Imaging Surveys of Select Areas in the Northern Gulf of Maine for Deep-sea Corals and Sponges during 2013-2014.

Report to the New England Fishery Management Council - 30 October 2014.

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Since the late nineteenth century, deep-sea octocorals were known to occur in the Gulf of Maine region; specimens collected during early natural resource expeditions as well as by fishermen as bycatch were contributed to natural history museums (Watling and Auster 2005, Gass and Willison 2005). Early ecological studies (e.g., Wigley 1968, Theroux and Grosslien 1987) listed corals as a common component of the hard bottom faunal assemblage in the Gulf of Maine. However, it appears that coral distributions have contracted significantly since then and are now limited to small refugia in rocky areas (Watling and Auster 2005; Auster 2005, Auster et al. 2013, Cogswell et al. 2009).

To inform discussions of deep-sea coral management and fish habitat usage, we are providing the New England Fishery Management Council with a brief review of research surveys conducted in 2013 and 2014. These surveys identified coral-dominated communities in U.S deep waters (200-250 m depth) of the northern Gulf of Maine. This report focuses only on geographic distributions of octocorals based on direct observations. Detailed analyses of imagery to determine fine-scale attributes of coral and sponge distributions in relation to geology, benthic community composition, species associations, and coral size structure are ongoing. Additionally, coral samples were collected for taxonomic, reproductive biology, age-size, and population genetics studies. Results from all projects will be reported as they are completed.

Two different camera platforms were used to assess the presence and composition of coral communities. Both platforms were outfitted with real-time color video and digital still photographic imaging equipment. A 14-day cruise (11-24 July 2013) aboard the RV *Connecticut* utilized the University of Connecticut's ISIS2 towed camera sled. Thirty-five ISIS camera tows were conducted in four areas (Western Jordan Basin, Mount Desert Rock, Outer Schoodic Ridge, off Monhegan Island; Figure 1). A second cruise (23 July - 6 August 2014) aboard the RV *Connecticut* employed the ROV Kraken 2. During this cruise, 21 ROV dives were conducted in three areas (Outer Schoodic Ridge, Western and Central Jordan Basin; Figure 1).

Previous surveys in the region guided the selection of survey sites in 2013. Initial investigations using ROVs in 2003 and 2004 documented a limited number of locations with dense coral communities (e.g., Auster 2005, Watling and Auster 2005). During a cruise of the NOAA Ship *Ronald H. Brown* during 2005, preliminary multibeam sonar data was collected in Western Jordan Basin and revealed that hard substratum in the immediate area around one of those sites (i.e., around the 114 Bump site indentified in 2004-2004) was more spatially extensive than previously suspected (Watling and Auster, unpublished). Using these data and a detailed bathymetric chart of the Jordan Basin-Mount Desert Rock-Schoodic Ridge regions (Fisheries and Oceans Canada LC 4011), we selected areas of steep topographies in depth ranges where corals were expected to occur (i.e., the deeper depths of Maine Intermediate Water and Maine Deepwater regimes). These initial surveys and mapping efforts, along with historical records (Watling and Auster 2005, Packer et al. 2007, in review), were the basis for the current coral zone alternatives for the northern Gulf of Maine region, as described in the June 2012 Draft Deep-Sea Coral Management Alternatives (Figure 3; NEFMC 2012).

Much needed high quality multibeam data were recently collected in the region after our 2013 survey. Maps of the two primary survey areas (i.e., Western Jordan Basin and Outer Schoodic Ridge) were produced during a collaborative effort with the Ecosystem Monitoring group of NEFSC and NOAA's Office of Exploration and Research (OER) during the fall 2013 ECOMON cruise aboard the NOAA Ship *Okeanos Explorer* (Figure 4 a,b). Thus, selection of ROV dive locations in 2014 were based on topographic features illustrated in these detailed maps. A map of the Central Jordan Basin dive site, immediately along the U.S.-Canada boundary, was produced during a June 2014 cruise (HB1402) of the NOAA Ship *Henry B. Bigelow* (Figure 4c). Based on these data, we conducted one dive in the Central Jordan Basin region in 2014. Time constraints prevented additional investigations. No dives were made at Mount Desert Rock during 2014.

Results of our surveys revealed extensive coral cover in our two primary survey sites (Western Jordan Basin and Outer Schoodic Ridge; Figure 5). This pattern is somewhat biased given that we focused our efforts on topographic features that we reasoned could support coral communities in order to increase the likelihood that coral habitat would be discovered. As the map indicates, other areas in the region, such as Mount Desert Rock and Central Jordan Basin also have coral communities. Although habitat suitable for coral colonization appears to be more patchy in these areas than in the primary survey areas, additional work is needed to better define the extent of coral habitat. The spatial extent of surveys in these areas were inadequate due to limited dive time. (Note: we only report octocoral data here, as this is the primary focus and defining rationale for the coral omnibus amendment.)

Structure-forming corals at all sites were predominantly octocorals (Subclass Octocorallia, Order Alcyonacea), although scarce numbers of tiny, stony cup corals (Subclass Hexacorallia, Order Scleractinia) were observed on some dives. We classified coral occurrences as either coral present (sparse to medium density) or coral garden (high density patches). Coral gardens are defined as areas where octocorals are among the dominant fauna and occur at densities higher than surrounding patches (Bullimore, Foster, and Howell 2013). Based on ISIS2 imagery in 2013, areas in Western Jordan Basin, off Mount Desert Rock, and Outer Schoodic Ridge with steep and short vertical rock faces (ca. 2-4 m maximum height) had higher densities of octocorals (primarily *Paramuricea placomus* with lower abundances of *Primnoa resedaeformis* and *Acanthogorgia* cf. *armata*) than nearby areas with less vertical relief (Figure 6). Density of coral colonies on these rock faces, calculated using 20 cm parallel laser dots to calibrate the area of digital still images, had highest density values of 15.7–38.6 colonies m^{-2}. These density values are well above the threshold of 0.1 colony m^{-2} used by ICES (2007) to define coral garden habitat. Areas adjacent to these steeper features as well as open 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*). Corals in these low relief environments co-occurred with other attached and emergent structure-forming fauna (e.g. burrowing anemone *Cerianthus borealis*, sea pen *Pennatula aculeata*, sponge *Polymastia* sp. and other sponge taxa).

Surveys with the highly maneuverable Kraken 2 ROV during 2014 revealed additional coral-dominated sites as described above (Figure 7). Tall vertical rock walls in the Schoodic Ridge area with extremely dense and spatially extensive communities dominated by *Primnoa resedaeformis* were also observed (Figure 8). The geologic setting in Schoodic is unique, and analogous in topographic structure to slot canyon morphologies found on land (e.g., in the western United States). Coral colonies were so dense in most of these settings it was impossible to identify and count individual colonies. The vertical walls had the highest coral cover of any area along Outer Schoodic Ridge. One discrete community measured approximately 42 m horizontally x 12 m in height based on ultra-short baseline acoustic tracking and Kraken 2 altitude sonar data.

A site in Central Jordan Basin was added to the 2014 cruise to survey areas likely to support corals in U.S. waters along the U.S.-Canada boundary. The single dive revealed low-density patches of *Paramuricea* on lower vertical relief rock outcrops and mud-covered gravel (Figure 9). (In June 2014 scientists aboard NOAA Ship *Henry B. Bigel*ow cruise used the Canadian ROV ROPOS to investigate deep-sea coral habitats and associated fauna in submarine canyons and the Gulf of Maine on both sides of the international boundary. Only one ROPOS dive, south of the study site reported here, was conducted in U.S. waters of Jordan Basin. Results of the *Bigelow* cruise will be reported elsewhere.)

In all areas surveyed, sponges and anemones often occurred in high density patches amongst the more extensive corals on walls and on steep features without corals (Figure 10). Sea pens also occurred in dense patches in mud and gravel-mud habitats adjacent to hard substratum habitats. Sea pens have been documented to serve as habitat for larval redfish in Canadian waters (Baillon et al. 2012).

Pandalid shrimp, amphipods, and aggregations of krill (*Meganyctiphanes norvegica*) were commonly associated with coral communities along steep walls. Acadian redfish used coral for shelter whereas Atlantic cod (juvenile and adult size classes), cusk, goosefish, pollock, silver hake and spiny dogfish were observed searching for and catching prey (i.e. pandalid shrimp, krill, small fish) near and amongst coral colonies (Figure 11). Corals also provided flow refuges for fishes from tidal generated currents. Crustacean taxa (American lobster *Homarus americanus*; king crab *Lithodes maja*) occurred in association with structure-forming organisms on the seafloor, including corals, and were observed foraging amongst these features as well.

Noteworthy is the first documentation of the occurrence of *Anthothela grandiflora* in the Gulf of Maine (Figure 12). This species has been observed off the Northeast Channel along the continental margin at depths deeper than 1400 m (Cogswell et al. 2009). Also, we observed the sea star *Hippasteria phrygiana* preying on *Primnoa*. These predation events occurred on living coral colonies that had been detached from rock walls and were laying on the seafloor (Figure 13).

