First Investigation of Recently Discovered Cold-Water Coral Ecosystems in the Deep Coral Triangle

REPORT

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Background

The coral triangle is the epicenter of shallow-water marine biodiversity. This area includes regions from the exclusive economic zones of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste. The shallow-water coral reefs in the coral triangle contain 76% of all the zooxanthellate hermatypic scleractinian species in the world [1], which represent 12% of all the coral species, i.e., 605 out of 5080 species [1,2]. These shallow water reefs also contain 37% of all the reef fishes in the world. The species richness of a plethora of other groups, such as lobsters, stomatopods, gastropods, bryopsidale macroalgae, pontoniinae crabs, coral-associated barnacles, and bivalves also peaks in the Coral Triangle [5,6,7,8,9,10].

A handful of recent studies have also identified the Coral Triangle region as a potential biodiversity epicenter for some deep-sea fauna. The greatest species diversity of Azooxanthellate scleractinian corals, crinoids and galatheid squat lobsters are found in the deep Coral Triangle [2,11,12]. However, biogeographic datasets for most other deep-water taxa remain largely incomplete, so no clear consensus regarding its importance in shaping the biodiversity in the deep ocean has been reached. Thus the question of whether the extreme biodiversity observed in the shallow-water ecosystems in the Coral Triangle extends into the deep-sea remains unanswered.

Why is this particular region so diverse? One of the first persons to try answering this question was Alfred Russel Wallace, an original co-proponent with Charles Darwin, of the theory of evolution by natural selection. Wallace identified this region as a transition point for species diversities and community compositions that separates the biogeographical regions of Asia and Australia. The changes in sea level during glacial and inter-glacial periods, which combined with the dynamic geological settings of this area (e.g., low sea level stands created small isolated seas), constitute the ideal ingredients for diversification and speciation to occur both in shallow and deep waters.

Between June and August 2010, the INDEX-SATAL 2010 expedition explored benthic ecosystems in the deep-sea promontories of Sangihe Talaud region using the Remotely Operated Vehicle (ROV) *Little Hercules* aboard the NOAA ship R/V *Okeanos* Explorer. The high-resolution imagery obtained from the 27 ROV dives revealed remarkably high abundances and diversity of animal species, many of which appear to be novel.

Main Findings

Our image analyses revealed the discovery of more than 25 deep-sea habitats between 250 meters to more than 3600 meters in the previously unexplored Salawesi sea of Indonesia.

From hydrothermally-active volcanoes, seamounts and ocean ridges, coral habitats hosting specific types of faunal species, to organic falls (including wood and coconuts), to sediment-covered slopes and plains. Throughout these depths, diverse benthic habitats harbored distinctly different ecosystems, including thriving chemosynthetic and non-chemosynthetic communities.

The fauna in the discovered active volcano's (named Kawio Barat) hydrothermal-vent systems were dominated by shrimp which covered the sides of active smokers and stalked barnacles that carpeted inactive chimneys and areas of diffuse flow. Other fauna discovered here included alvinellid polychaete worms and scale worms, and galatheid and brachiuran crabs. Downslope of the active vents, in areas covered by pyroclastic sediments and fragments of basalt we found different kinds of life, such as clams, anemones and bacterial mats.

In the Coral Triangle, where over 65 percent of the world's reef-forming coral species are known to exist in shallow waters and constitute approximately 12 percent of all coral species, dozens of putative new deep-water coral species were observed and imaged. A greater number of potential new species of other animals were also observed.

Corals, especially gorgonians and black corals, represented the greatest number of foundation species living on hardground seafloor. Corals were followed in abundance by glass sponges and stalked crinoids. Most of these sessile species harbor a wide variety of associated fauna. Ophiuroids, squat lobsters, shrimp, amphipods, anemones, zoanthideans, barnacles are the animal groups most commonly found forming these associations. Similar diverse communities, although differing in their assemblages and abundances of organisms were observed on the flanks of seamounts. Although less abundant and diverse in comparison to the hard bottom habitats, the sediment-covered slopes and plains were also found to be full of life. Stalked sponges, sea pens, sea cucumbers (Holothuroidea) and brittle stars dominated these habitats.

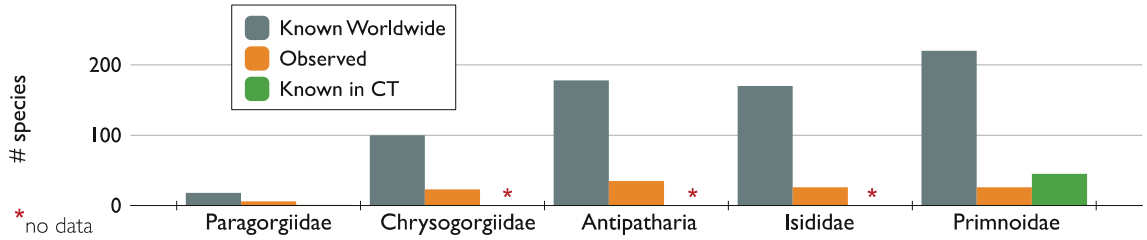

Figure 1. Species diversity estimates for gorgonian and black corals based on morphs identified from imagery.

