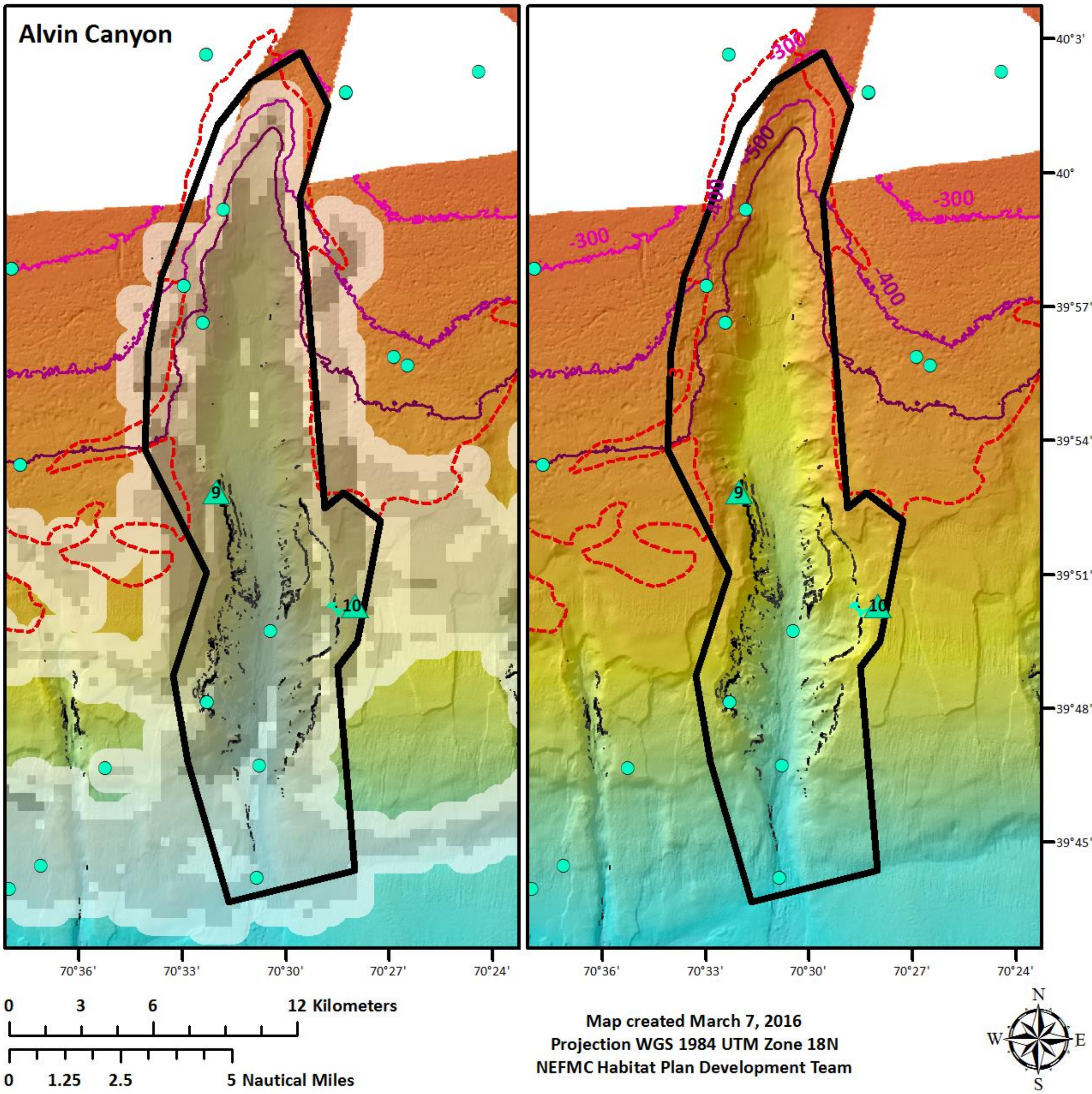
There are eleven historical records of coral observations that fall within the proposed zone, including observation of stony corals, sea pens, and soft corals. The two observations just outside the recommended zone boundary are a cup coral (*Dasmosmilia lymani*), which is type of hard coral, and the 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)[4]. 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.

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.

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

Map 1 – Recommended Alvin Canyon discrete zone



Atlantis Canyon

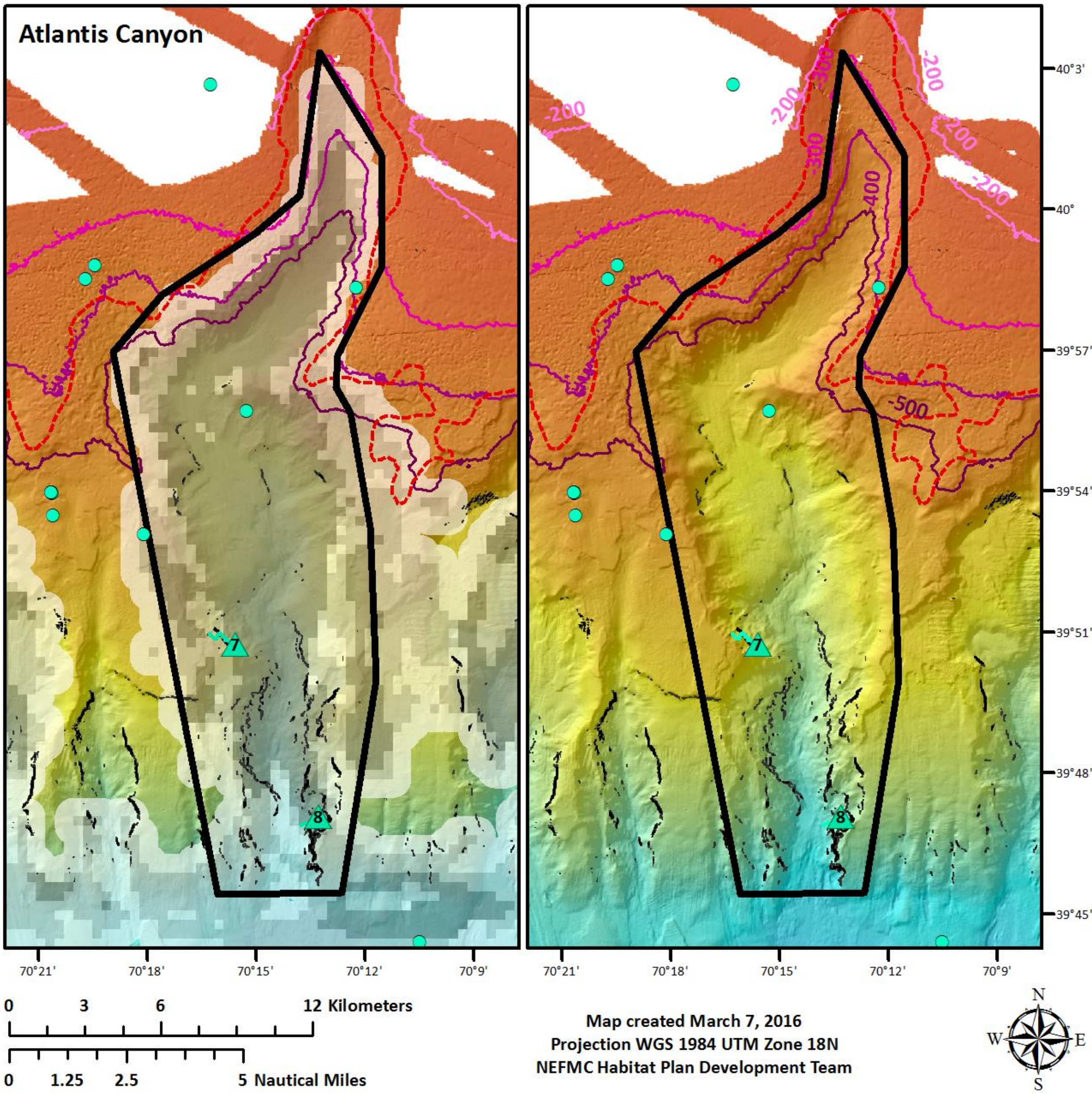
Atlantis Canyon incises the continental shelf break, encompassing an area of approximately 200 km^2. The proposed zone follows the 300-meter depth contour at the head of the canyon and aligns fairly closely with the 3° slope contour. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 280 to 2,052 meters below sea level.

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.

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.

Map 2 – Recommended Atlantis Canyon discrete zone



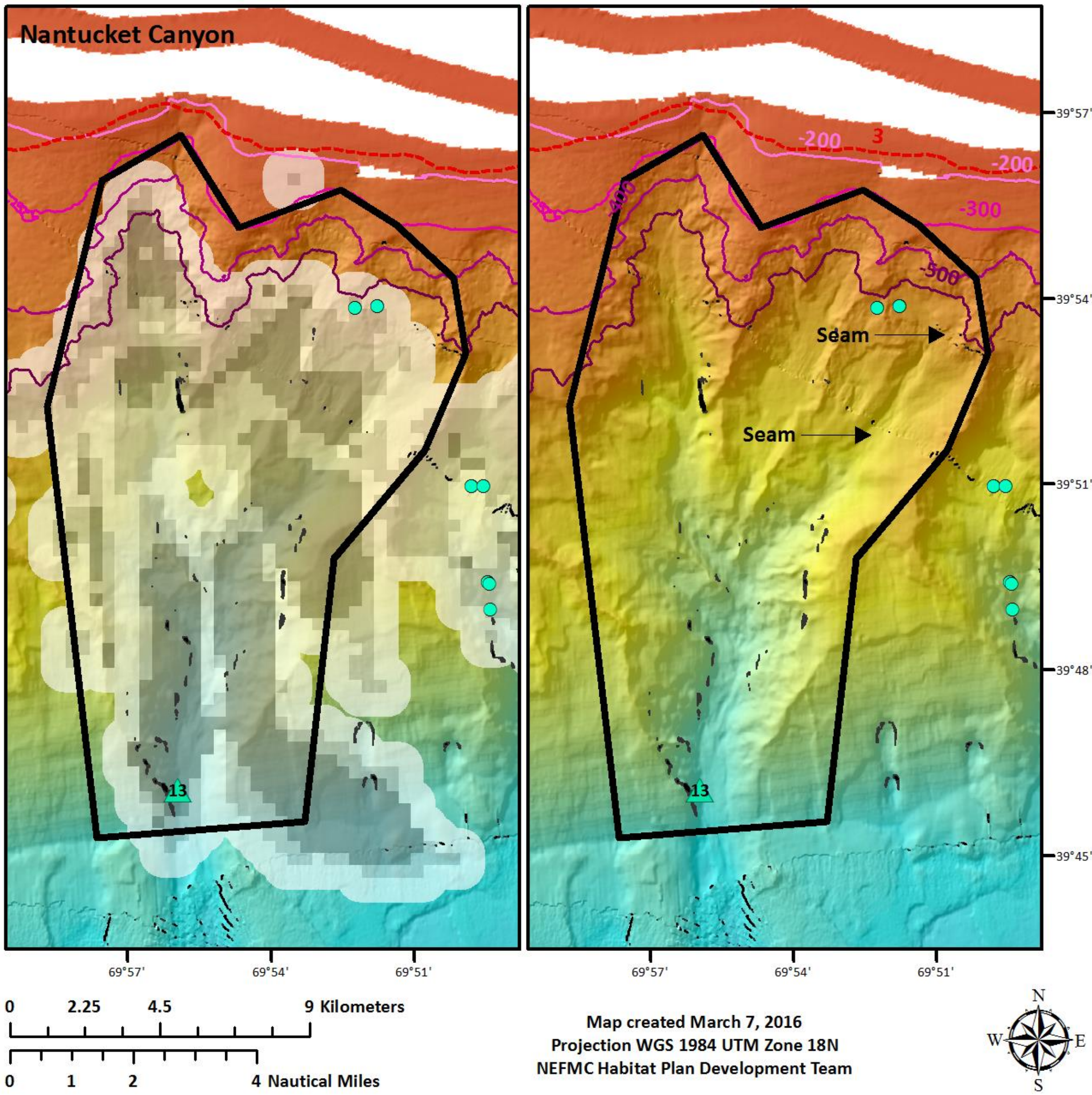
Nantucket Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 281 to 1,956 meters below sea level.

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.

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 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.

Map 3 – Recommended Nantucket Canyon discrete zone



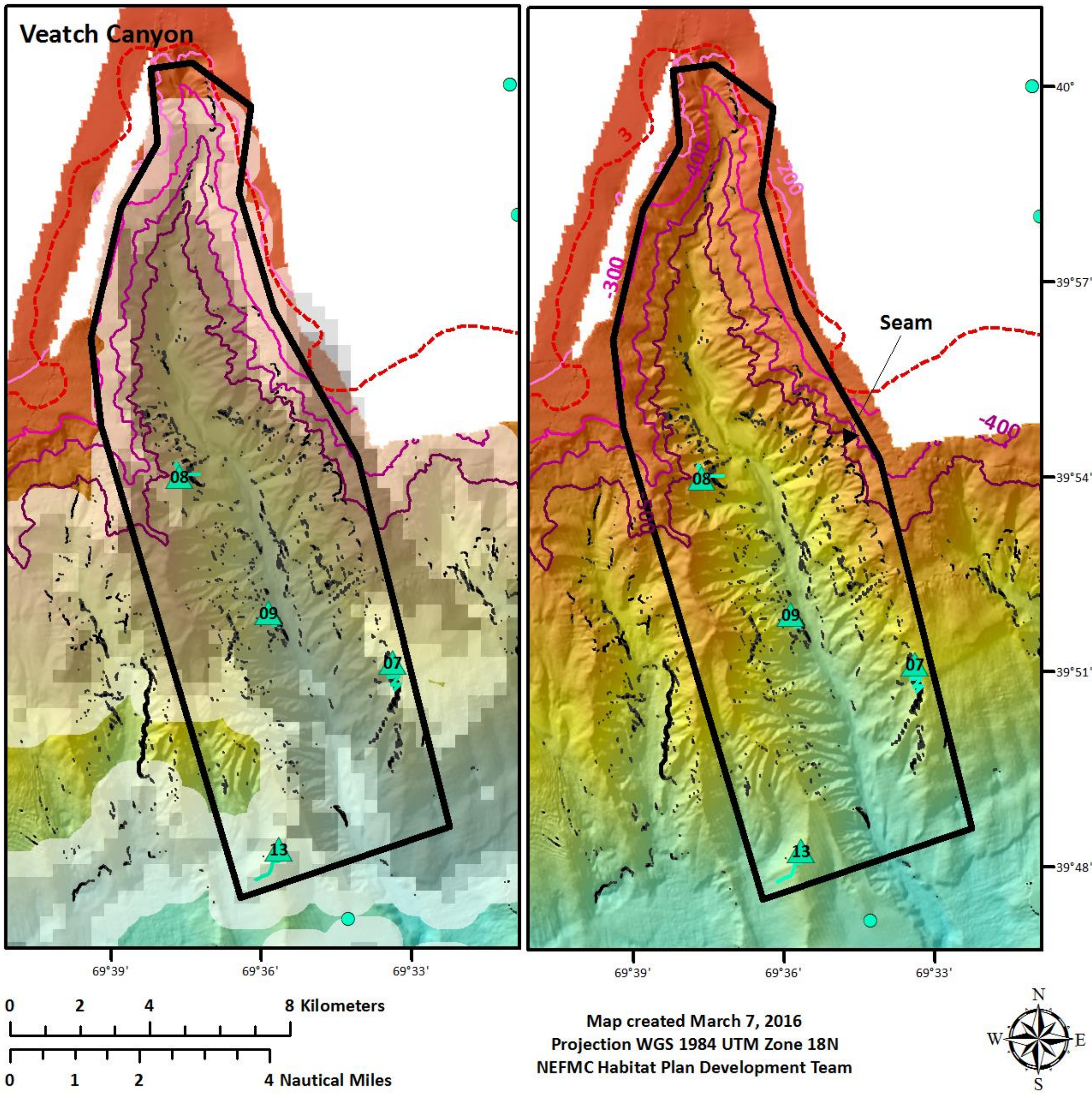
Veatch Canyon

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. Based on ACUMEN bathymetric data, the recommended zone has a depth range of 150 to 1,821 meters below sea level.