Areas exhibiting recent direct impacts from fishing activities were observed at sites in Western and Central Jordan Basin and Outer Schoodic Ridge. In steep areas, paths or tracks, consistent with setting or recovery of trap gear, were denuded of corals and associated fauna (Figure 14a-c). The peaks of some ridges and nearly horizontal sections of wider outcrops were also denuded. Tracks observed here were consistent with impacts from mobile fishing gear (Figure 14d-e). Some coral patches exhibited damage to large but still living colonies. Smaller colonies were also distributed within the patch, producing a disjunct size class structure, and suggesting previous impacts with subsequent recruitment (Figure 14f).

Here we have summarized results from recent research cruises focused on deep-sea coral resources within the northern Gulf of Maine region with the intent to provide the Council with improved information for conservation and management. This project principally addressed the "Exploration and Research" goal of NOAA's Deep Sea Coral Research and Technology Program (DSCRTP)(NOAA 2010) and the specific objectives to: "locate and characterize deep-sea coral and sponge ecosystems, understand the biology and ecology of deep-sea corals and sponges, understand the biodiversity and ecology of deep-sea coral and sponge ecosystems, and understand the extent and degree of impact to deep-sea coral and sponge ecosystems." Meeting these objectives links directly to the second DSCRTP goal of "Conservation and Management." Data collected provides information needed to inform the management process to protect coral communities from fishing gear impacts and conserve those areas not currently fished. This work also meets NOAA's long-term mission Goal #3 focused on "Healthy Oceans." In particular, research and information products that result from this deep sea coral survey effort will directly inform NOAA Fisheries and the New England Fisheries Management Council and improve conservation and sustainable use of "[m]arine fisheries, habitats, and biodiversity ..." by aiding development of management alternatives related to deep sea corals and essential fish habitat.

Highest abundances and diversity of deep-sea corals off the Northeast United States occur in deep submarine canyons and seamounts far offshore along the edge of the continental shelf (Packer et al. 2007). That said, the extremely high densities observed for at least two large-sized, structure forming species of corals in the relatively shallow waters of the Gulf of Maine is unique. The proximity of these habitats so close to shore increases the potential role of these habitats to function as EFH (e.g., Auster 2005). Finding these spectacular walls of corals in the Gulf of Maine for the first time in 2014, after 40-plus years of submersible surveys, illustrates how much more we need to understand about the Gulf of Maine ecosystem in order to better conserve and manage our natural resources.

Acknowledgements

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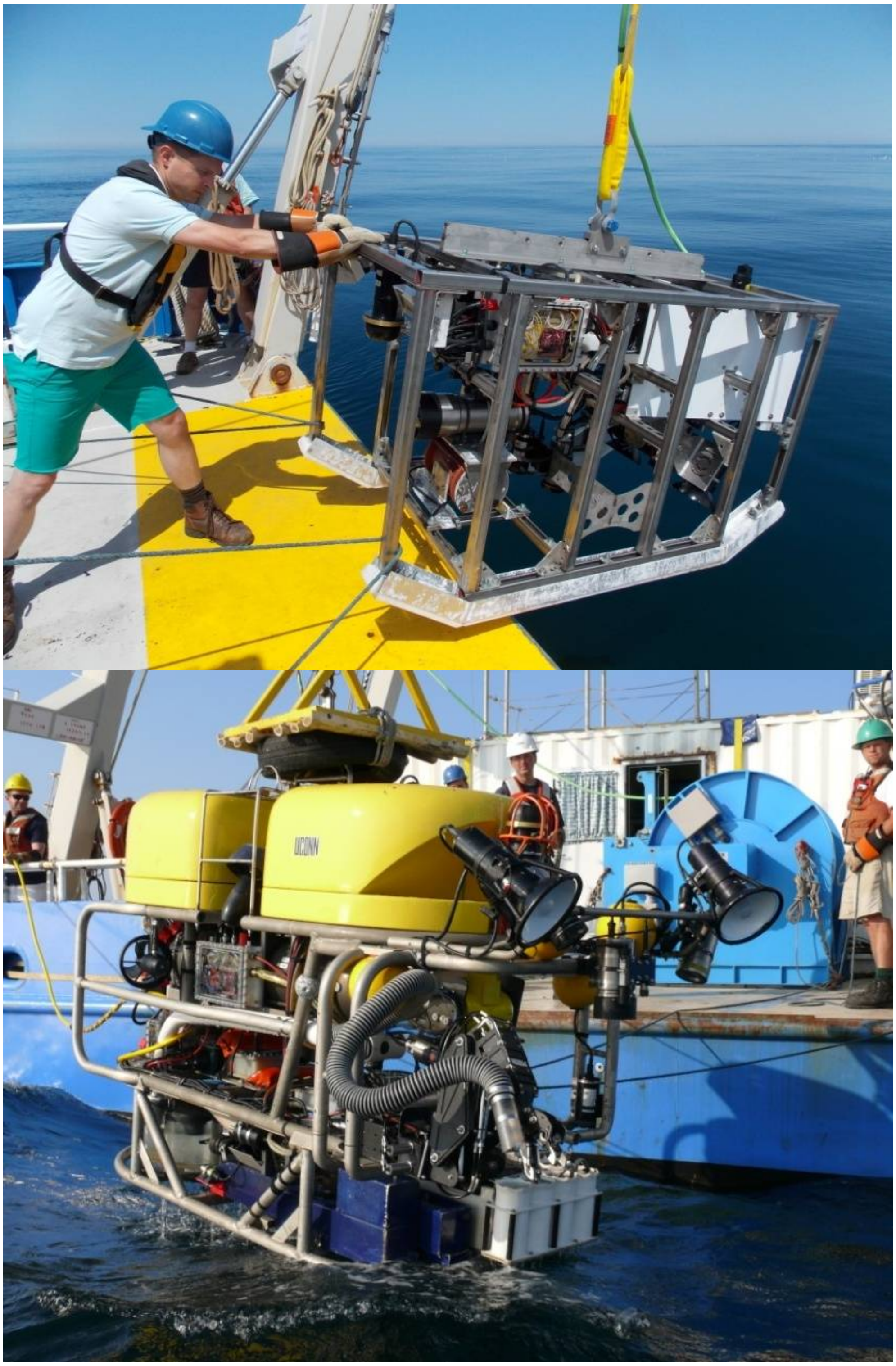


Figure 1. (Top) Instrumented Seafloor Imaging System 2 (ISIS 2) and (bottom) Kraken 2 Remotely Operated Vehicle (ROV). Both systems have forward and down-looking video and digital photographic capabilities. ISIS 2 can be rapidly deployed and recovered but can only maneuver in X-Y directions along complex seafloor via ship movement using dynamic positioning, with depth adjusted via shipboard winch. This system is limited to imaging tasks. Kraken 2 has more complex launch-recovery requirements but is able to finely maneuver for imaging as well as to collect and store samples with a manipulator arm and suction sampler.

