Deepwater Exploration of Kingman Reef, Palmyra Atoll, and Jarvis Island

GEOLOGICAL AND BIOLOGICAL DISCOVERIES FROM THE US LINE ISLANDS

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In June and July 2019, E/V *Nautilus* explored the two easternmost units of the Pacific Remote Islands Marine National Monument (PRIMNM), the Kingman Reef and Palmyra Atoll unit, and the Jarvis Island unit. This expedition followed an initial survey in 2017 (Bohnenstiehl et al., 2018) as a part of the NOAA CAPSTONE program (Kennedy et al., 2019). While previous expeditions provided brief glimpses into the nature of geological and biological aspects of the deep-sea environment, this expedition leveraged previous mapping and exploration dives in order to maximize bottom time and sampling effort at specific sites within the units. In total, 28,340 km^2 of seafloor were mapped. During high-seas transits, six ocean wave buoys and one small sailboat drifter (part of the Educational Passages program) were deployed (Figure 1).

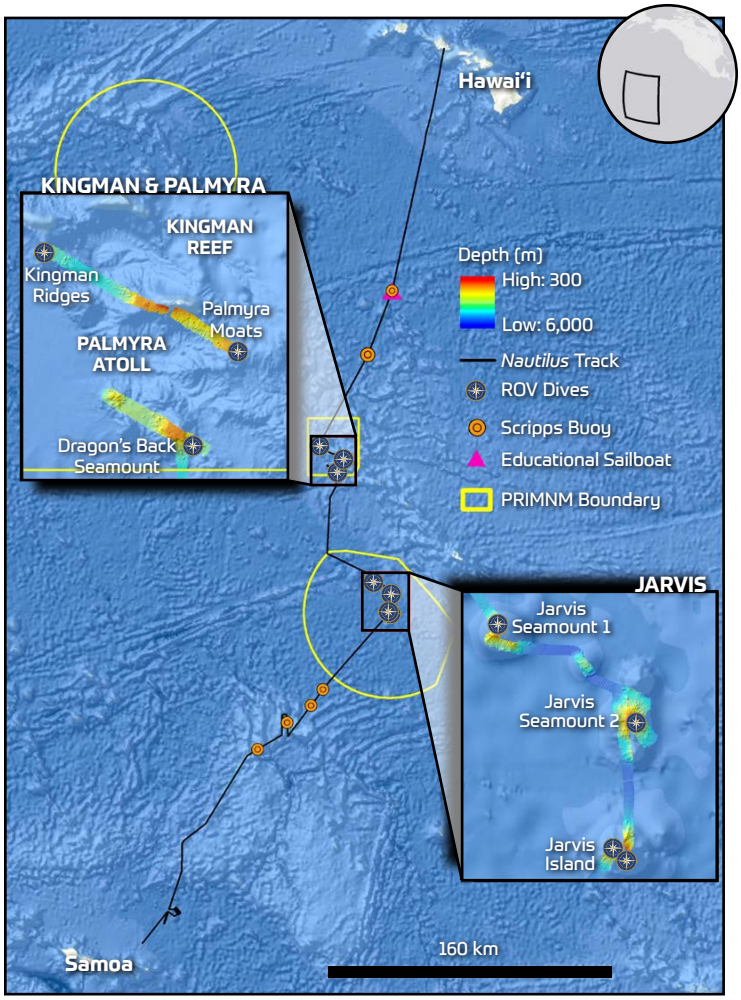

FIGURE 1. Overview map of the NA110 cruise track. Insets show dive site locations and new detailed multibeam bathymetry gathered in the Kingman and Palmyra and Jarvis units.

Across seven ROV dives, this expedition accumulated 117 hours of bottom time and traversed approximately 23 km of seafloor within PRIMNM's boundaries (Figure 1). In order to better characterize biodiversity and the geological setting, intensive sampling was a priority. Seventy-six primary biological specimens were collected, including 64 deepwater corals and sponges. Sampling targeted individuals that represented characteristic fauna for the area, new records for the Line Islands, or potential new species requiring further examination by taxonomic experts. To evaluate new tools for exploring biodiversity on seamounts, eDNA samples were also taken in high-density or high-diversity benthic communities (Everett and Park, 2018).

Thirty-nine rock samples were collected for age dating as well as for analysis of regional ferromanganese crust composition. Within the Line Islands region, geologic sampling focused on recovering volcanic rocks from the deep flanks of guyots (flat-topped seamounts) as well as from younger volcanic cones that sit atop the guyots and that erupted through the guyot platform. Sample analyses will test whether these volcanic cones represent episodes of rejuvenated volcanism that occurred within a few million years after the ocean island subsided, reactivated volcanism driven by local tectonic stress long after the island subsided, or reoccupation of the volcanic conduits by a separate mantle hotspot (e.g., Davis et al., 2002). Age determinations of the recovered lava samples will aid in placing the seamounts surrounding Jarvis Island within the broader tectonomagmatic framework of the Pacific basin.