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.

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.

Map 4 – Recommended Veatch Canyon discrete zone



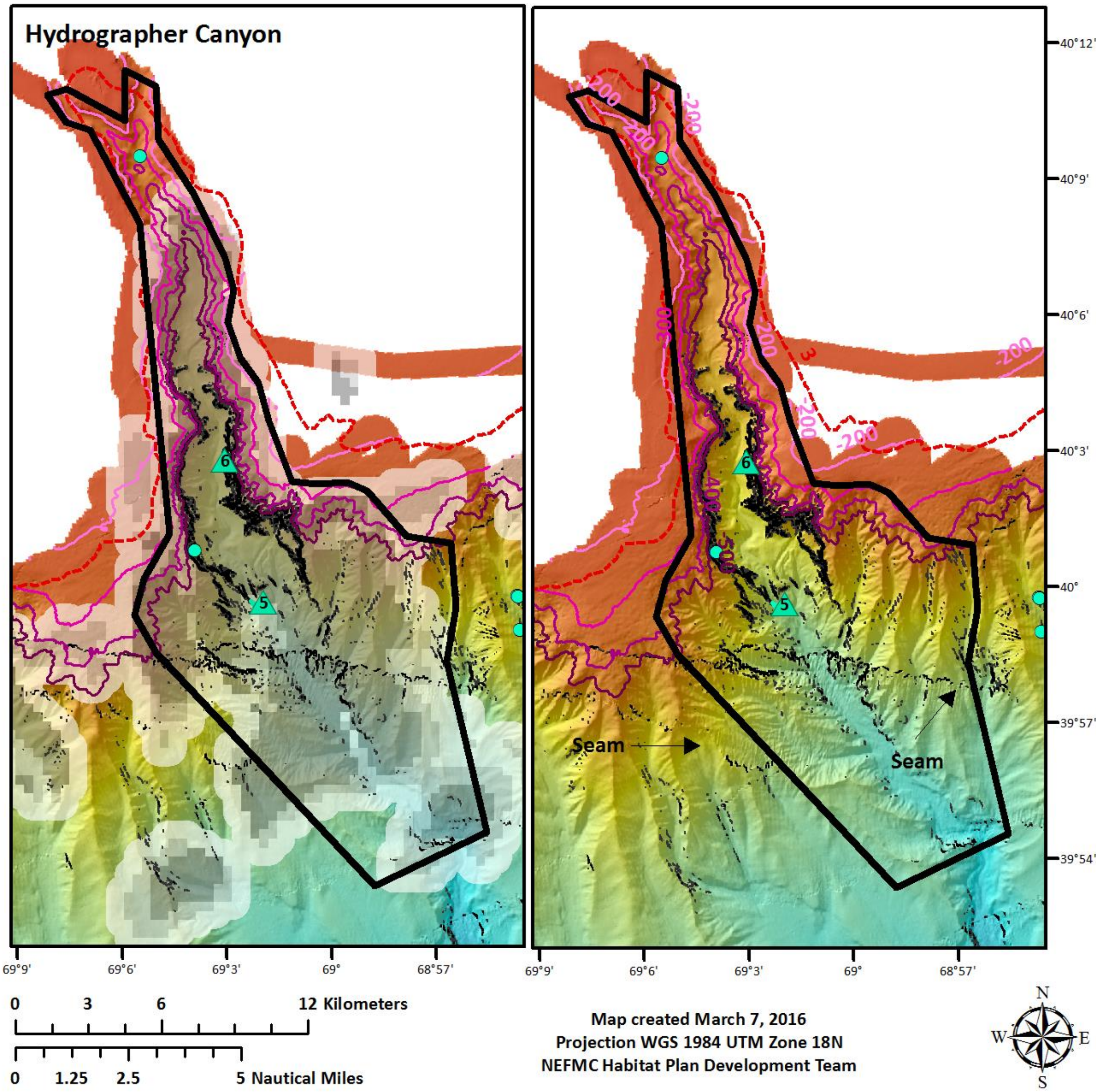
Hydrographer Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth of 119 to 1,989 meters below sea level.

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.

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.

Map 5 – Recommended Hydrographer Canyon discrete zone



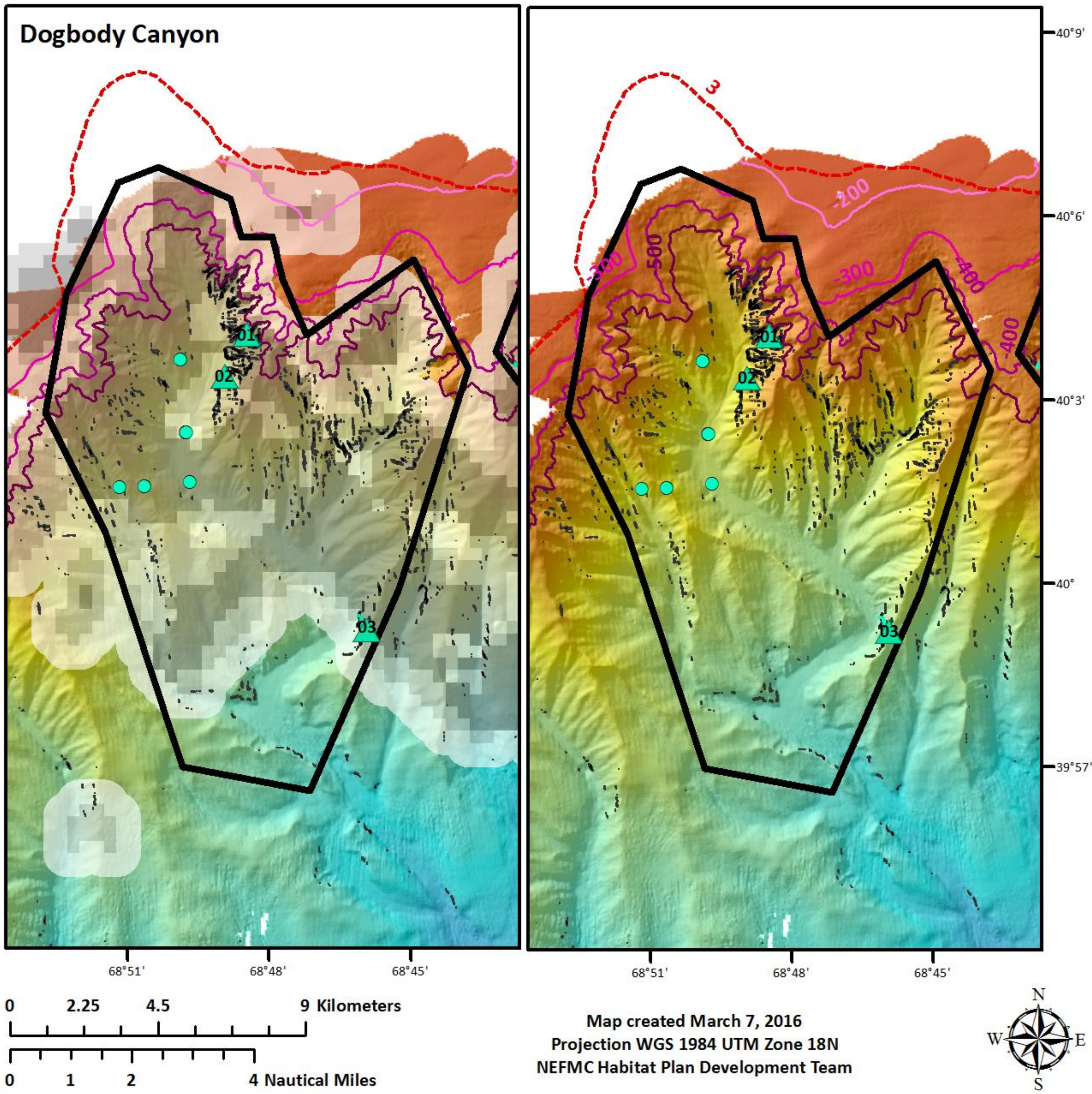
Dogbody Canyon

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. Based on ACUMEN bathymetric data, the proposed zone has a depth range of 234 to 1,897 meters below sea level. The main thalweg is somewhat sinuous with a smaller branch to the east.

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.

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.

Map 6 – Recommended Dogbody Canyon discrete zone

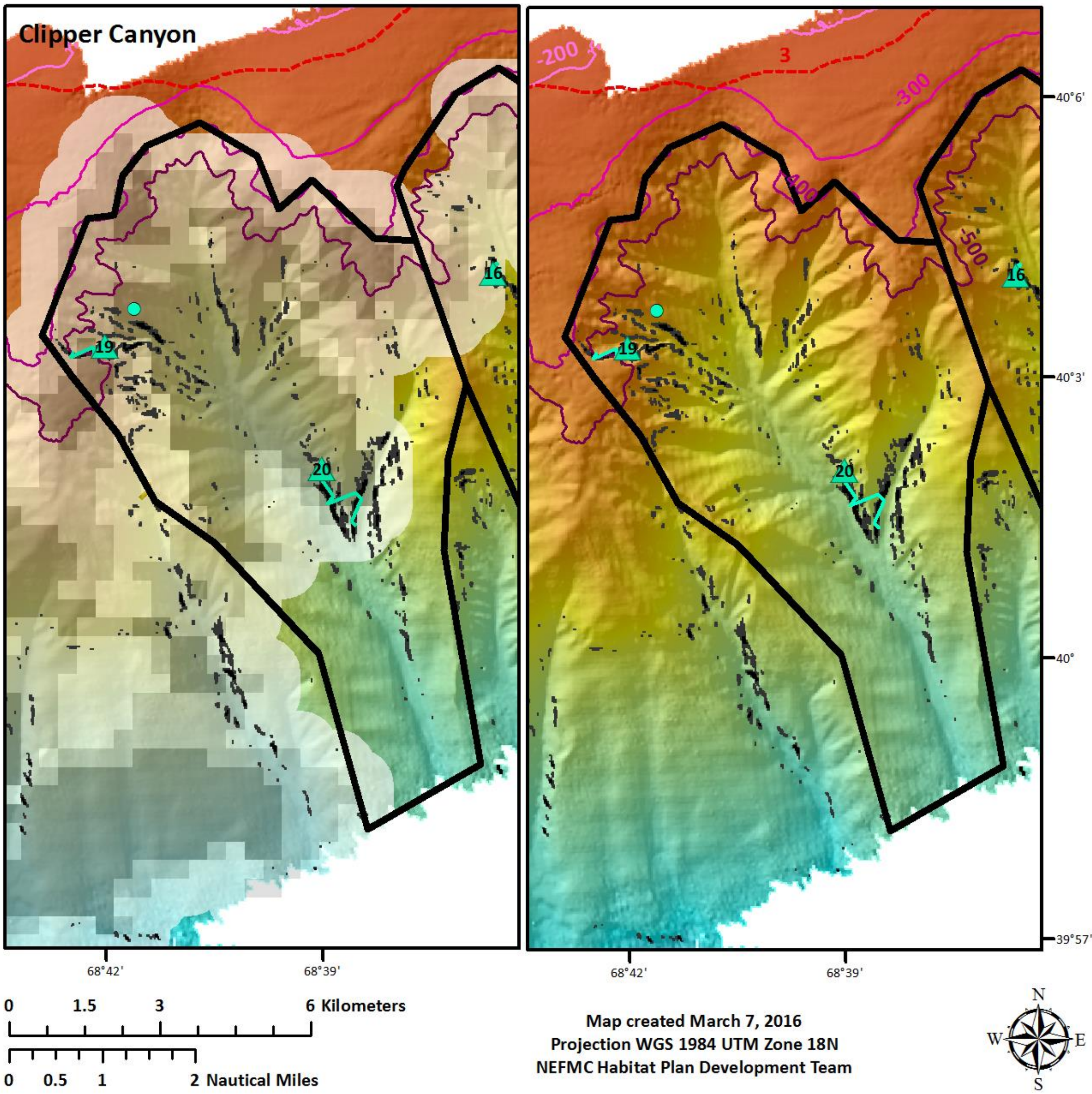


Clipper Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 363 to 1,838 meters below sea level. Clipper has one main branch and a smaller branch to the east.

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). 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.

Map 7 – Recommended Clipper Canyon discrete zone



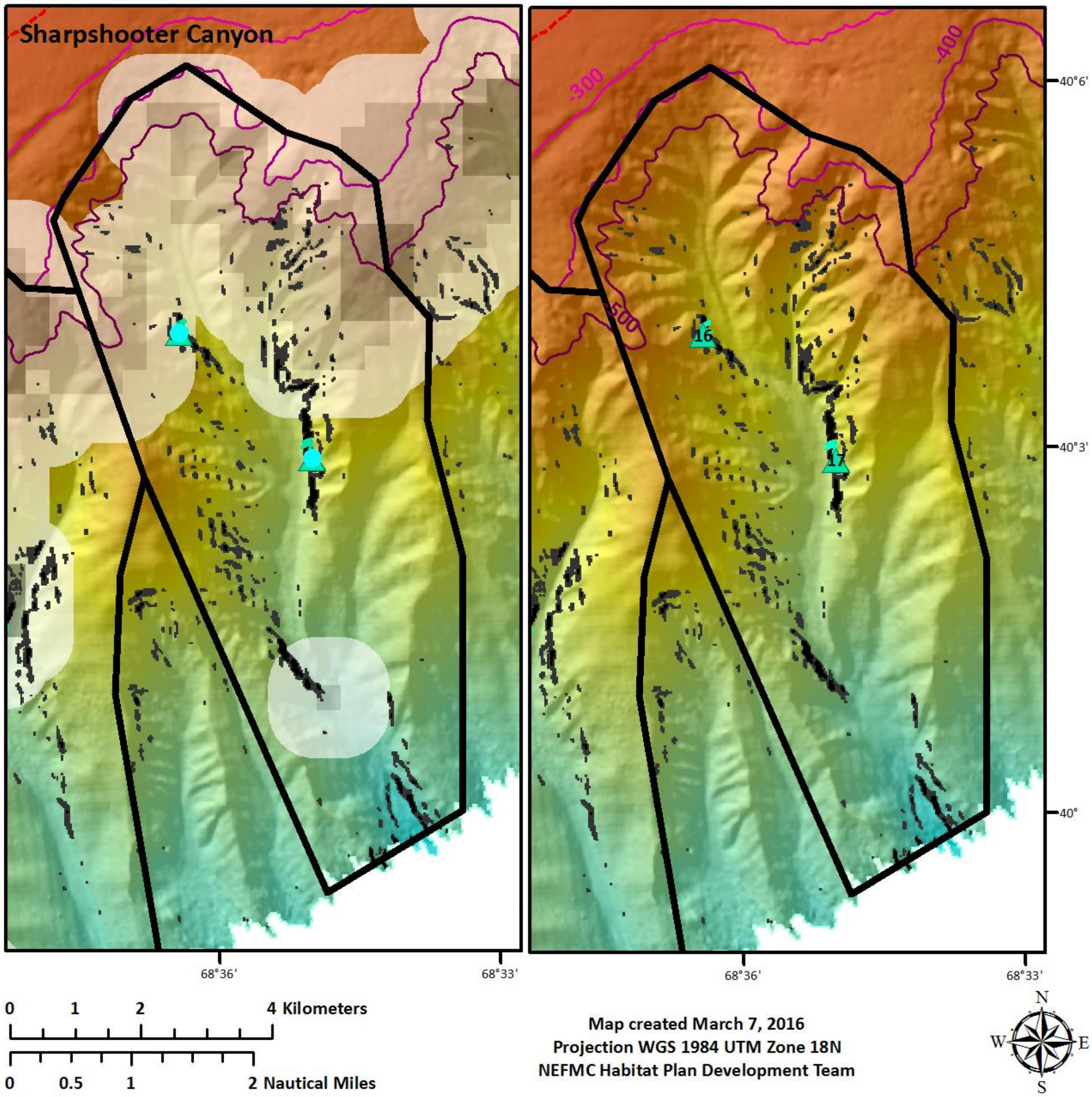
Sharpshooter Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 348 to 1,994 meters below sea level.