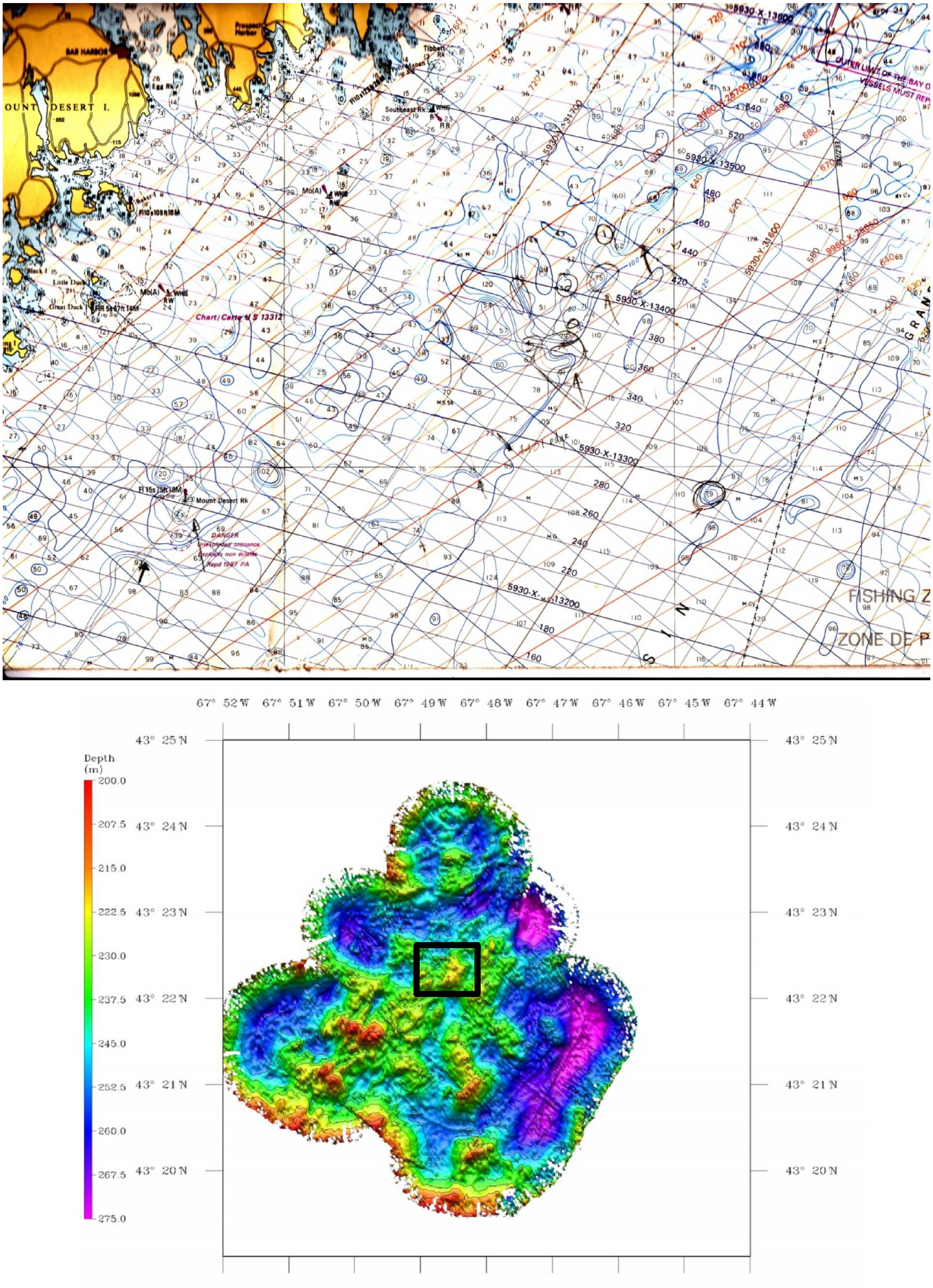


Figure 2. (Top) Bathymetric chart of Mount Desert Rock – Schoodic Ridges region (Fisheries and Oceans Canada LC 4011) used to identify 2013 ISIS2 camera tow stations along areas of steep topography. (Bottom) Multibeam bathymetric map from NURP-UConn 2005 NOAA Ship *Ronald H. Brown* cruise. The 114 Bump site, identified during 2003-2004 cruises in Western Jordan Basin, is indicated by the box.

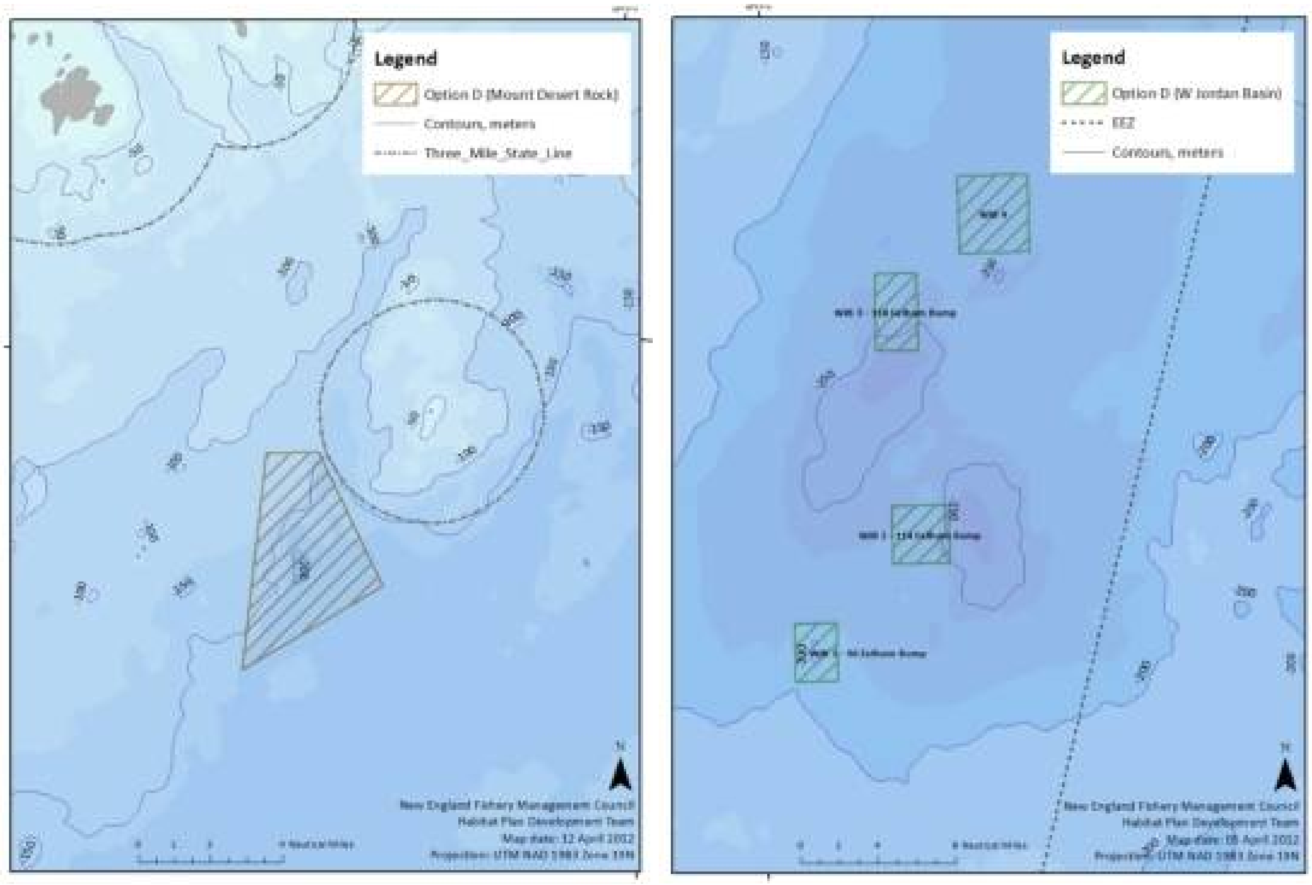


Figure 3. Maps of current draft alternatives for discrete deep-sea coral zones in the Gulf of Maine: Mount Desert Rock area (left) and Western Jordan Basin (right). Source: Maps 12 and 13 in NEFMC June 2012 Draft Deep-Sea Coral Management Alternatives.