Analyses of the imagery obtained in this expedition revealed that the diversity in the deep Sulawesi Sea is indeed high. The observed diversity in the most prominent families of gorgonian and black corals is equivalent to approximately 20% of the total number of species known worldwide (Fig. 1). This fraction is likely to include both already described and new species. Since these estimates are based on images, and due to the common presence of cryptic species in corals, it is likely too that this number will increase once animal samples from this region are collected.

Documenting the abundance, biodiversity and distribution of deep-ocean animals allows us to better understand the functioning of the ecosystems and infer how resilient they could be to

the imminent impacts of human activities. The observations from this expedition provided a substantial foundation of data that will enable us to compare these results to biodiversity around the world as well as identify possible changes in regional biodiversity in the future. This is increasingly important not only in Indonesian Seas where changes in ocean environments are occurring, but throughout the world.

Products to Date

Conference presentations

T. Shank, Herrera S.*, E. Bors, C. Munro, E. Sibert, N. Nganro, S. Makarim, S. Wirasantosa, V. Tunnicliffe, E. T. Baker, D. A. Butterfield, J. F. Holden, S. R. Hammond (2010), Hydrothermal Vents and Organic Falls in the Heart of the Coral Triangle: Chemosynthetic Communities Discovered via Telepresence in the Sangihe-Talaud Region, Northern Sulawesi, Indonesia. Abstract OS11D-04 **talk** presented at the 2010 Fall Meeting, AGU, San Francisco, CA, 13-17 Dec.

Herrera S.*, C. Munro, N. Nganro, V. Tunnicliffe, S. Wirasantosa, E. Sibert, S. R. Hammond, E. Bors, D. Butterfield, J. F. Holden, E. T. Baker, J. Sherrin, S. Makarim, R. Troa, **T. M. Shank** (2010), Biodiversity of the Deep-Sea Benthic Fauna in the Sangihe-Talaud Region, Indonesia: Observations from the INDEX-SATAL 2010 Expedition. Abstract OS13C-1234 **poster** presented at the 2010 Fall Meeting, AGU, San Francisco, CA, 13-17 Dec. **Outstanding Student Paper Award**

Butterfield D.A.*, J.F. Holden, **T.M. Shank**, V. Tunnicliffe, J. Sherrin, **S. Herrera**, E.T. Baker, D. Lovalvo, S. Makarim, M.A. Malik, S. Wirasantosa, S. R. Hammond (2010) Video Observations by Telepresence Reveal Two Types of Hydrothermal Venting on Kawio Barat Seamount. Abstract OS13C-1236 poster presented at the 2010 Fall Meeting, AGU, San Francisco, CA, 13-17 Dec.
*Presenter

Invited seminars and presentations

Herrera S. (2010), Biological Observations in the INDEX-SATAL 2010 Expedition. Talk presented at Deep-Sea Exploration in Sangihe-Talaud 2010 (INDEX-SATAL 2010) Scientific Results Colloquium, Sam Ratulangi University, Manado, North Sulawesi, Indonesia.

Herrera S. (2010), Deep-sea biogeographical patterns in the Sangihe-Talaud region**.** Talk presented at the Indonesia-US Science Team Workshop, Deep-Sea Exploration in Sangihe-Talaud 2010 (INDEX-SATAL 2010), Manado, North Sulawesi, Indonesia.

Herrera S & Shank TM (2011) Live from the Galapagos Rift, NOAA Signature Explorations: INDEX-SATAL 2010 and GALREX 2011, Peanut Butter Club, WHOI. July 2011.

Herrera S (2011), Recent Discoveries of Benthic Biodiversity via Telepresence in the Deep-Sea, Ocean Science Journalism Fellowship, WHOI. September 2011.

- Shank, T. M. (2011) Deep-Ocean Technology for Research and Exploration. Agency for the Assessment and Application of Technology, Jakarta, Indonesia.

Selected media features

- Scientific American, Indonesia expedition maps rich undersea life, 2010.
- Our Amazing Planet, Possible New Species Found in Ocean Crossroads, covered by MSNBC News, 2010.
- NOAA News, U.S. and Indonesian Scientists Find Biodiversity Runs Deep in Sulawesi Sea, 2010.

Future Work

- A series of peer-reviewed publications describing the biodiversity of habitats and species observed during the expedition are in preparation.
- Proposals to return to this area and collect animal specimens have been submitted (NSF and NOAA), and future ones are anticipated.

References

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