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.

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. Tows 16 and 17 were conducted in two of the larger contiguous areas of high slope. There are no issues with seams in the bathymetric data in this canyon.

Map 8 – Recommended Sharpshooter Canyon discrete zone



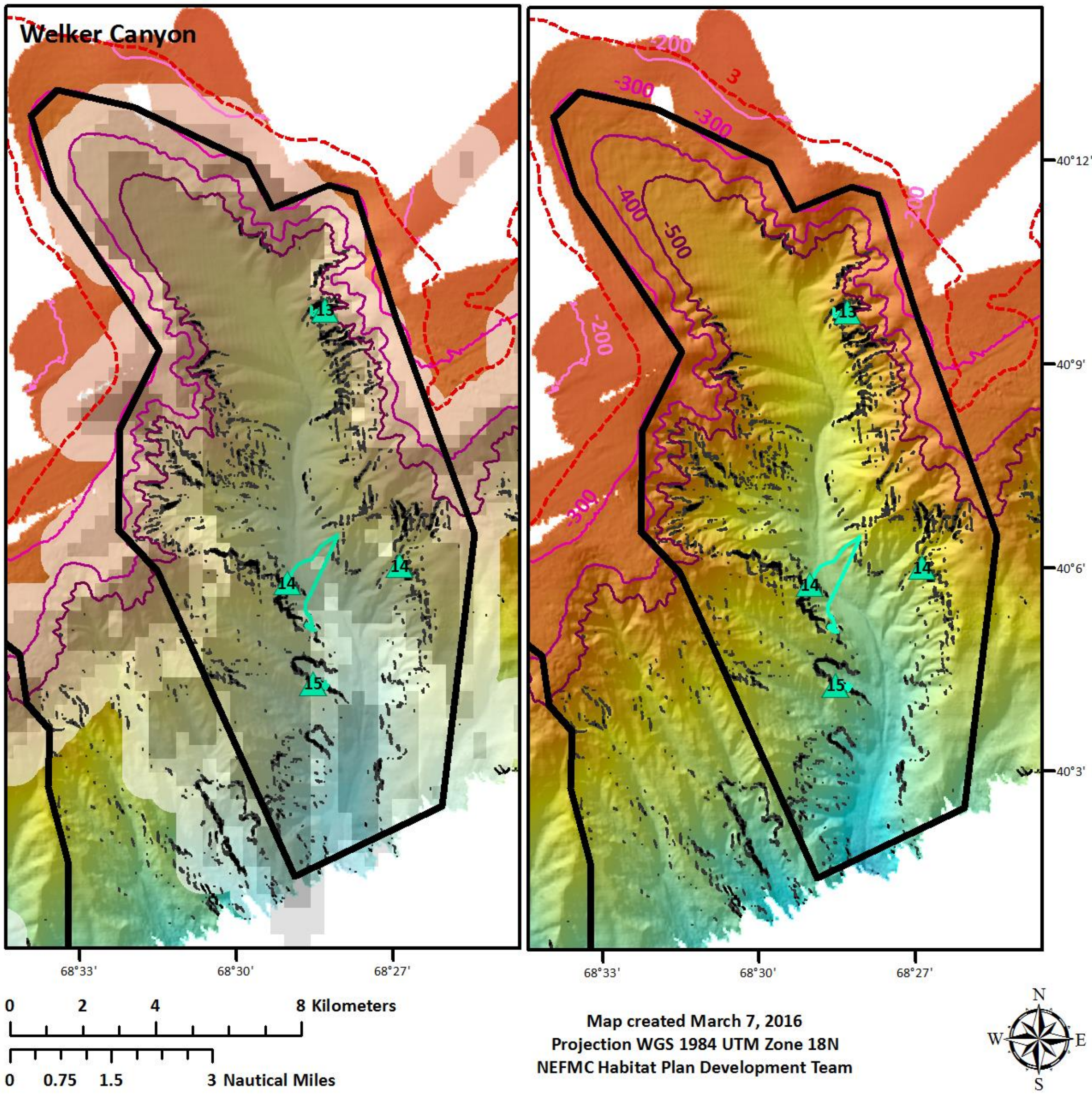
Welker Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 265 to 2,094 meters below sea level. The head of the canyon is not very steeply sloped, but there are large areas of high slope along both walls.

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.

Nearly all 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.

Map 9 – Recommended Welker Canyon discrete zone



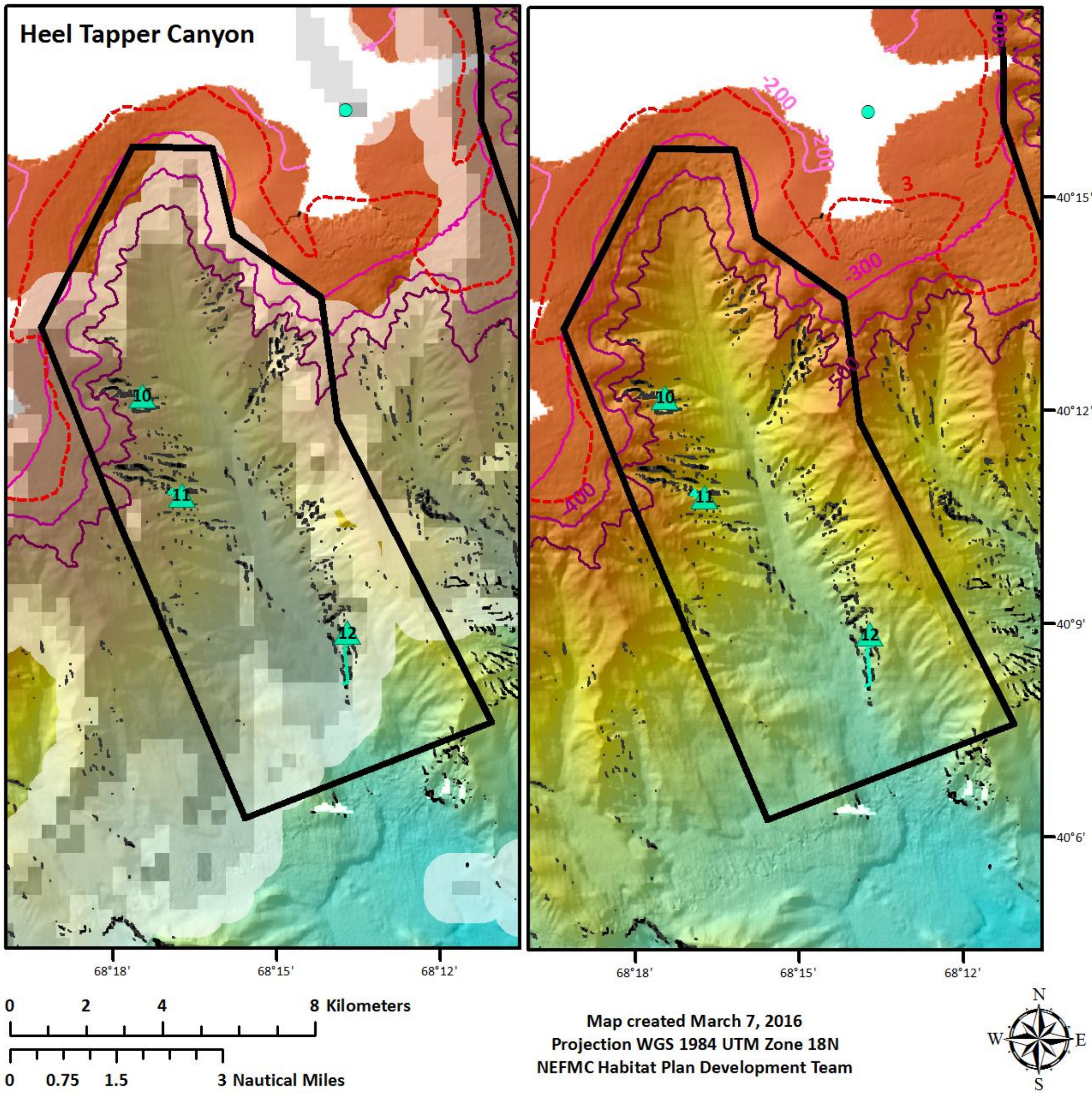
Heel Tapper Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 271 to 1,792 meters below sea level.

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*).

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.

Map 10 – Recommended Heel Tapper Canyon discrete zone



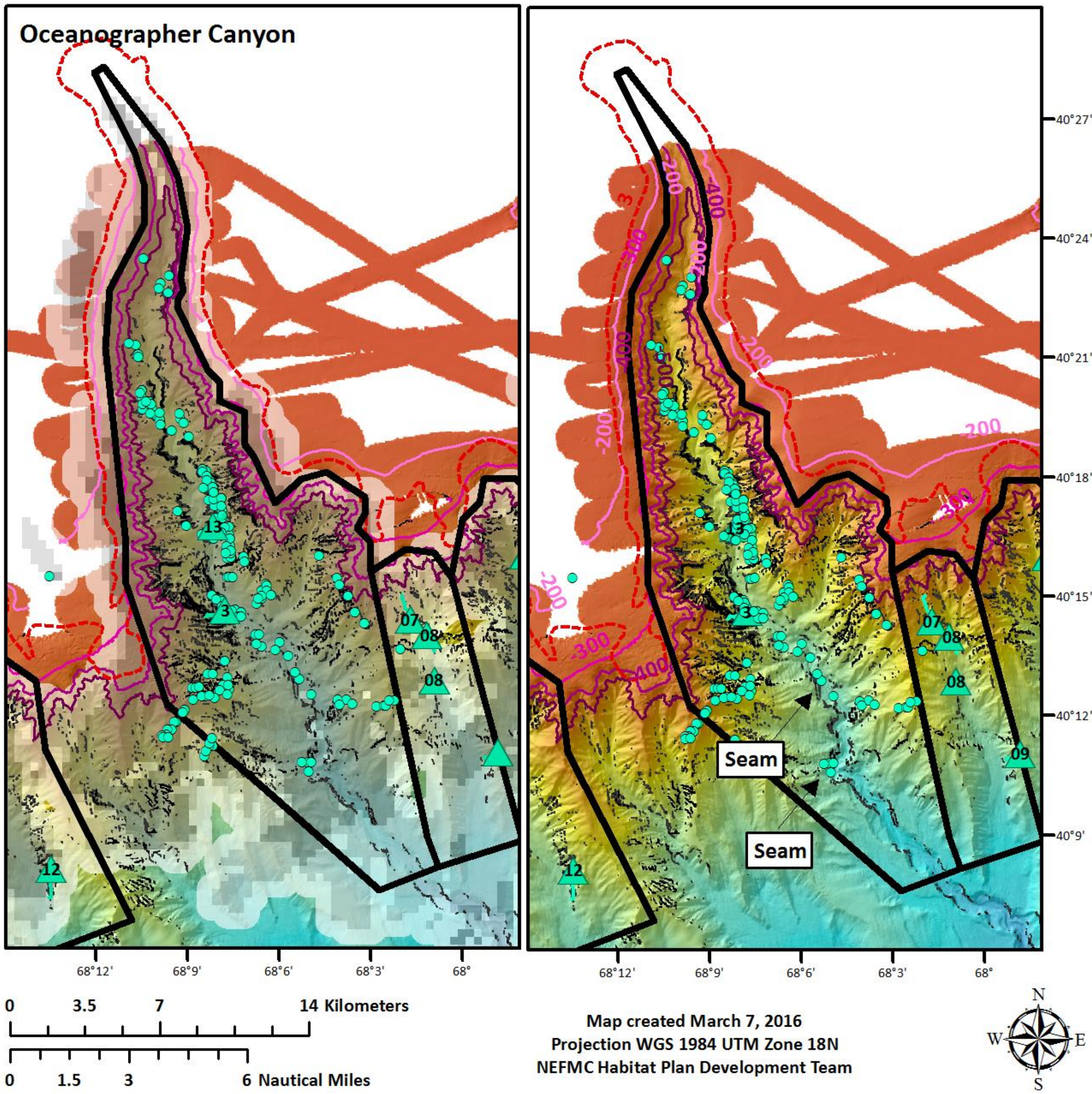
Oceanographer Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 259 to 2,068 meters below sea level. Oceanographer has a clear main axis with a smaller branch on the eastern side.

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.

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.

Map 11 – Recommended Oceanographer Canyon discrete zone

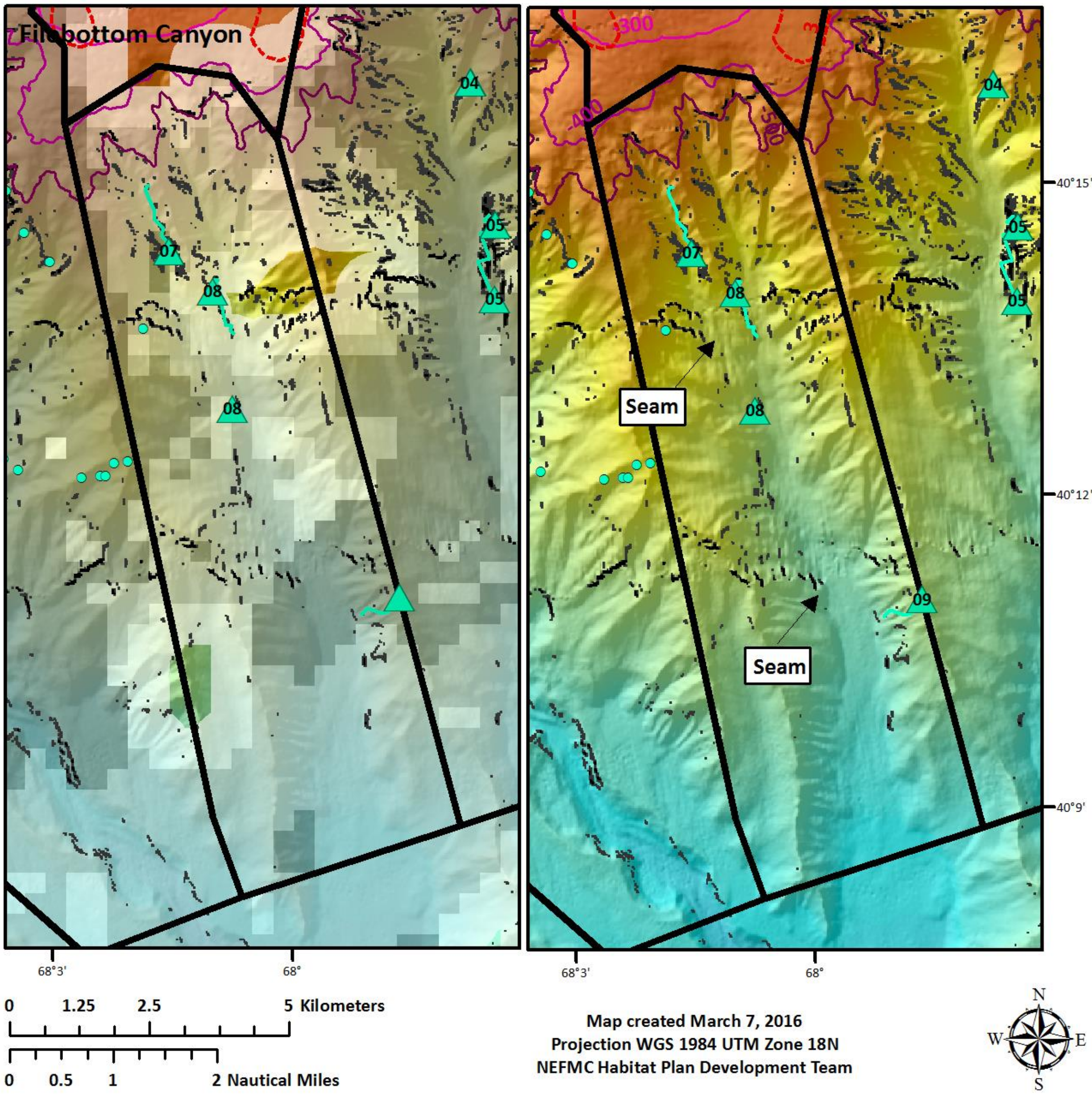


Filebottom Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 371 to 1,995 meters below sea level. 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 12 – Recommended Filebottom Canyon discrete zone