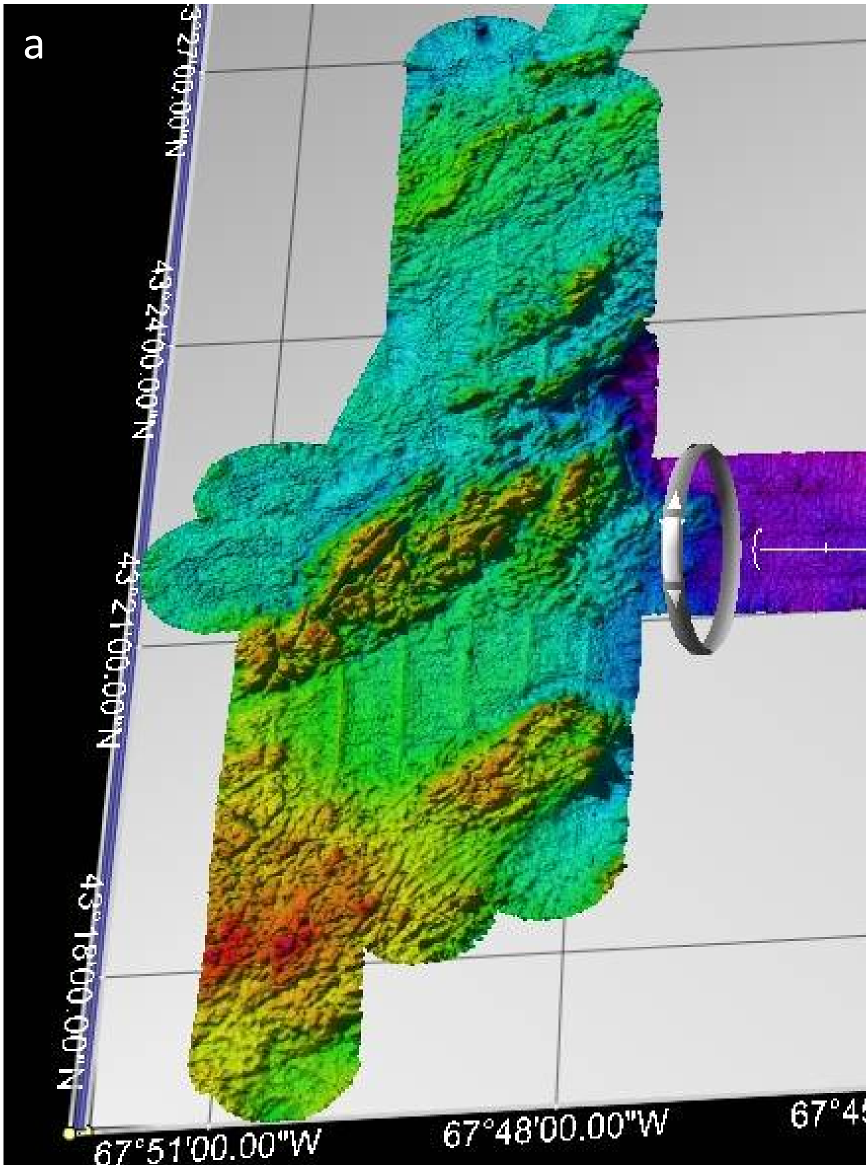
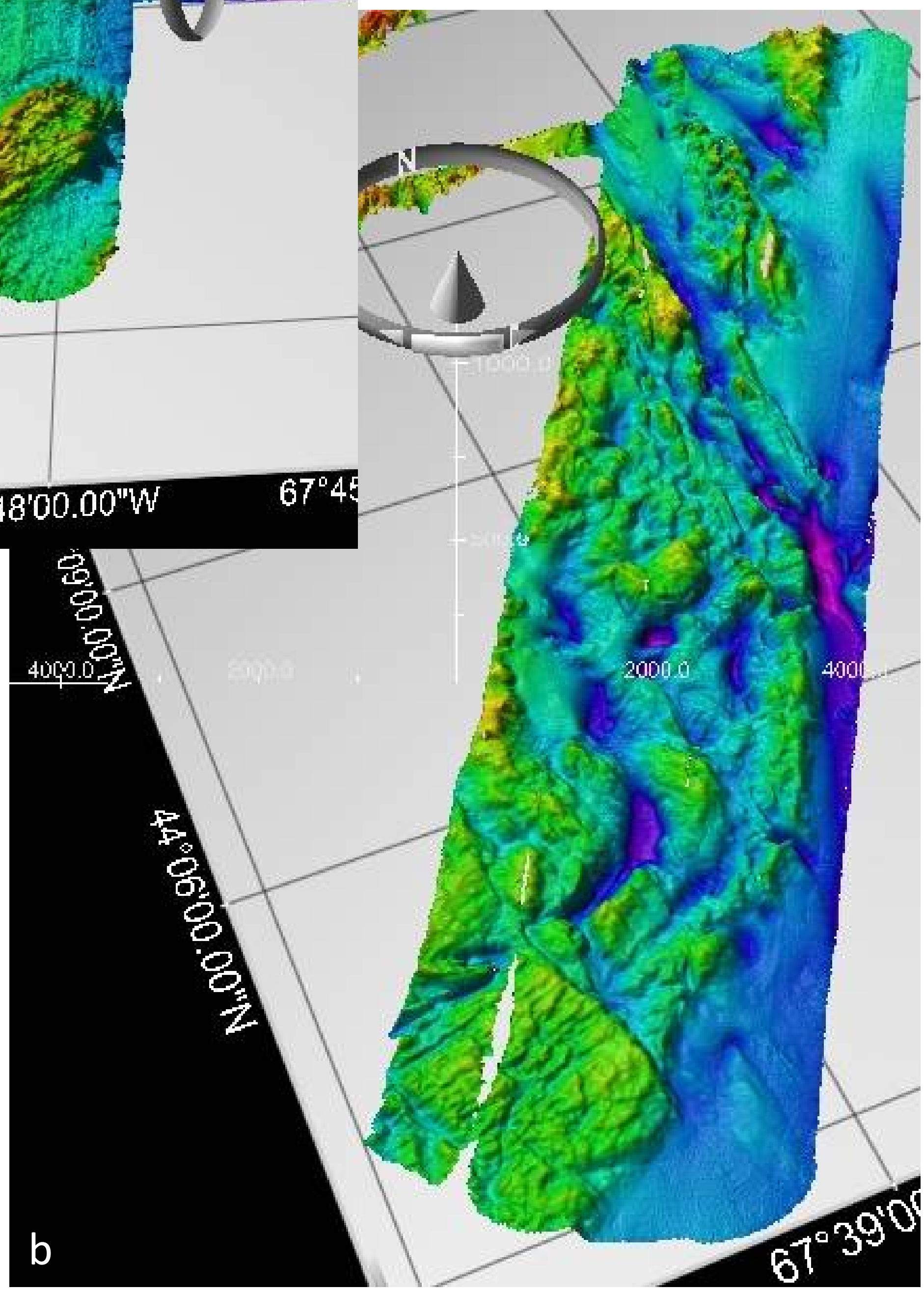
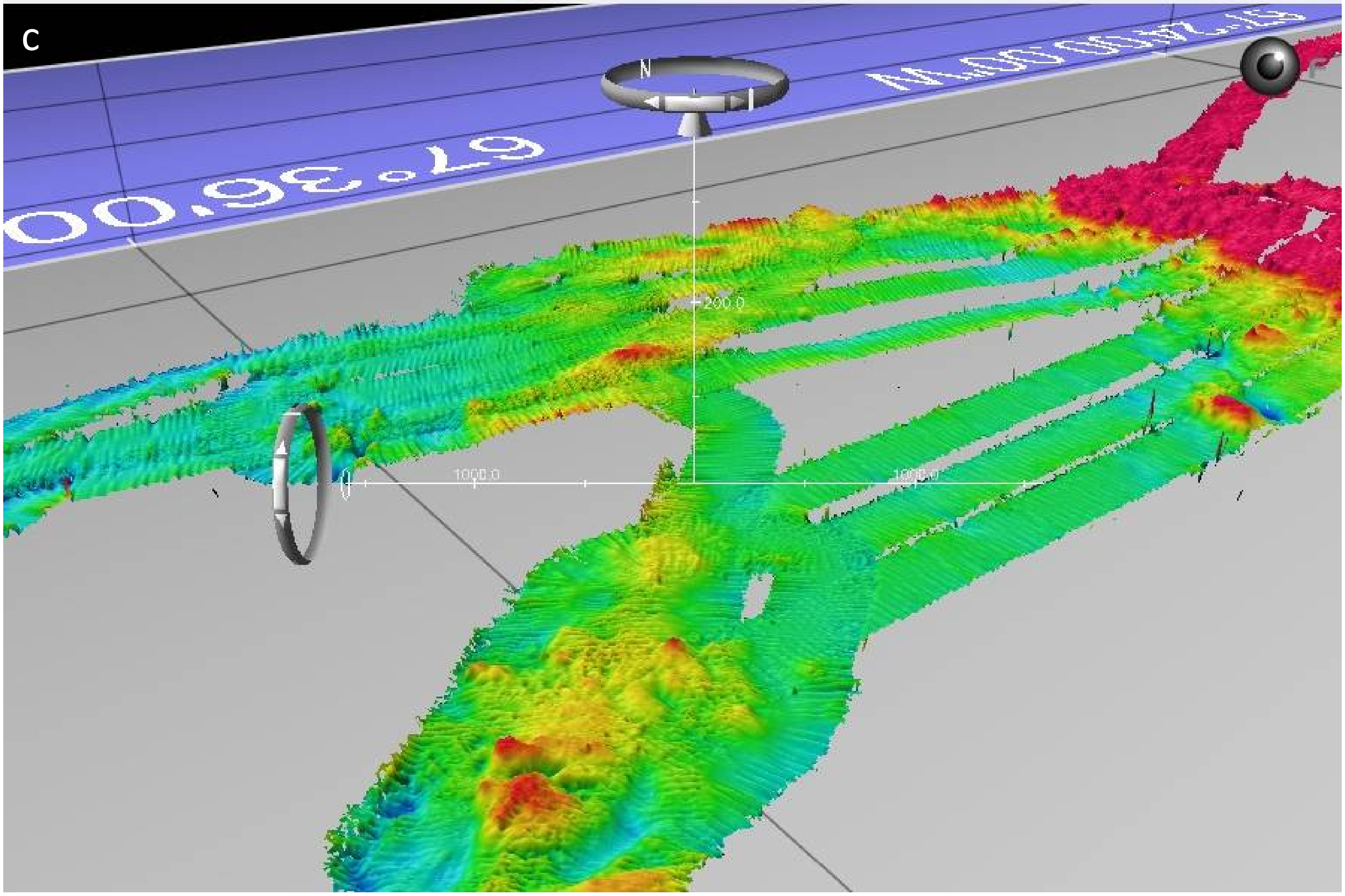


Figure 4. Detailed multibeam maps of (a) Western Jordan Basin and (b) Outer Schoodic Ridge. Refer to Figure 3 for regional geographic setting. These maps were produced on an ecosystem monitoring cruise (EX 1305) of the NOAA Ship *Okeanos Explorer* by Mashkoor Malik. (c) Multibeam map (next page) of an area in the Central Jordan Basin region along the U.S.-Canada boundary. This unprocessed multibeam was produced in support of ROV operations on the NOAA Ship *Henry B. Bigelow* by Brian Kinlan.