Three dives with ROV *Hercules* were conducted within the Kingman and Palmyra unit of PRIMNM between 1,417 m and 3,225 m depth. The three features explored included a prominent ridge exposed by mass wasting west of Kingman Reef, a series of enigmatic moat-ringed seamounts southeast of Palmyra Atoll, and a ridge named Dragon's Back Seamount, based on its undulating bathymetric profile. Biological communities at these depths were

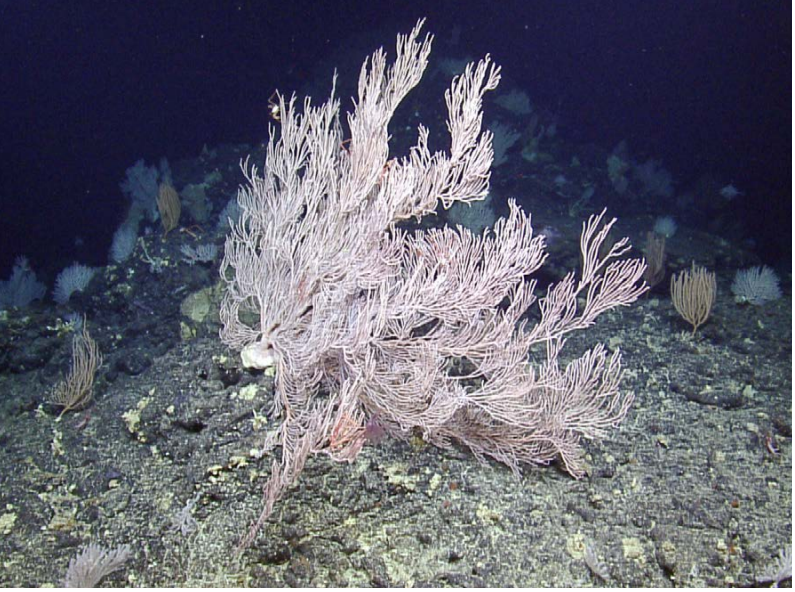

FIGURE 2. A mixed assemblage of stony corals (*Enallopsammia* sp.) and sea fans (mainly *Calyptrophora* and *Paracalyptrophora* spp.) capped the summit of Cone 2 at Jarvis Seamount 1 at 920 m depth.

sparsely populated. Deepwater corals from the families Chrysogorgiidae and Plexauridae, as well as precious corals and stony corals (*Enallopsammia* sp., at depths shallower than ~1,500 m), were most common.

A series of small, late-stage volcanoes on top of Kingman Ridge were also characterized by lightly sedimented lobate flows and pillow basalts along their flanks. Shallow depressions (i.e., moats) surrounding the volcanoes were characterized by ripples of carbonate sands that changed orientation approaching the volcanoes. The orientation and asymmetry of the ripples suggest transport toward and around the moats at the bases of the volcanoes.

Four dives were conducted within the Jarvis Island unit between 255 m and 1,828 m depth: two on Jarvis Island proper and two on unexplored guyots north of Jarvis. Both guyots were found to host sparse biological communities on their flanks and summits. However, smaller parasitic volcanic cones shallower than the main guyot plateau at Jarvis Seamount 1 were occupied by dense octocoral and stony coral assemblages at around 900 m depth (Figure 2).

The surficial geology of the seamounts in the Jarvis Island region was very similar, but significantly different, than Jarvis Island proper along the upper reaches of the seamounts. The lower sections were covered by lightly sedimented lobate and pillow flows; however, the upper 800 m of Jarvis Island was composed of carbonate reef material. The Jarvis seamounts were primarily composed of lava flows all the way to their summits, where relatively thin layers of carbonate were covered by carbonate ooze with evidence of ripples and scoured bed forms. The lack of significant carbonate cliffs on the Jarvis seamounts suggests that these guyots, with small parasitic cones, may never have been subaerially exposed.

FIGURE 3. A striking and enigmatic blue octocoral (cf. *Muriceides* sp.) was observed at high densities along the western carbonate slope of Jarvis Island at 386 m depth.

Dive observations at Jarvis Island suggested that it has both dense and diverse biological communities. A continuous transect from 1,700 m to 255 m depth conducted on the southeastern side of the island identified a prominent zone of stony coral reef structures between 600 m and 1,000 m depth. Primarily composed of *Enallopsammia rostrata* and *Madrepora oculata*, these reef structures are ecologically significant, as they have likely been in place for several hundred years or longer given their size, extensive debris fields, and slow growth rates (Houlbrèque et al., 2010). On the shallower carbonate platform, between 300 m and 600 m depth, often nested among the carbonate cliffs and overhangs, dense deepwater coral and sponge communities were observed that differed in species composition from those on the southeastern side (Figure 3).

In light of these biological observations, immediate follow-up work to this expedition will focus on establishing baseline deepwater benthic species inventories from DNA barcoding and morphological identification of collected specimens, as well as annotation of ROV video. These data are valuable additions to management efforts that seek to identify and characterize high-density and diverse communities within monument boundaries.