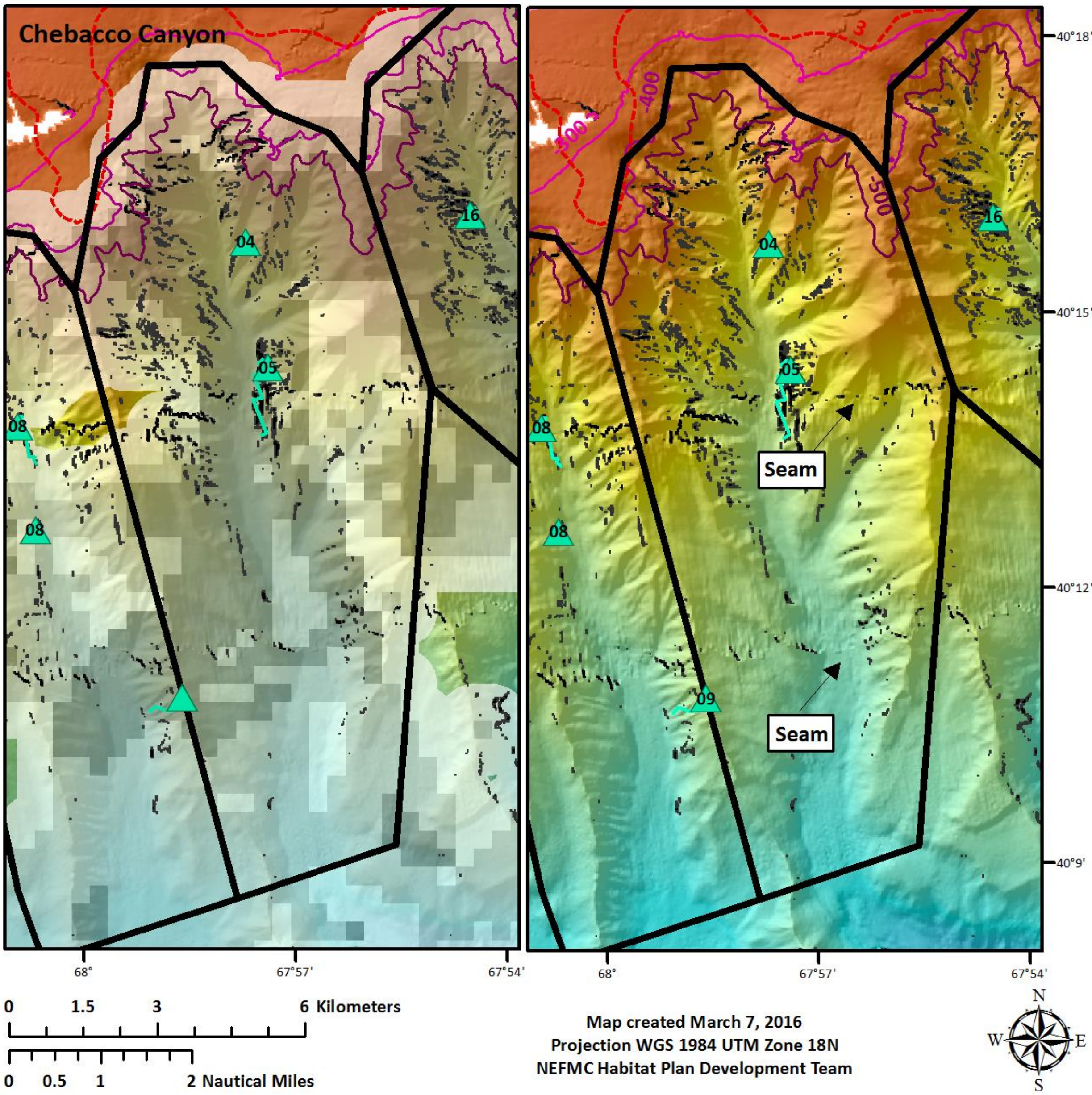


Chebacco Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 340 to 1,963 meters below sea level. 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 13 – Recommended Chebacco Canyon discrete zone



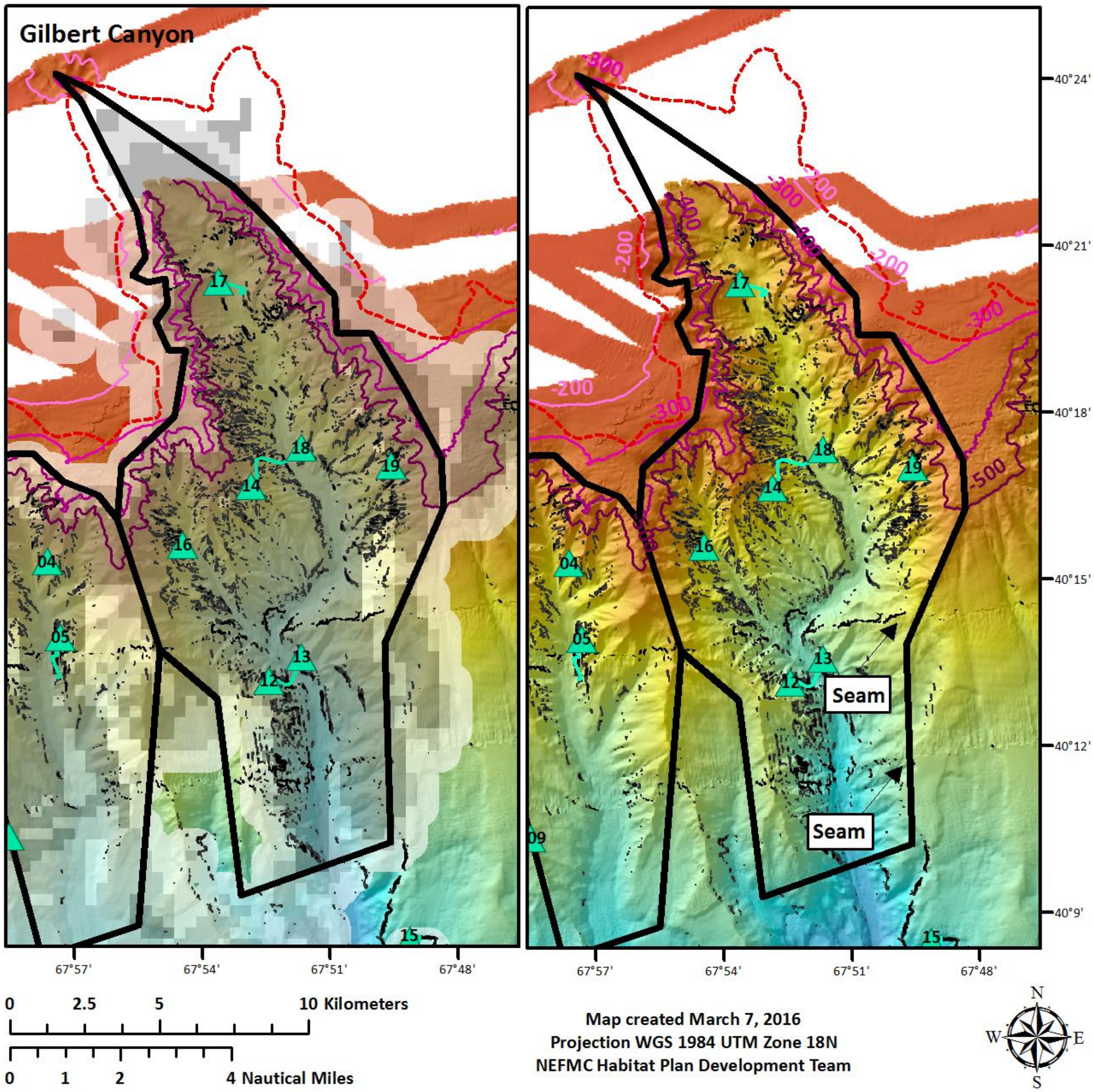
Gilbert Canyon

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. Based on the ACUMEN bathymetric data, the recommended zone has a depth range of 256 to 2,143 meters below sea level. The head of the canyon is not well mapped using these data, however.

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*).

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.

Map 14 – Recommended Gilbert Canyon discrete zone



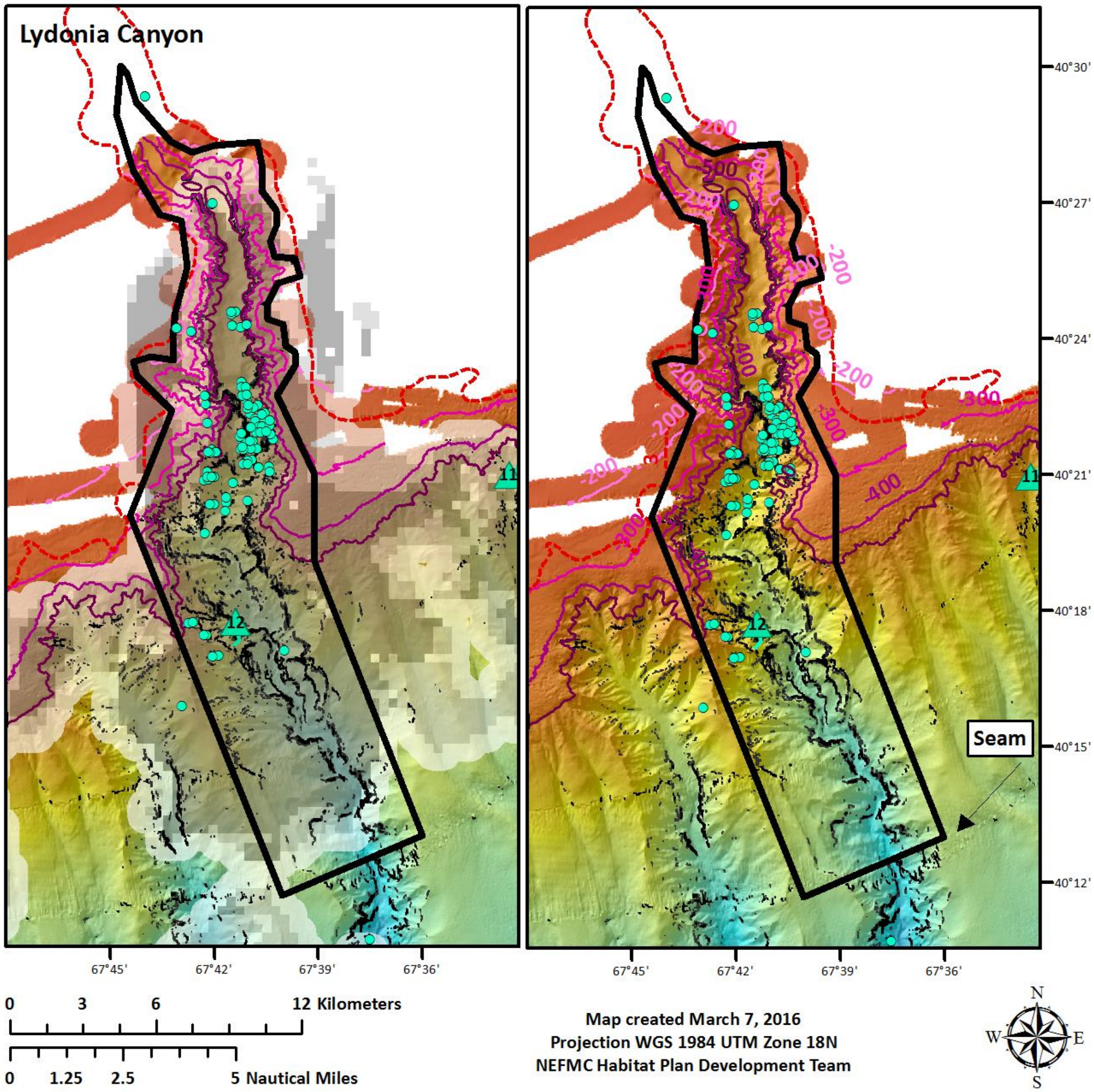
Lydonia Canyon

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.

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.

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.

Map 15 – Recommended Lydonia Canyon discrete zone



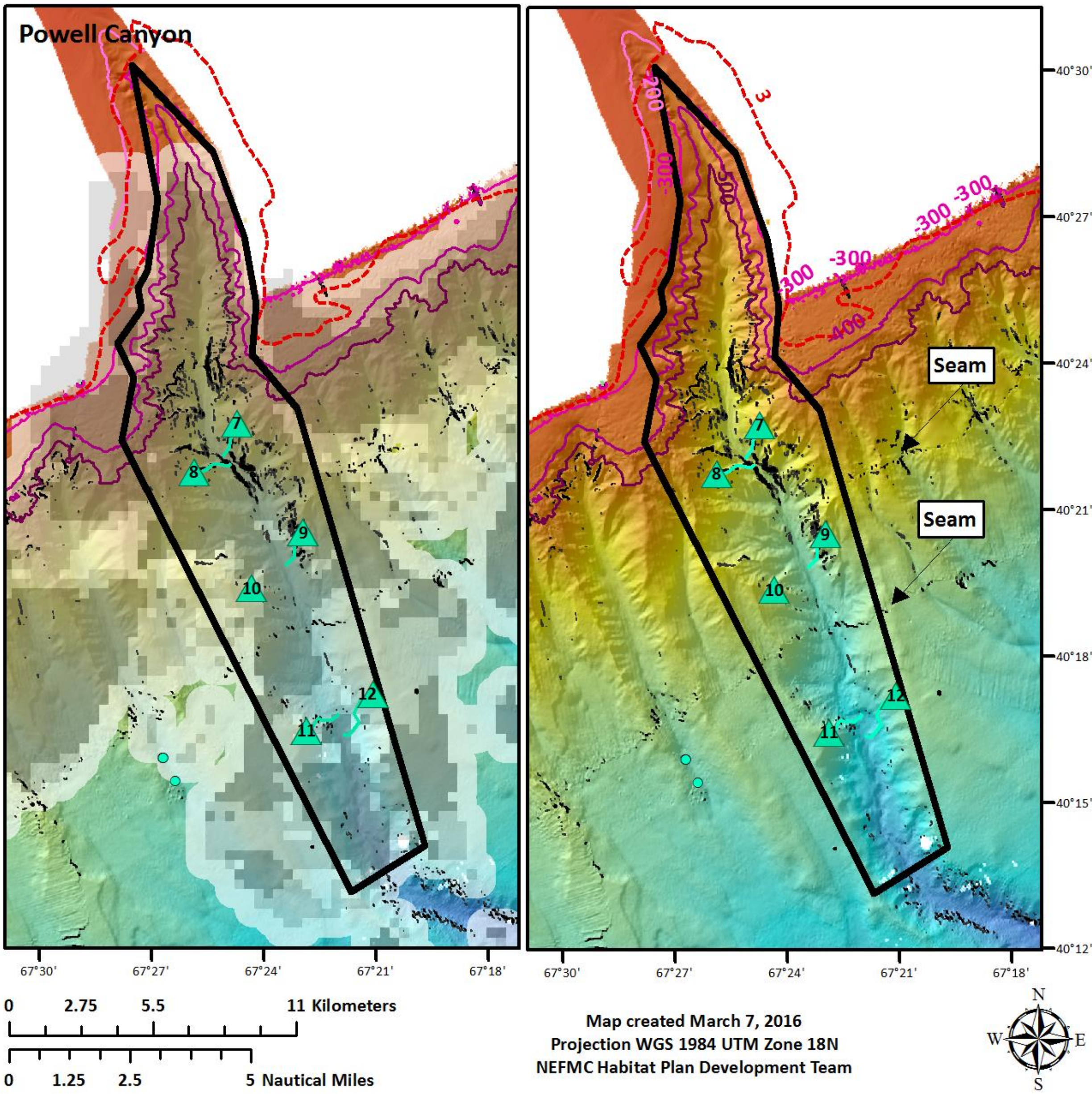
Powell Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 260 to 2,636 meters below sea level.