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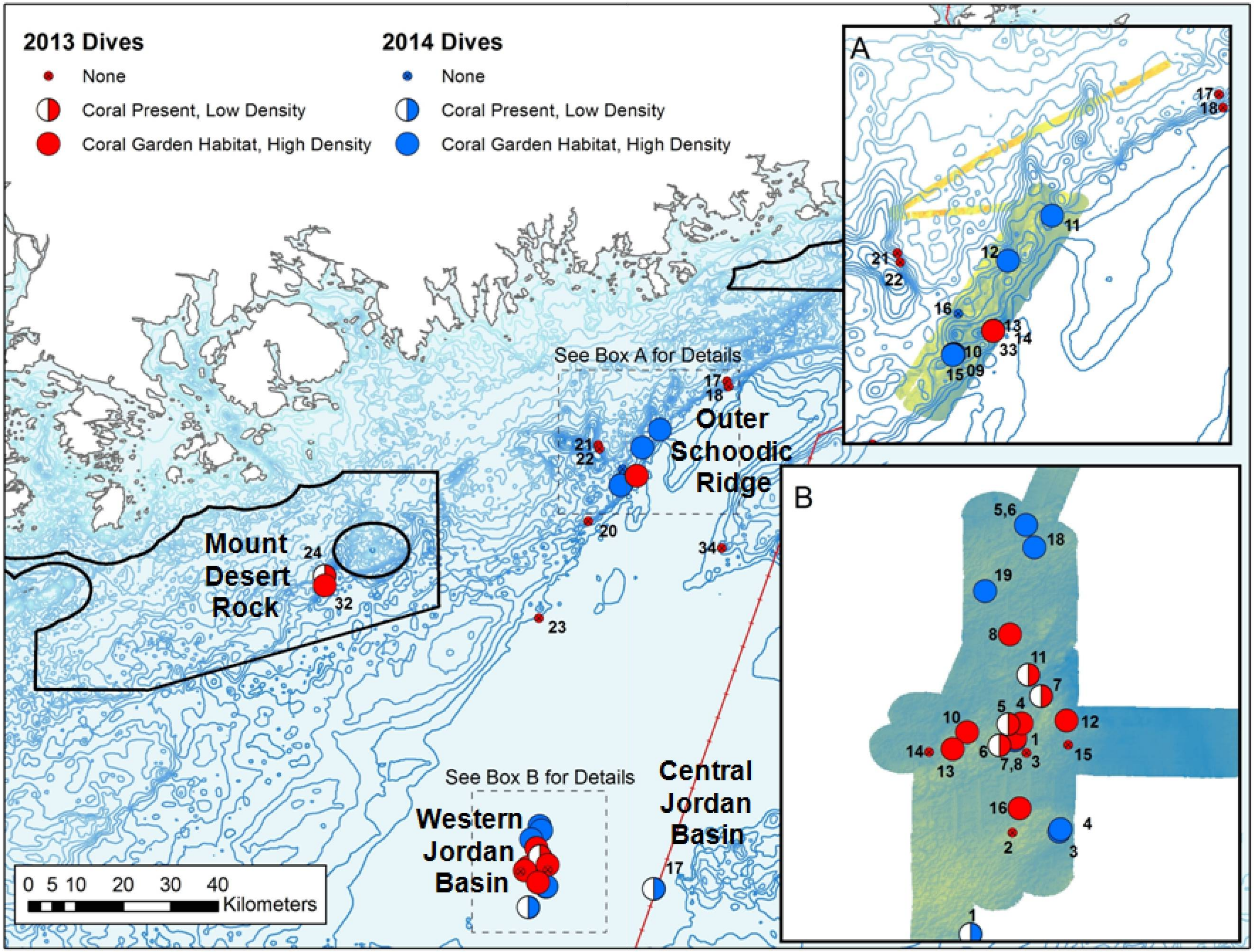

Figure 5. Location of ISIS 2 tows (2013) and Kraken 2 dives (2014) in relation to bathymetry and habitat management alternatives. Coral presence and coral garden classifications are based on definitions in the text. Refer to Figure 4 for multibeam topographic details of inset maps.

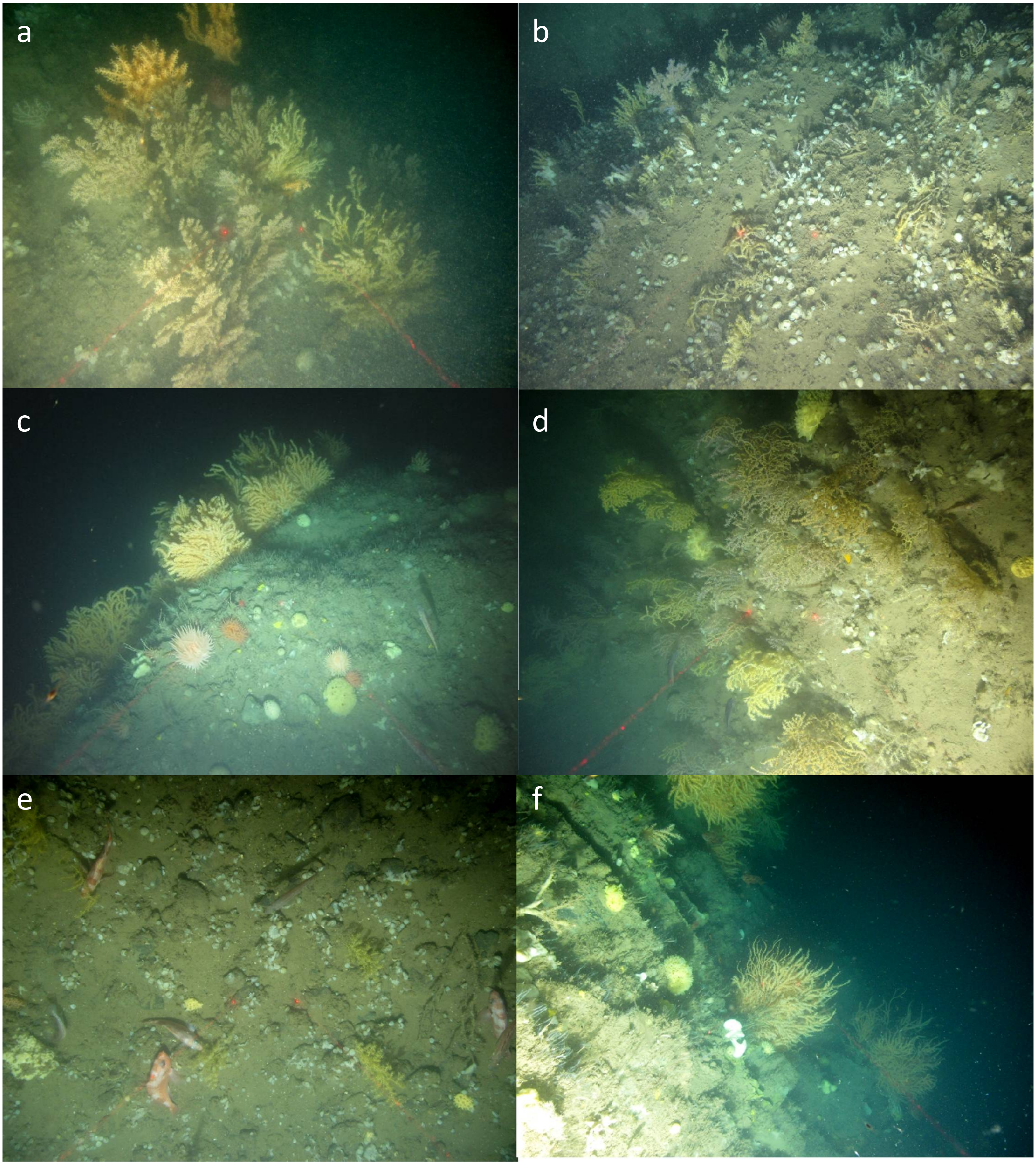

Figure 6. Figure 6. Down-looking images from ISIS2 2013 cruise with 20 cm parallel laser dot spacing of (a) *Paramuricea placomus* (yellow), *Primnoa resaediformis* (orange), and perhaps *Acanthogorgia cf. armata* (brown) along a steep escarpment in Western Jordan Basin. (b) mostly *P. placomus* distributed along sloping rock face with brachiopods in Western Jordan Basin. (c) View from rock crest illustrating *P. resaediformis*(?) on vertical wall at Outer Schoodic Ridge. (d) Color morphs of mostly *P. placomus* at Outer Schoodic Ridge. (e) *P. placomus* on coarse gravel at Outer Schoodic Ridge. (f) Large colonies of *P. resaediformis*(?) along rock wall off Mount Desert Rock.