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.

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.

Map 16 – Recommended Powell Canyon discrete zone



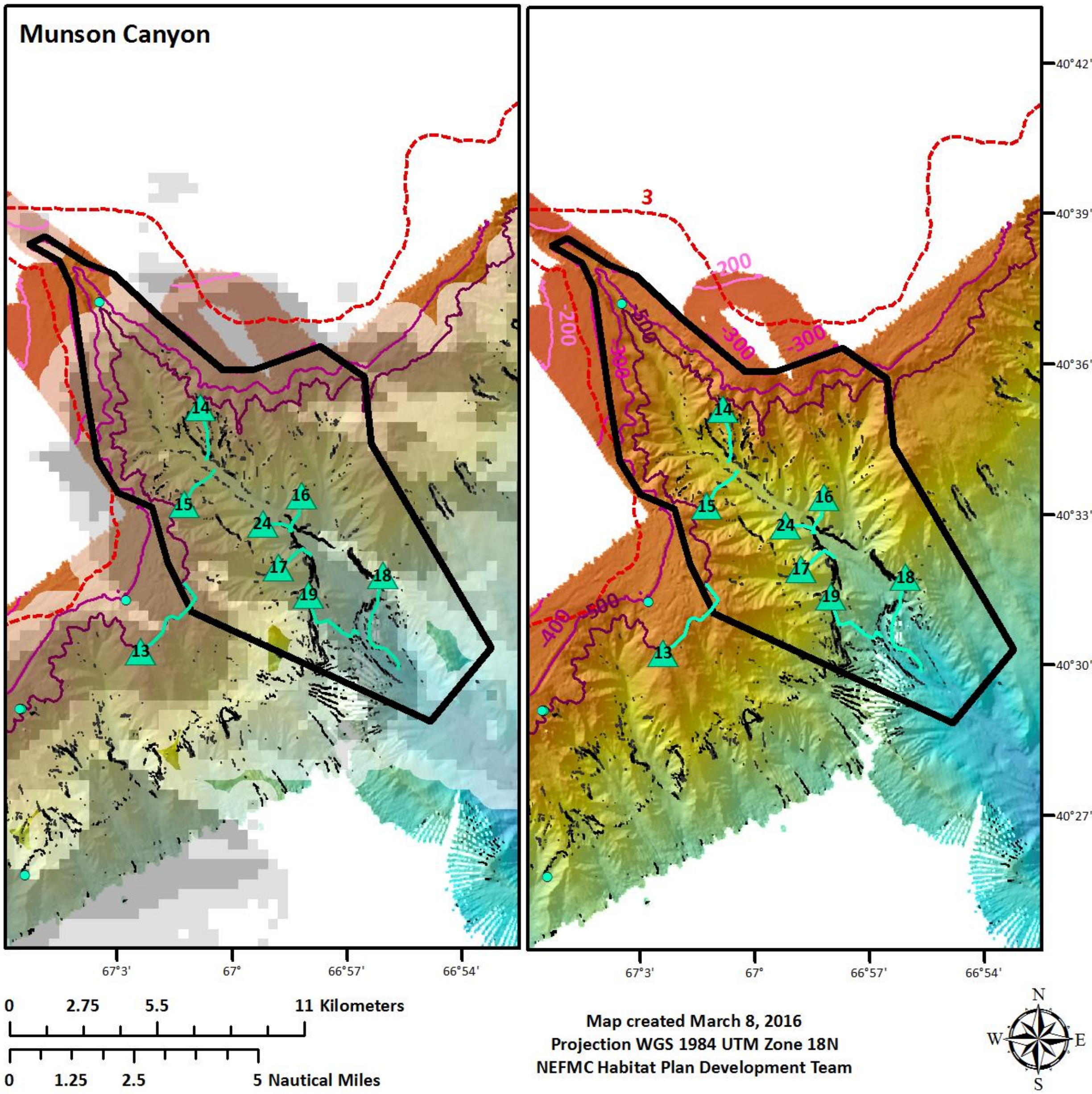
Munson Canyon

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. Based on the ACUMEN bathymetric data, the proposed zone has a depth range of 256 to 1,979 meters below sea level. Munson has one main branch and a smaller branch to the east.

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.

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.

Map 17 – Recommended Munson Canyon discrete zone



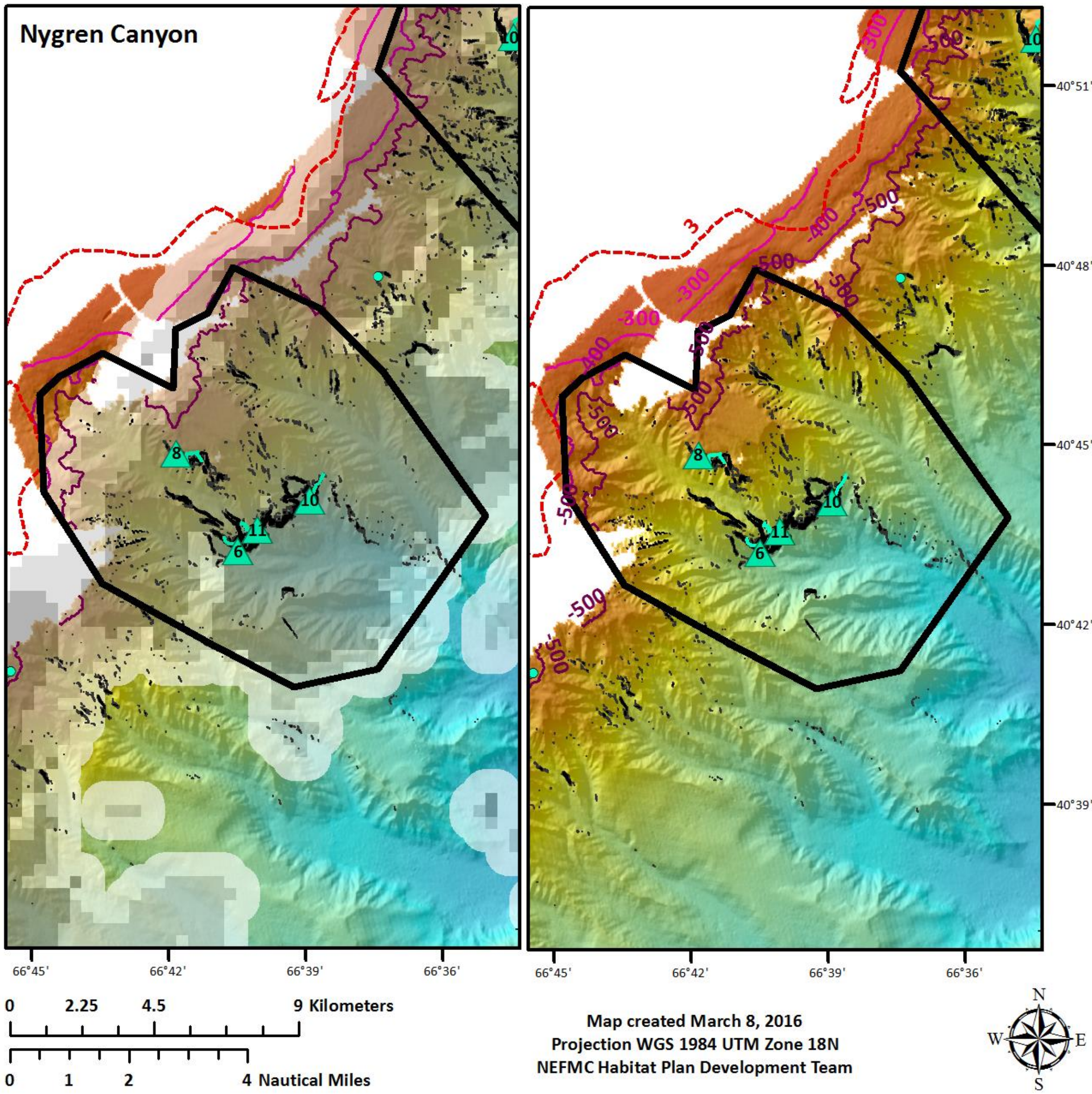
Nygren Canyon

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. Based on the ACUMEN bathymetric data, the zone has a depth range of 358 to 2,030 meters below sea level.

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.

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.

Map 18 – Recommended Nygren Canyon discrete zone



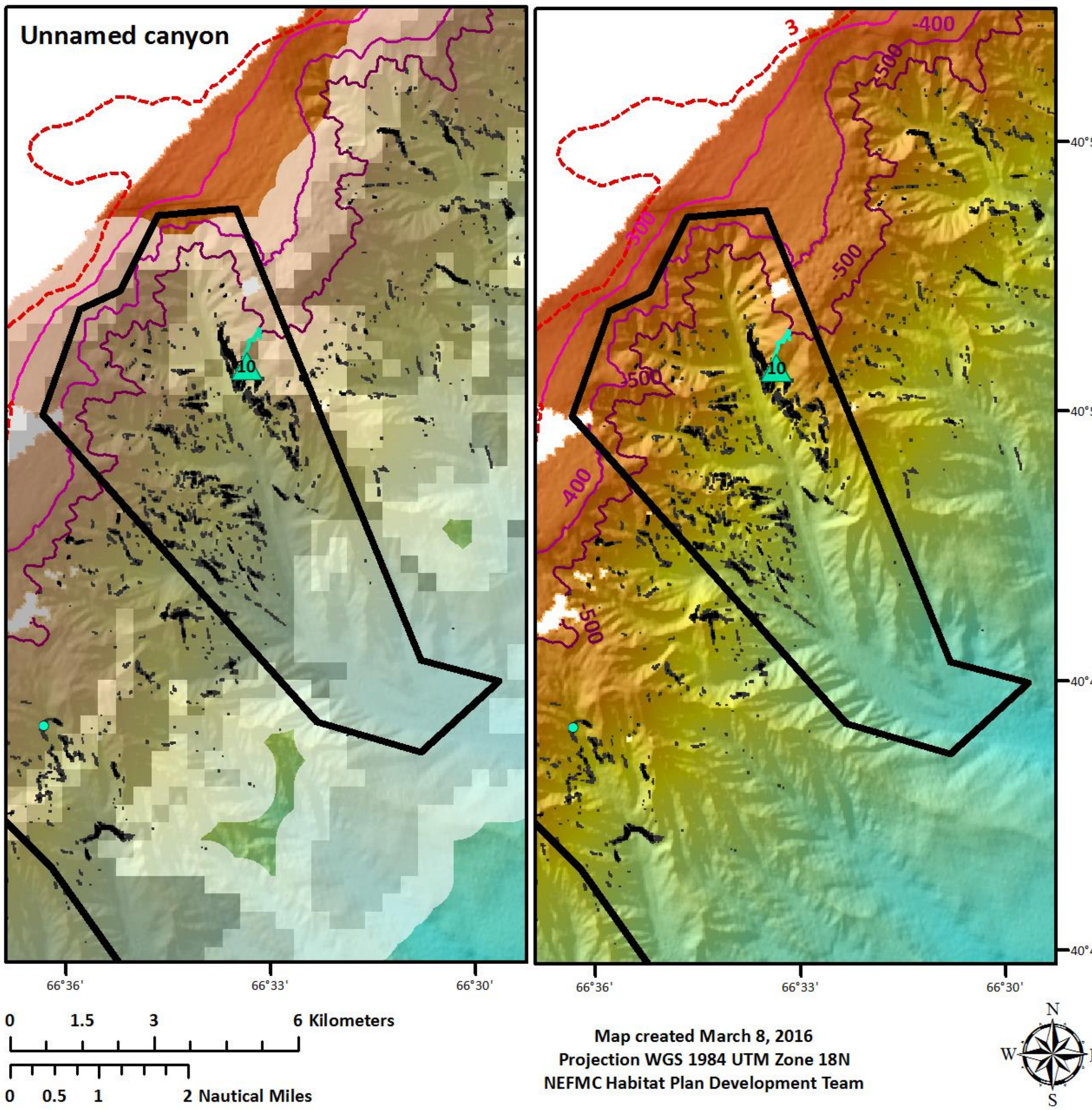
Unnamed Canyon

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. Based on the ACUMEN bathymetric data, the zone has a depth range of 345 to 1,878 meters below sea level.

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*).

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.

Map 19 – Recommended discrete zone in unnamed canyon located between Heezen and Nygren Canyons



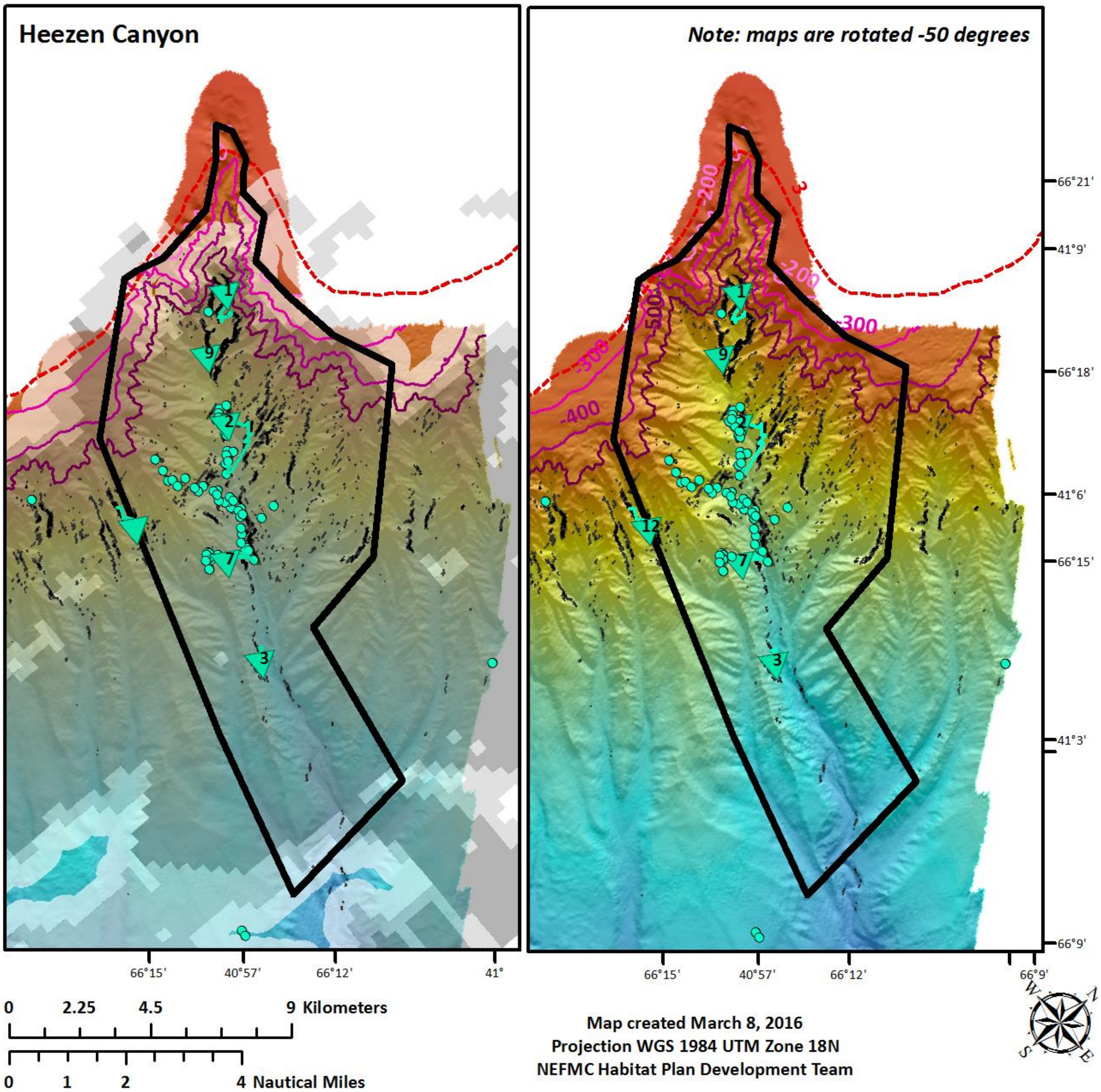
Heezen Canyon

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.

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.

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.

Map 20 – Recommended Heezen Canyon discrete zone



V. Seamount coral zones and boundaries

The PDT is not recommending any changes to the range of seamount zones or their boundaries. This section provides maps and descriptions that are broadly consistent with those in the canyon section above, and includes data collected on dives conducted during 2012, 2013, and 2014. 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 covered by each seamount. The boundaries were drawn using the bathymetry 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. The seamounts have depths at their peaks similar to the maximum depths of the canyon zones (Bear is somewhat shallower than this at around 1,100m), with maximum depths at their bases of between 3,000 and 4,000 meters.

Table 5 – Depth statistics for seamount zones

Seamount name	Area (km^2)	Minimum depth (meters)	Maximum depth (meters)	Mean depth (meters)
Bear	527	1,098	3,227	2,265
Mytilus	258	2,396	4,183	3,449
Physalia	169	1,875	3,712	3,108
Retriever	317	1,881	4,084	3,416

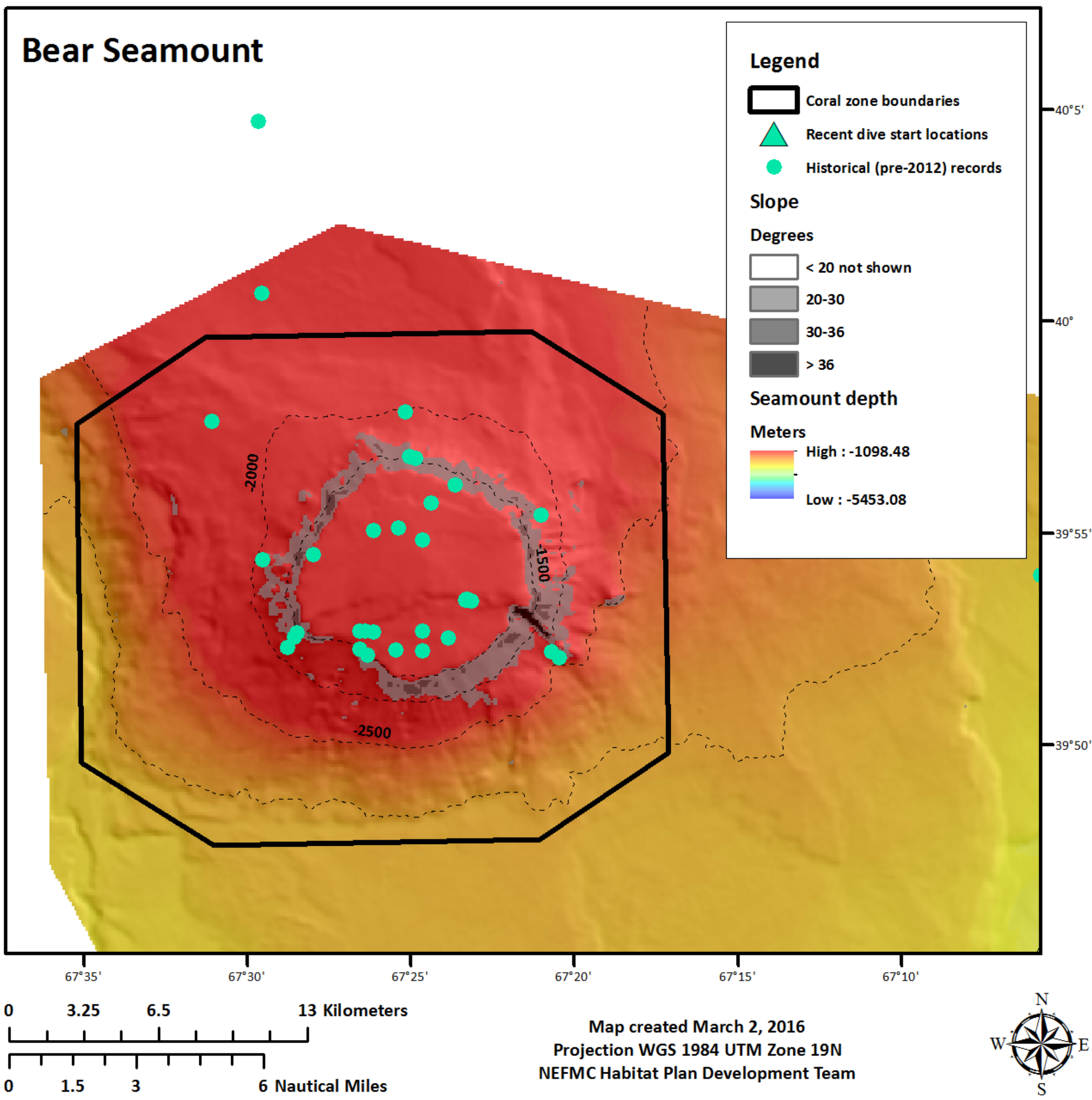
Table 6 – Number of historical records of corals in the seamount zones

Seamount name	Alcyonacea	Antipatharia	Pennatulacea	Scleractinia	Grand Total
Bear	32	6	1	5	44
Mytilus					0
Physalia					0
Retriever	12	1			13

Bear Seamount

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.

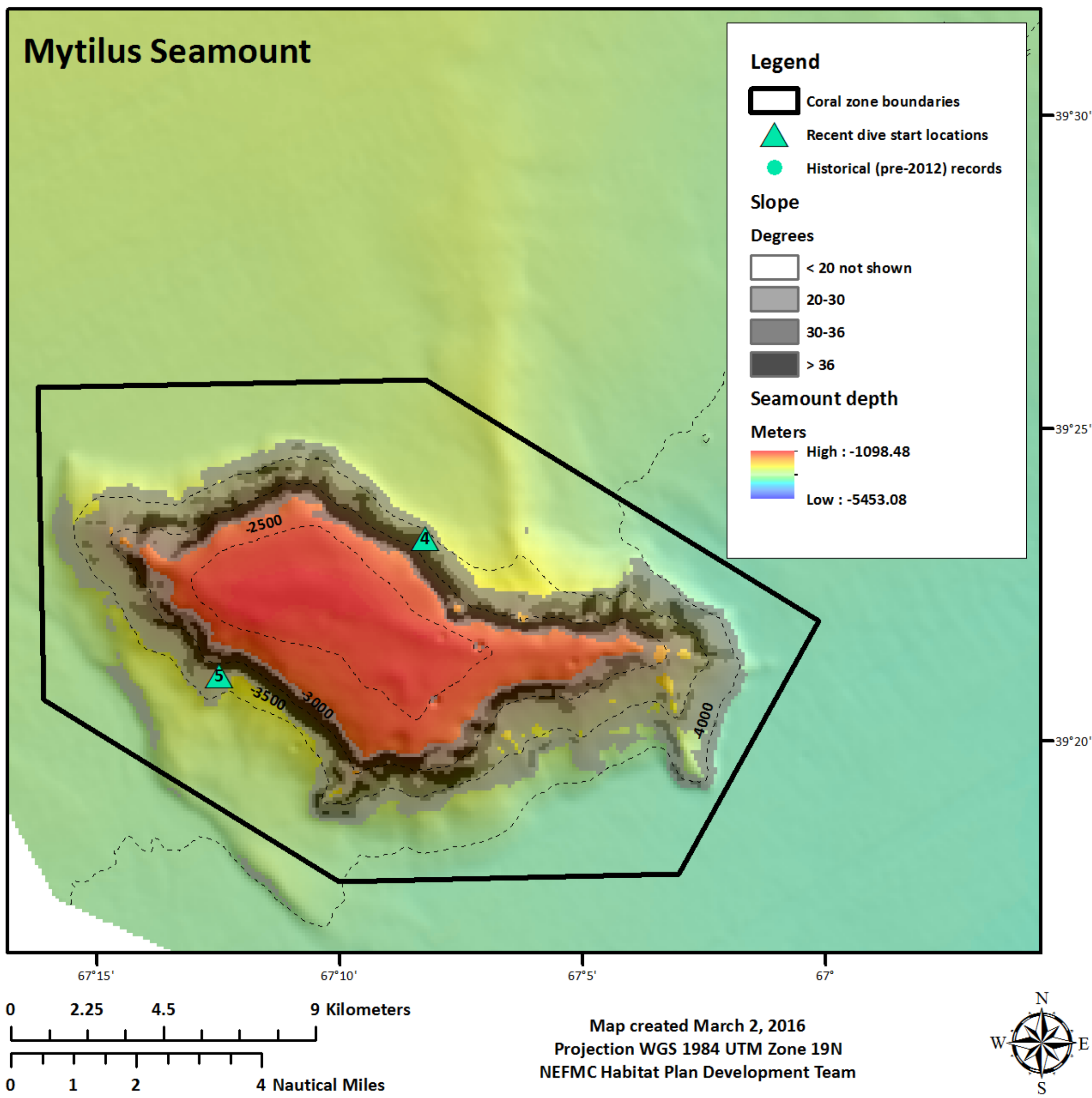
Map 21 – Current Bear Seamount coral zone boundary



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 were observed during both dives.

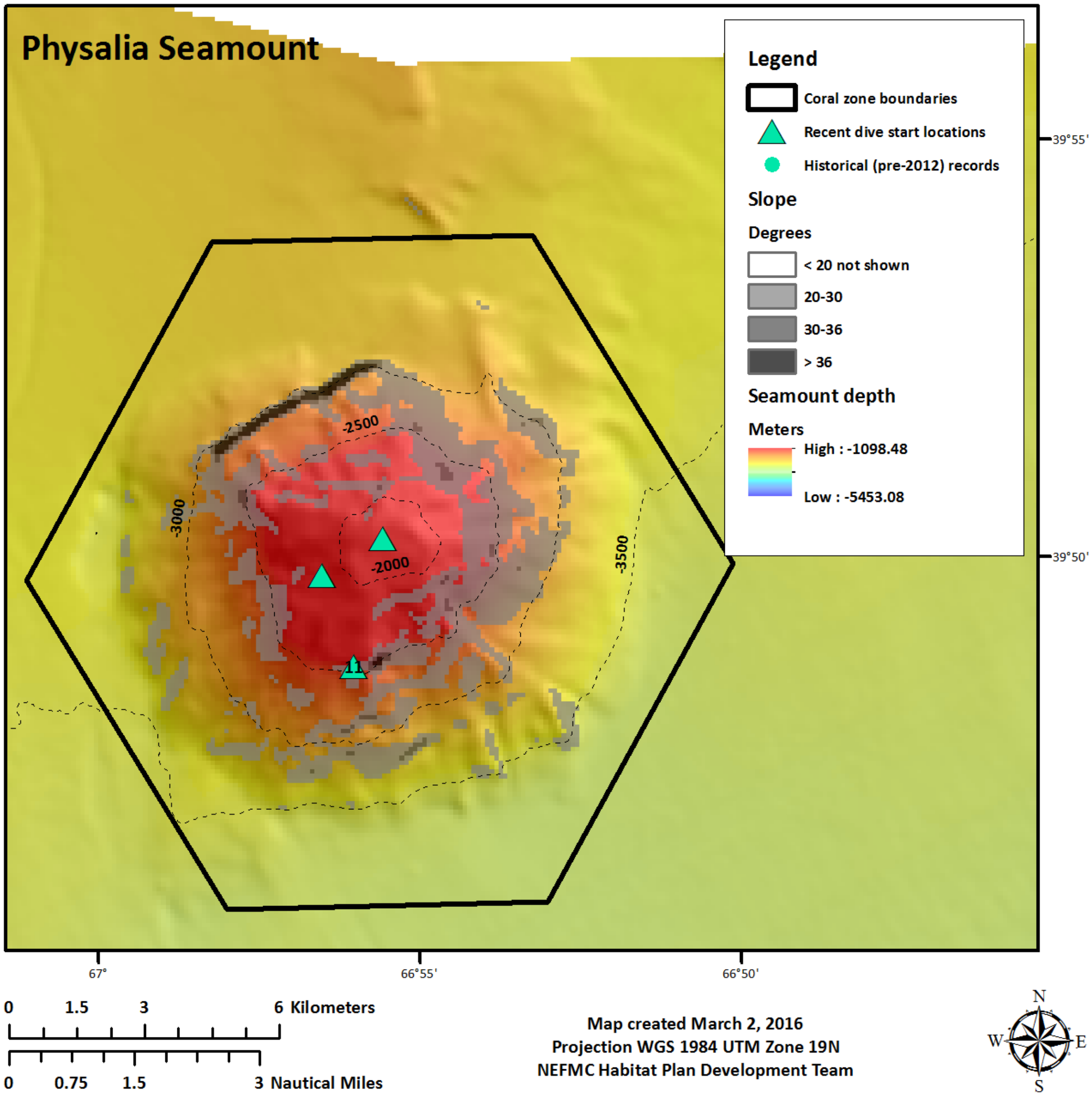
Map 22 – Current Mytilus Seamount coral zone boundary



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 a 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.

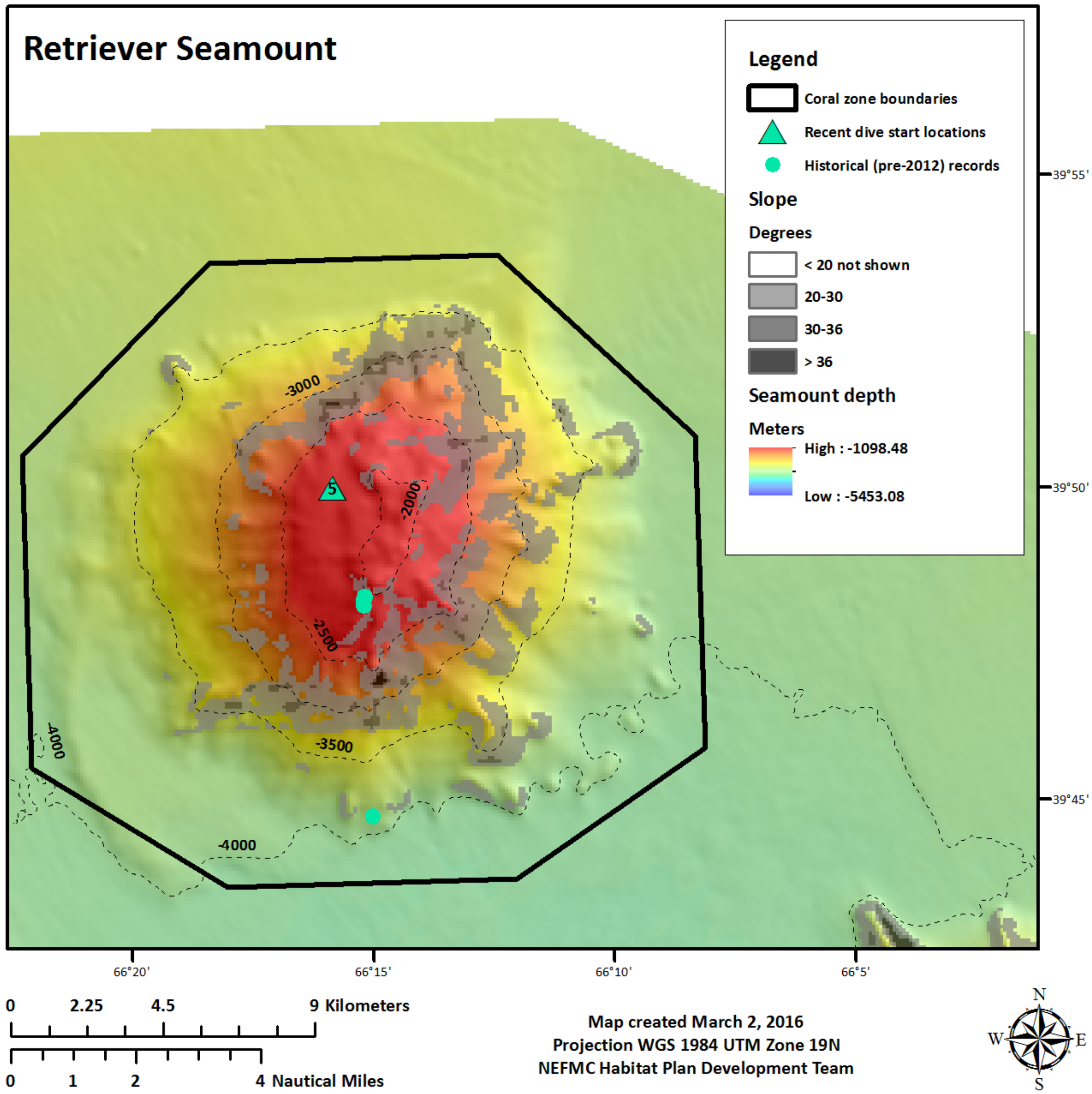
Map 23 – Current Physalia Seamount coral zone boundary



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 24 – Current Retriever Seamount coral zone boundary



VI. 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 low density corals vs. 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), but coral habitats in some areas exceed these densities (see sections below for details). Corals 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, Central Jordan Basin, and Lindenkohl Knoll within Georges Basin. All sites with multiple dive observations, specifically Outer Schoodic Ridge, Mount Desert Rock, the 114 Bump site in Western Jordan Basin, and Lindenkohl Knoll, had at least one dive where coral garden habitats were found.