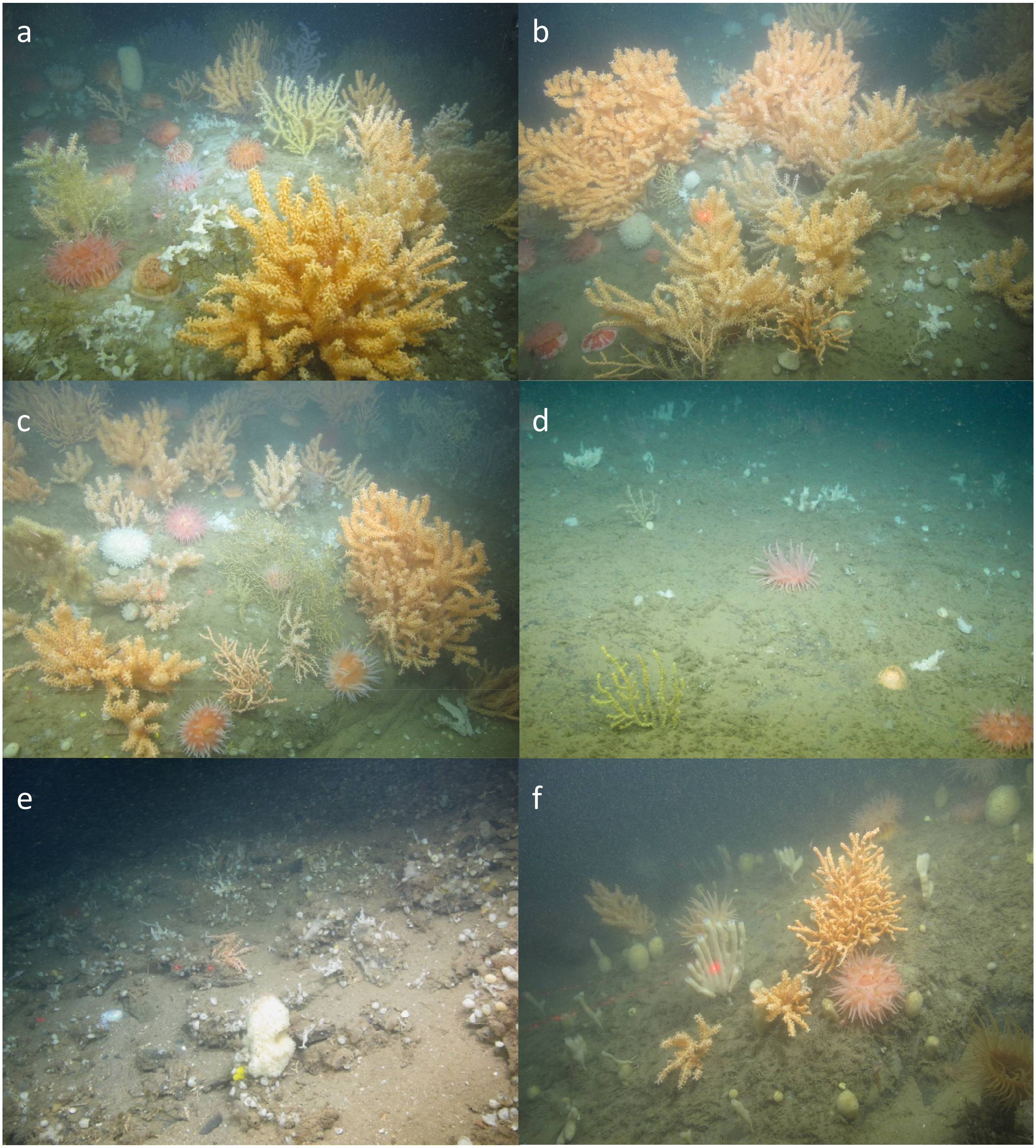

Figure 7. Examples from additional stations during the 2014 cruise illustrating coral garden and sparse coral habitats. All oblique images from Kraken2 with parallel laser dots at 10 cm spacing. (a-c) Dense garden habitat including *Primnoa resaediformis and Paramuricea placomus* in western Jordan Basin. (d) Sparse *P. placomus* distributed along horizontal outcrop in western Jordan Basin. (e) Sparse *P. resaediformis* on gravel pavement below vertical wall at Outer Schoodic Ridge. (f) Corals and sponges at Outer Schoodic Ridge.

Figure 8. Examples of coral garden habitat seen during 2014 formed by *Primnoa resedaeformis* on near vertical rock walls along Outer Schoodic Ridge. Laser dots are 10 cm apart. (a, b) Example of dense and continuous coverage of *P. resedaeformis* along rock walls. (c-e) Examples of discontinuities in coral cover. Sponges and anemones utilize spaces in these gaps. (f) Patch of coral amongst larger patch of sponges and other attached fauna.

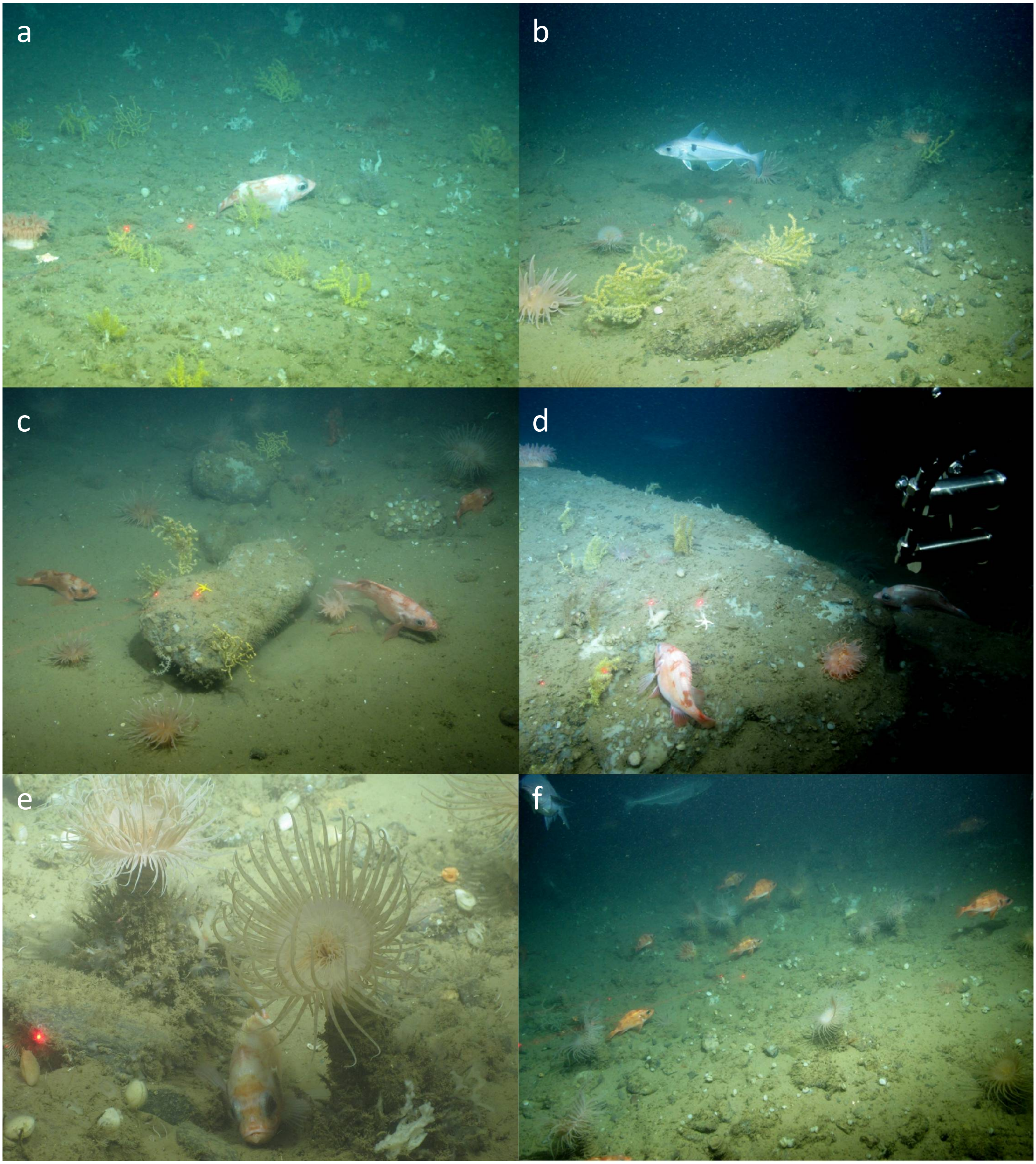

Figure 9. Examples of coral distribution, primarily *Paramuricea placomus*, at the Central Jordan Basin site during 2014. Laser dots are 10 cm apart. (a) Example of low density corals on gravel pavement. (b, c) *P. placomus* on scattered boulders distributed on mud draped gravel. (d) Coral and other attached fauna on rock outcrop. (e, f) The burrowing anemone *Cerianthis borealis* also serves as a primary structure forming organism in muddy areas.