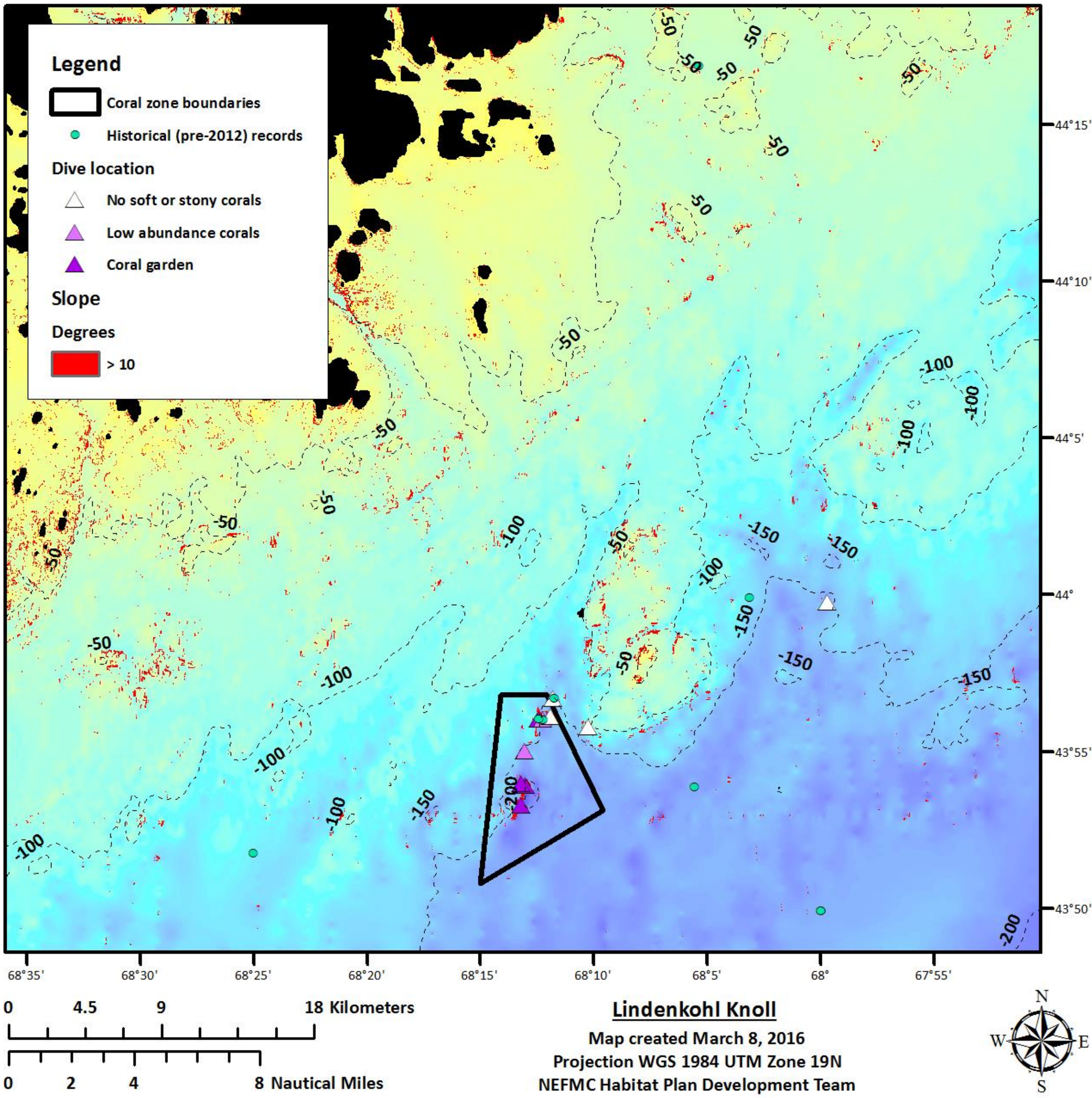
Other recently collected data that inform the delineation of coral zones include high resolution multibeam bathymetry in the Outer Schoodic Ridge and Western Jordan Basin regions. In general, the boundaries of the recommended coral zones were developed to encompass dive sites where corals were positively identified, and not to encompass the full spatial extent of specific terrain features, as is the case with the canyon and seamount sites. That being said, dives without corals were used to limit the extent of the deep-sea coral zone in the Outer Schoodic Ridge area, where multiple additional dives at similar depths did not find coral habitats.

Note that while similar colors are used for the depth shading on all the maps in this section, the scales are different between maps to best depict the change in depth at each site.

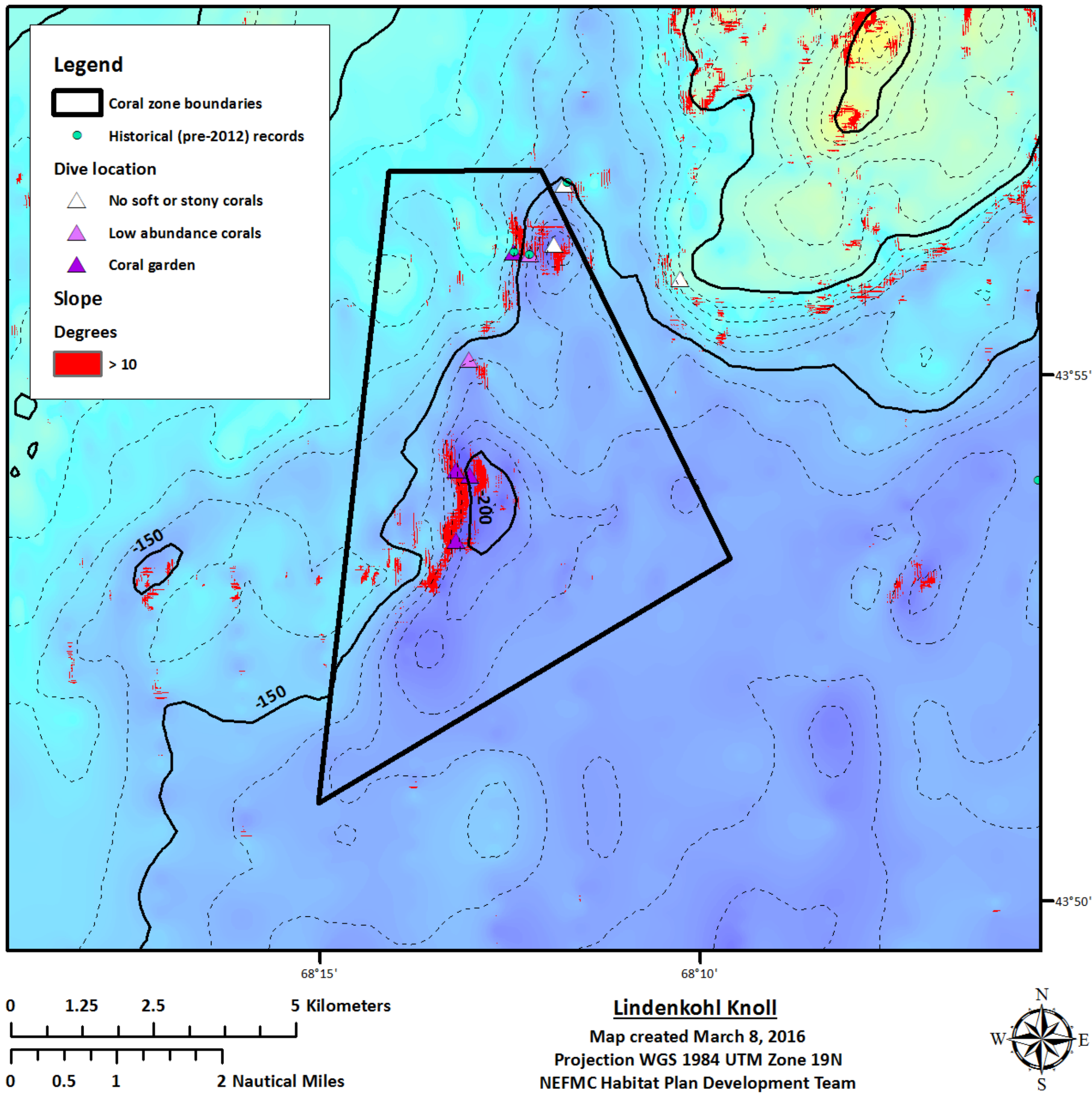
Mount Desert Rock

Mount Desert Rock is a small island off the eastern Maine coast, offshore of Mount Desert Island and Bar Harbor (Map 25). The proposed coral zone lies just to the southwest of Mount Desert Rock, and has depths ranging from approximately 100m to 200m (Map 26). 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 25 – Regional siting of Mount Desert Rock Coral Zone



Map 26 – Current Mount Desert Rock coral zone boundary, including recent dive locations and relative abundance of corals. Contours are in ten-meter intervals with 50 meter intervals highlighted. This map has the same color shading as the previous of the Mount Desert Rock region.



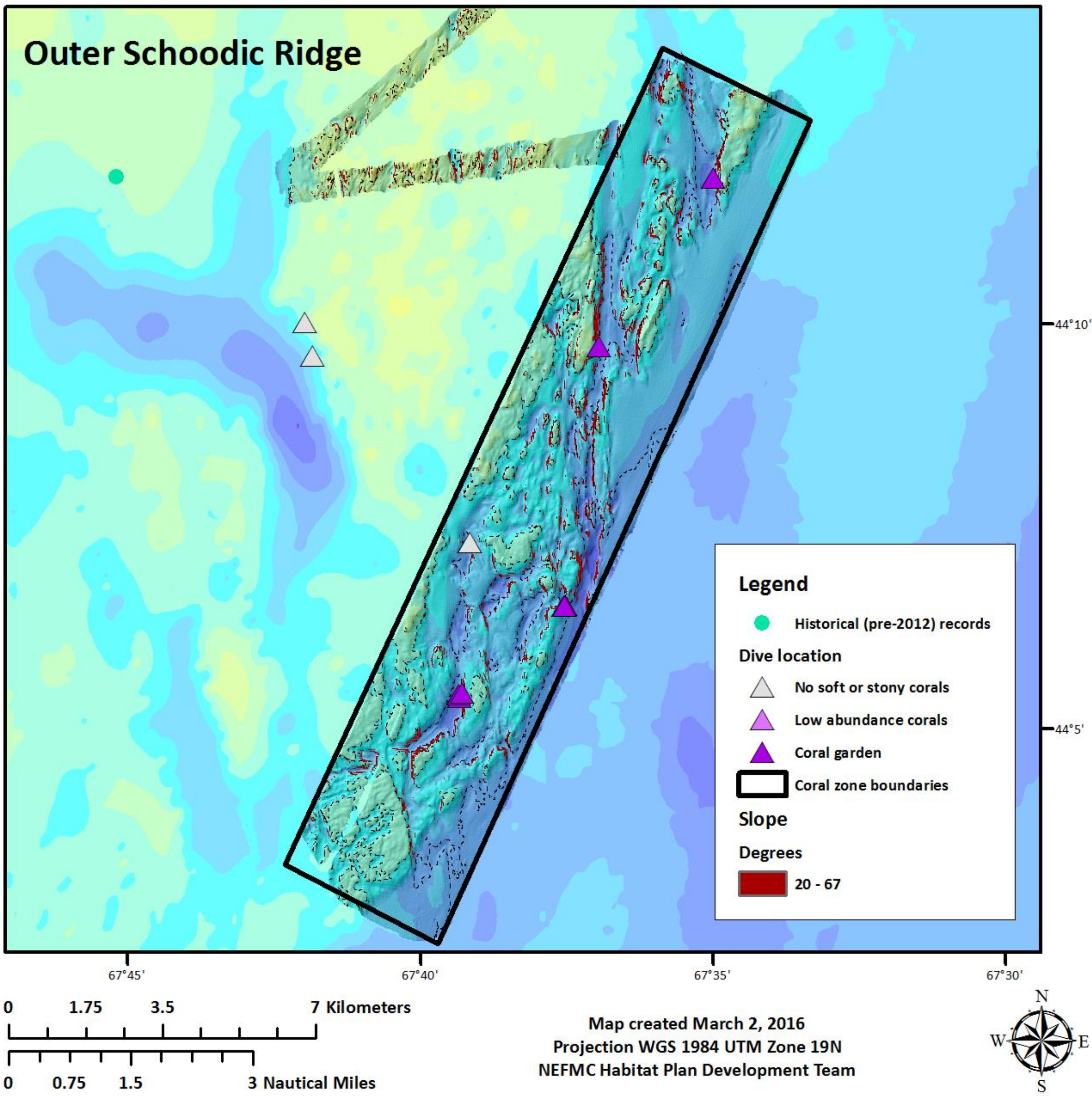
Outer Schoodic Ridge

Recent high resolution mapping details the complex terrain in the Outer Schoodic Ridge area. According to the high resolution multibeam bathymetry, depths in the recommended zone range from 104m to 248m, with a mean depth of 174m.