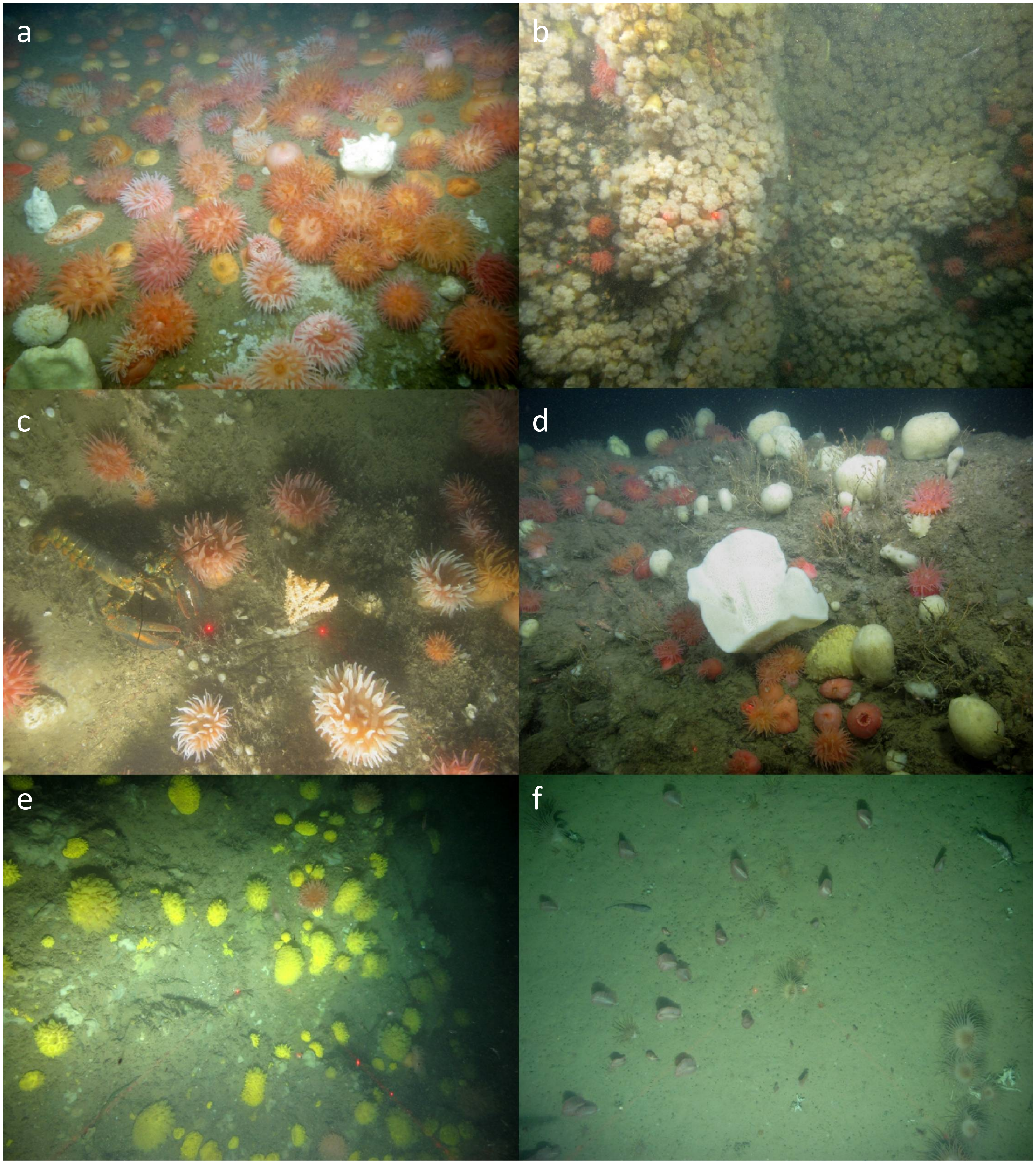

Figure 10. Examples of dense patches of other structure forming fauna from 2013 (laser dots 20 cm apart) and 2014 (laser dots 10 cm apart) surveys. (a) Anemones and sponges, Western Jordan Basin, 2014. (b) Anemones on vertical wall, Outer Schoodic Ridge, 2014. (c) *P. resedaeformis,* lobster, and anemones, Western Jordan Basin, 2013. (d) Sponges (*Polymastia* and *Phakellia* among them) and anemones, Outer Schoodic Ridge, 2014. (e) *Polymastia* sponges and anemones, Outer Schoodic Ridge 2013. (f) Sea pens (*Pennatula aculeata*) and burrowing anemones on mud bottom, Outer Schoodic Ridge 2013.

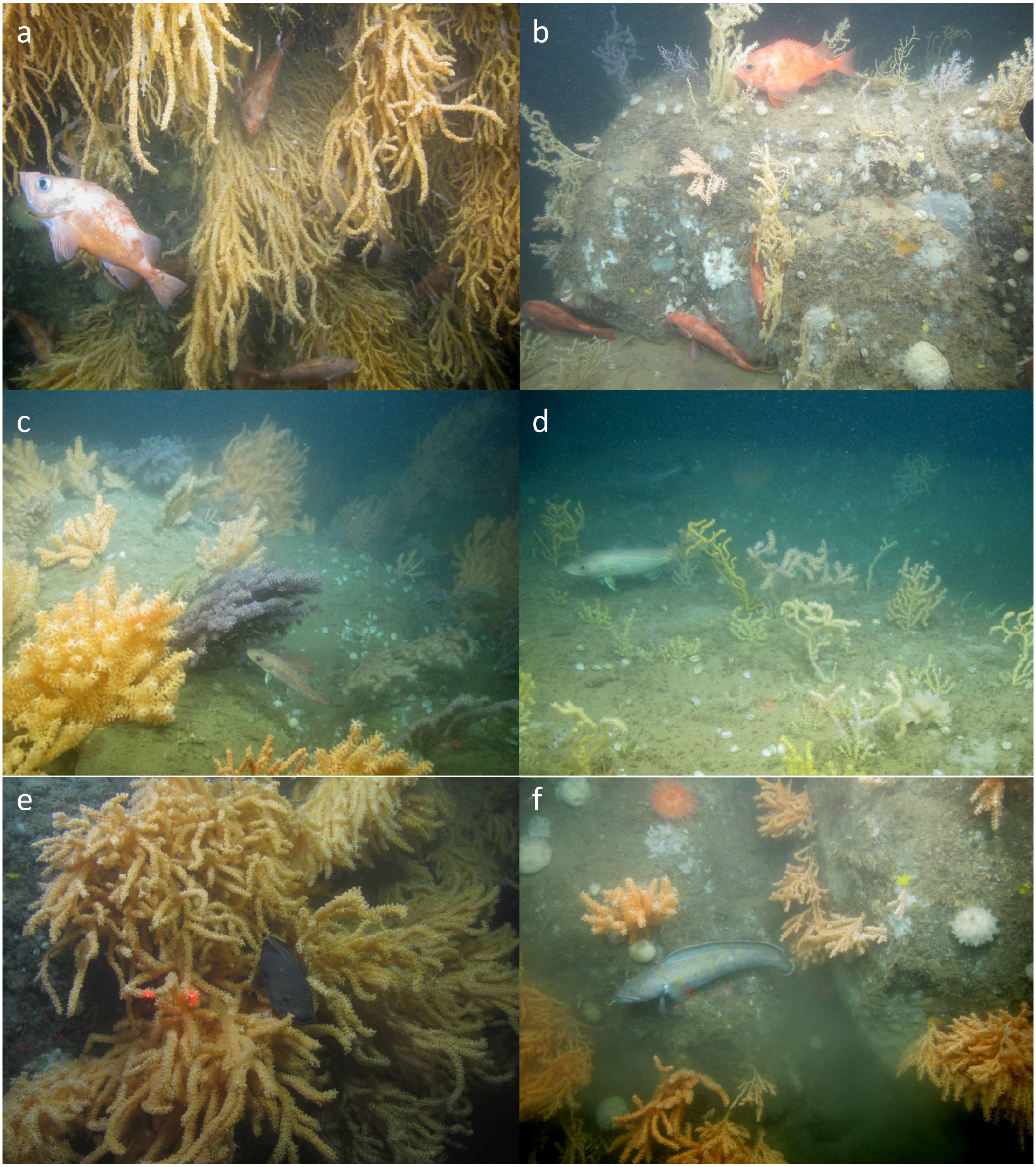

Figure 11. Examples of fish associations with coral habitats. All from 2014 surveys (laser dots 10 cm apart) except (h) from 2013 (laser dots 20 cm apart). (a, b) Acadian redfish, Outer Schoodic Ridge and Western Jordan Basin, respectively. (c, d) Atlantic cod, Western Jordan Basin. (e, f) Cusk, Outer Schoodic Ridge.

Figure 11. (continued) (g) Pollock, Outer Schoodic Ridge. (h) Juvenile silver hake, Outer Schoodic Ridge. (i) Spiny dogfish and cusk, Outer Schoodic Ridge. (j) Pollock, Atlantic herring and spiny dogfish, Outer Schoodic Ridge. (k) Goosefish, Western Jordan Basin; (l) Goosefish as in previous image unsuccessfully attacking a small silver hake (at arrow).

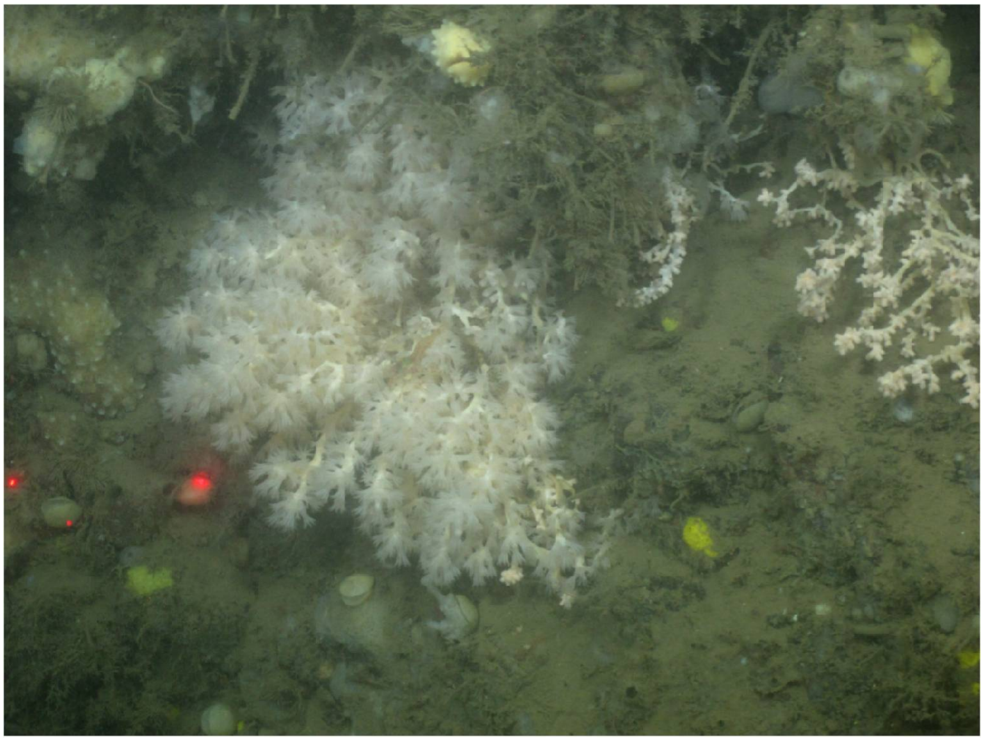

Figure 12. Specimen of *Anthothela grandiflora* at 214 m on Outer Schoodic Ridge (2014). A first report for this species in the Gulf of Maine.

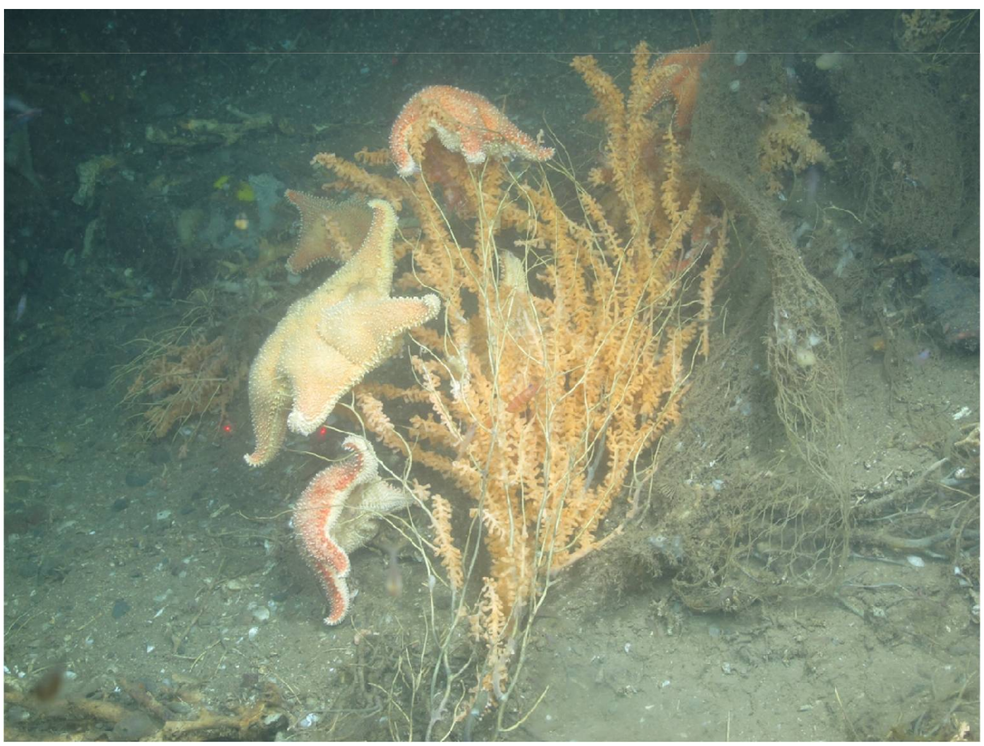

Figure 13. Cushion stars *Hippasteria phrygiana* preying upon a fallen colony of *Primnoa reseadiformis* on Outer Schoodic Ridge (2014).

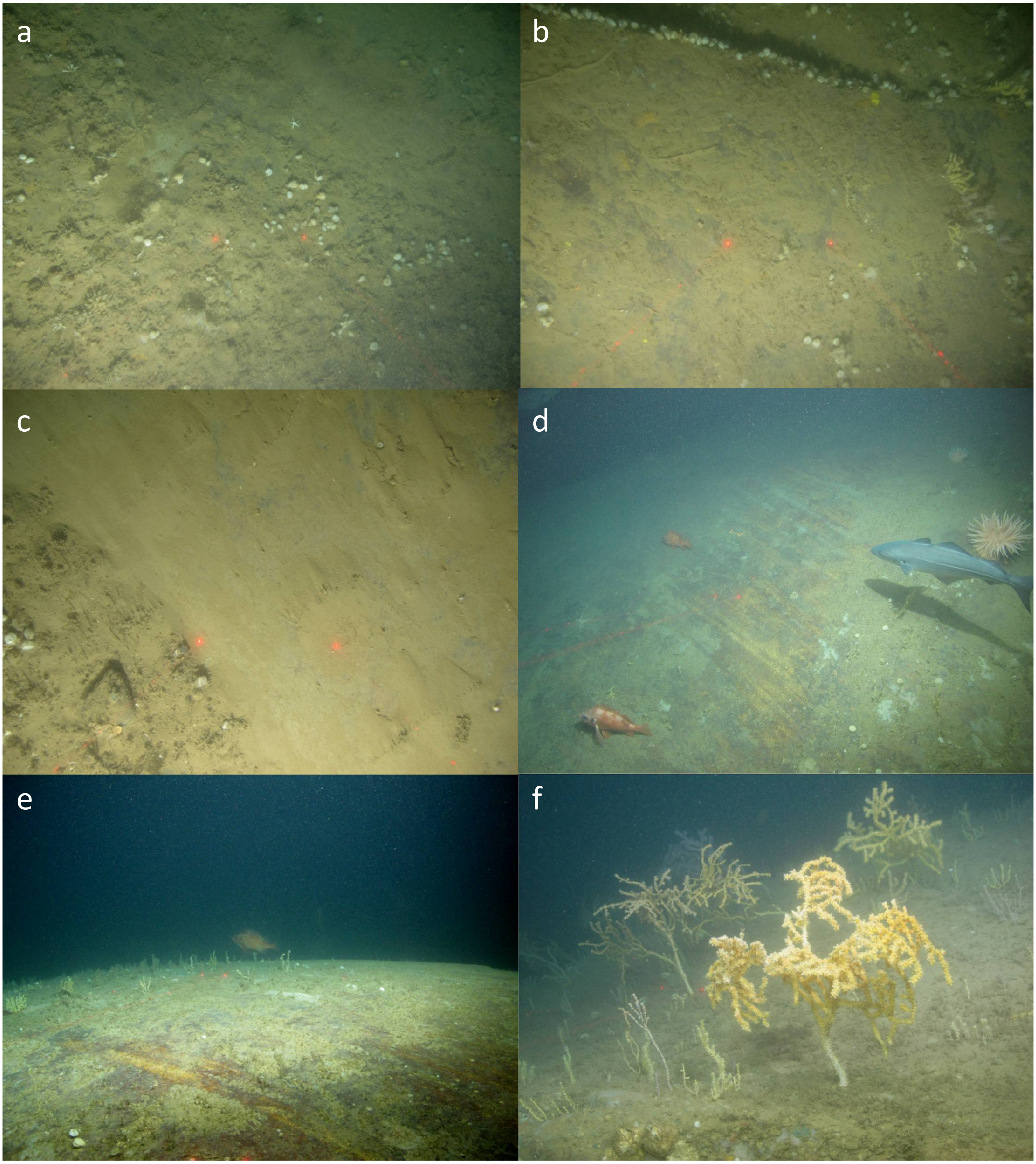

Figure 14. Examples of impacts to coral habitats. (a-c) Examples of impacts consistent with fixed gear from 2013 surveys (laser dots 20 cm apart), Western Jordan Basin. (d, e) Examples of mobile gear impacts to hard bottom from 2014 surveys (laser dots 10 cm apart), Central Jordan Basin site. (f) Example of sub-lethal damage to corals and subsequent recruitment resulting in disjunct size class structure, from 2014 surveys (laser dots 10 cm apart), Western Jordan Basin.