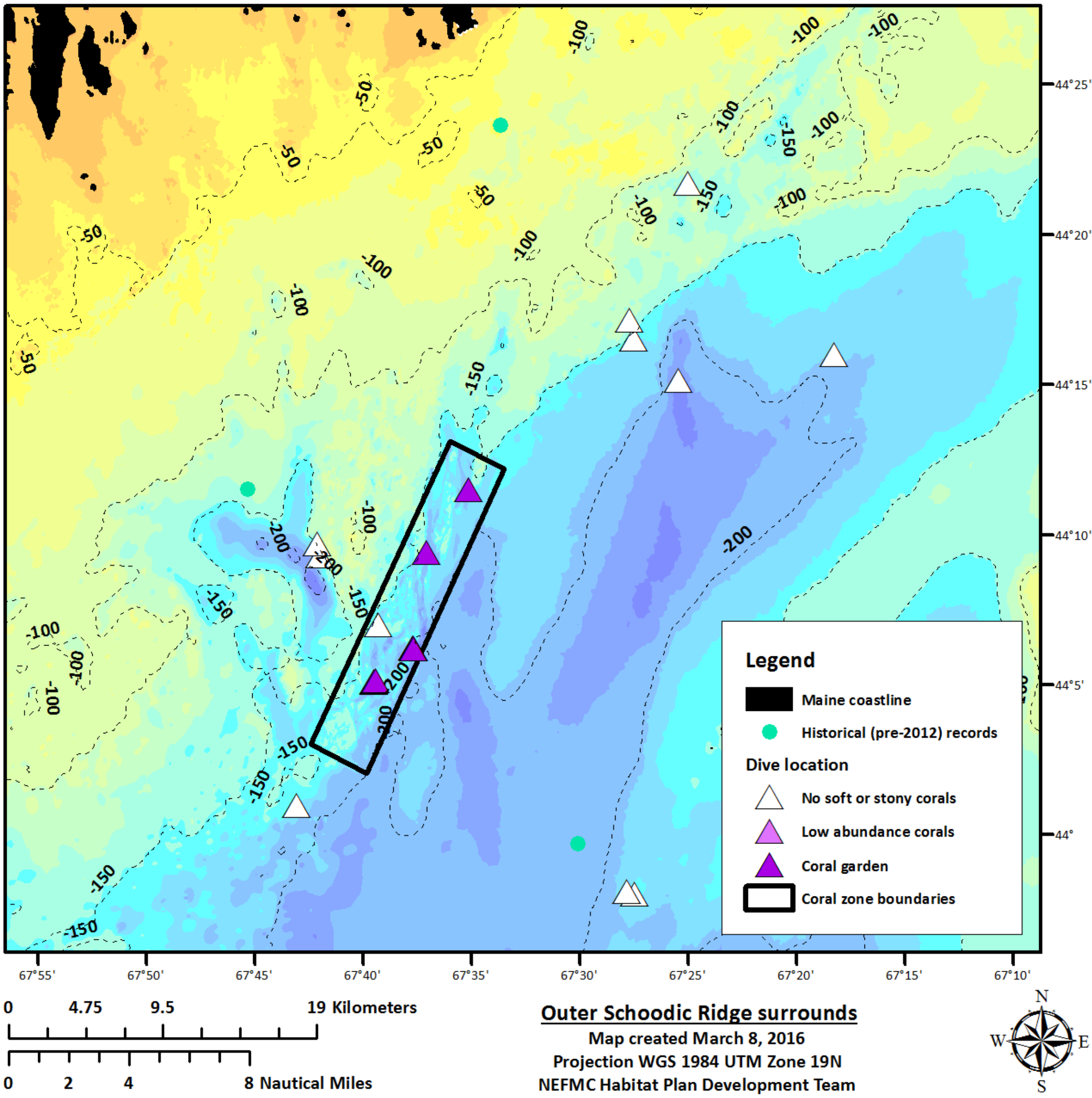
Corals at this location were studied during eight ROV dives and two camera tows during 2013, 2014, and 2015. Structure forming corals within the Outer Schoodic Ridge zone are mostly soft corals, although some smaller stony corals are also present. Highest densities of soft corals (e.g. 15.7-38.6 colonies 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 28).

Map 27 – Recommended Outer Schoodic Ridge coral zone boundary and high resolution bathymetry. Areas of high slope are shown in red. Relative coral densities during recent dives are shown in purple shading.



Map 28 – Area surrounding the recommended Outer Schoodic Ridge coral zone. Contours are at 50 meter intervals. Relative coral densities during recent dives are shown in purple shading.

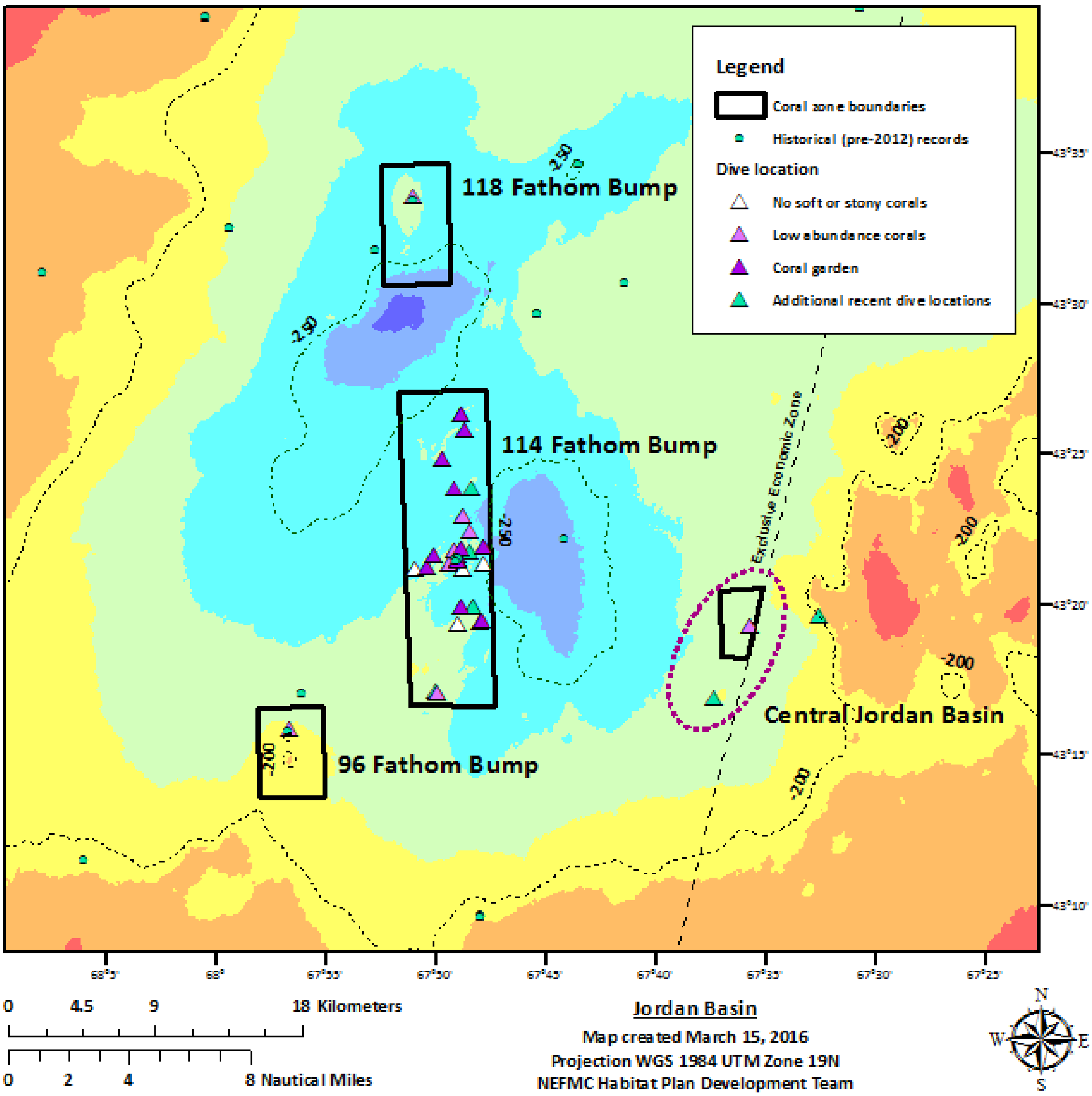


Jordan Basin

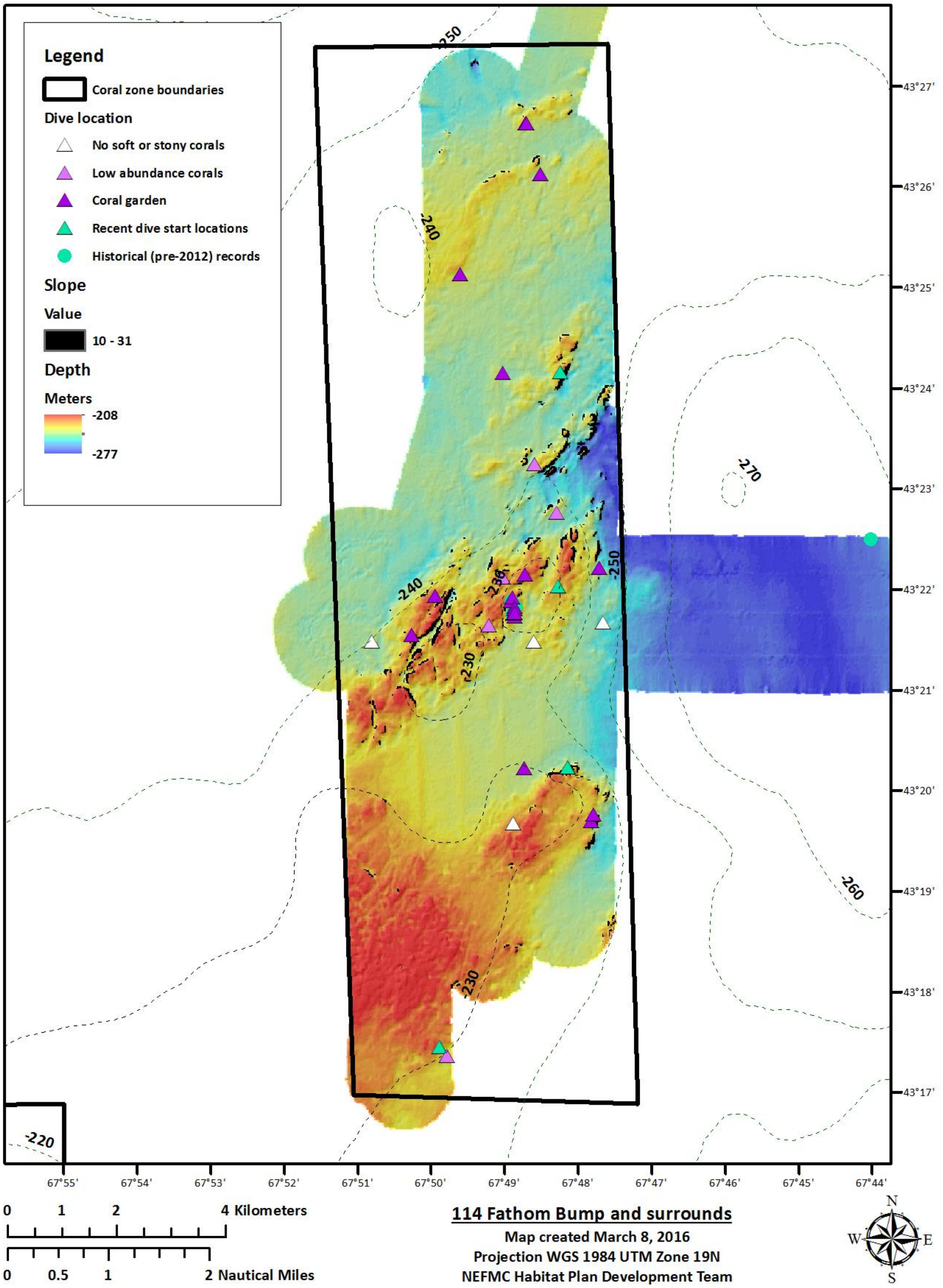
Jordan Basin, which straddles the EEZ boundary, has depths ranging from approximately 175 to 300 meters. Deep-sea corals have been observed on shallower rocky features within Western Jordan Basin, which are named for their charted depths: 98 Fathom Bump (179m), 114 Fathom Bump (208m), and 118 Fathom Bump (216m). Another site in Central Jordan Basin encompasses depths of approximately 220m to 235m.

The 114 Fathom Bump and its immediate surrounds is the best mapped of these four sites, and has the greatest number of dives. 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. There are two dives near the Central Jordan Basin site, although the imagery from only one of the two sites has been processed as of the most recent PDT discussions on February 22, 2016. The results of the image analysis for this dive may warrant an extension of the Central Jordan Basin zone boundary to the southwest.

Map 29 – Recommended coral zones in Jordan Basin. Boundaries for 118 Fathom Bump and 96 Fathom Bump are unchanged from current alternatives. The boundary for 114 Fathom Bump is expanded from the previously recommended alternative to encompass additional coral observations (purple triangles) from recent dives. The Central Jordan Basin zone is new. One of the dives near the Central Jordan Basin zone has not yet been analyzed. It may make sense to extend the boundary to the southwest within the dotted outline.



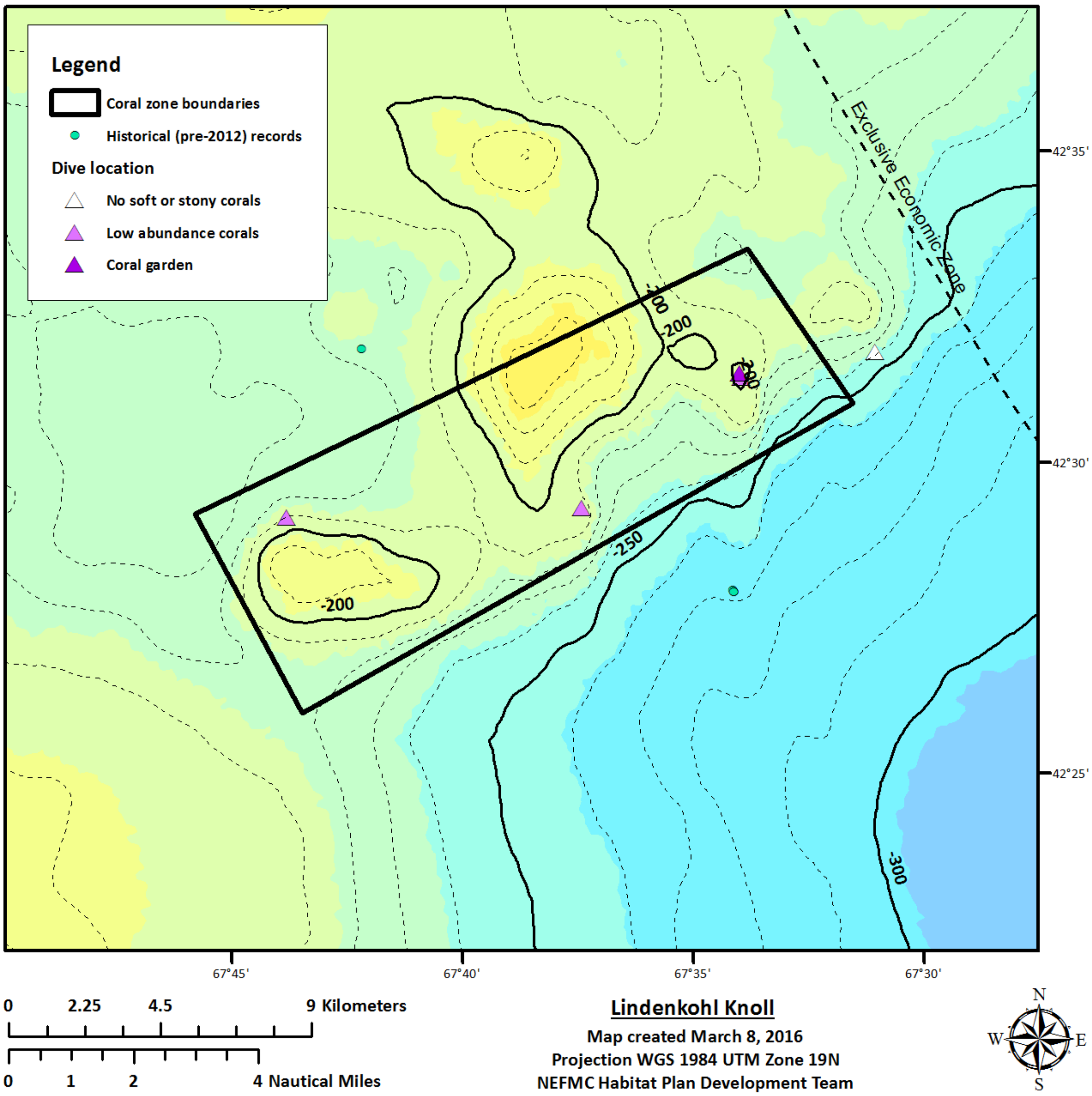
Map 30 – Larger scale image of the high resolution bathymetry at the 114 Fathom Bump zone. This map uses a different color scale than the previous map of the Western/Central Jordan Basin region.



Lindenkohl Knoll

Lindenkohl Knoll is a somewhat shallower feature on the western side of Georges Basin. The recommended zone has depths ranging from approximately 165m to 255m, while Georges Basin overall approaches a maximum depth of nearly 400m below sea level. Four 2015 camera tows found corals at both coral garden (one tow) and low densities (three tows). The soft coral *Paramuricea* was the most commonly occurring species.

Map 31 – Recommended Lindenkohl Knoll coral zone.



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