THE OCEAN EXPLORATION TRUST
2025 FIELD SEASON

NAUTILUS LIVE
OCEAN EXPLORATION TRUST

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INTRODUCTION

Allison Fundis and Daniel Wagner

The numbers tell part of the story: more than 2,265 days at sea over the last 17 years of E/V *Nautilus* expeditions, 13,000 hours of ROV exploration, 1.3 million square kilometers of seafloor mapped, 176 expeditions across 29 countries, and over 500 peer-reviewed publications that contribute to the trusted body of knowledge on which sound decisions about our ocean depend. But behind every metric is a volcano surveyed, a shipwreck uncovered, an ecosystem or new species seen for the very first time, and a student somewhere in the world watching it happen live. Seventeen years in, Ocean Exploration Trust's mission has never felt more purposeful—built on the conviction that rigorous, trusted science, openly shared, is how we begin to truly understand the world beneath the waves.

Our 2025 field season took E/V *Nautilus* across the Pacific, with seven multi-disciplinary expeditions exploring some of the region's most under-explored waters. Expeditions dove into the highly active submarine volcanoes of the Mariana Islands, traced the maritime heritage of the Battles of Guadalcanal in the Solomon Islands, surveyed seamounts in the Marshall Islands, investigated the seafloor around Howland and Baker Islands, and revealed the abyssal habitats of the Cook Islands. For every expedition, the guiding question was the same: what does meaningful exploration look like *here*, for *these* communities?

By centering the expertise and priorities of our local partners—including the Mariana Trench Marine National Monument, the Solomon Islands Government, the Marshall Islands Marine Resources Authority, the Cook Islands Government, and others—expeditions were shaped by local knowledge and context, because scientific exploration should not happen in isolation from the places it seeks to understand.

For the Ocean Exploration Trust, the measure of a successful expedition is not only what is discovered, but how many people it reaches and inspires. In 2025, E/V *Nautilus* teams hosted 418 live interactions from our onboard broadcast studio, welcomed 39 students and educators aboard, generated over 69 million social media impressions, and saw our expeditions covered in over 1,170 press stories across 80 countries. Over 40 new educational resources were developed and made freely available online, because inspiring curiosity about the deep sea—early and often—is as much a part of the Ocean Exploration Trust's mission as the science itself.

In 2025, E/V *Nautilus* also served as an integration platform for cutting-edge technologies from partner institutions: Orpheus Ocean's autonomous underwater vehicle, the University of New Hampshire's uncrewed surface vehicle *DriX*, a Norbit wideband sonar from the University of Rhode Island, and DeepSea's newly developed ultra-high-definition MxD SeaCam. Each technology brought different capabilities to the table, and together they expanded what a single expedition could accomplish, serving as a reminder that the most consequential advances in ocean exploration rarely happen alone.

None of this would have been possible without the remarkable community of partners who sustain this work—NOAA Ocean Exploration, the NOAA Ocean Exploration Cooperative Institute, the Office of Naval Research, the National Geographic Society, the Museum of Comparative Zoology, the Marine Geological Samples Laboratory, the Bureau of Ocean Energy Management, and the many new government, academic, and private partners we welcomed in 2025. Together with our dedicated staff, Board of Directors, and contractors, they are the reason this work gets done.

The deep sea remains the largest and least understood environment on Earth, and there is no more important time to understand it better. Ocean Exploration Trust is committed to exactly that, sharing every discovery openly and transparently with the scientists, communities, and curious minds who make this work meaningful. The full story of what that commitment looked like in 2025—the expeditions, the discoveries, the partnerships, and the people behind it all—is told in the pages that follow. We hope you enjoy the journey as much as we did.

TECHNOLOGY

Samantha Wishnak, Josh Chernov, Pavel Chubar, Derek Sowers, Michael D. Labriola, Megan Cook, Noelle Helder, Allison Fundis, and Daniel Wagner

E/V *NAUTILUS*

The Exploration Vessel (E/V) *Nautilus* is an efficient 68-meter ship, with berthing for 17 permanent crew members in addition to up to 35 berths for rotating members of the *Nautilus* Corps of Exploration. The ship is equipped with remotely operated vehicles (ROVs), acoustic mapping systems, and various other state-of-the-art technologies. E/V *Nautilus* has a data lab for processing digital data, as well as a wet lab for processing physical samples. As part of our effort to share expeditions with the scientific community and the public in real-time, we utilize telepresence technology to stream live video from the ROVs and various locations aboard the ship to the Nautilus Live website.

GENERAL

BUILT: 1967 in Rostock, Germany

IMO Number: 6711883

LENGTH: 68.28 meters (224 feet)

BEAM: 10.6 meters (34.5 feet)

DRAFT: 4.95 meters (16.24 feet)

TONNAGE: 1,337 gross, 402 net

RANGE: 24,000 kilometers (13,000 nautical miles) at 10 knots

ENDURANCE: 40 days at sea

SPEED: 10 knots service, 12 knots maximum

FUEL CAPACITY: 330 cubic meters

PROPULSION: Diesel Engine 1,472 kilowatt (1,974 horsepower) with controllable pitch propeller; 280 kilowatt bow tunnel thruster; 300 kilowatt jet pump stern thruster

DYNAMIC POSITIONING SYSTEM: Wartsila Nacos Platinum DP0 with two independent stations

SHIP SERVICE GENERATORS: Three x Caterpillar C18 585 kilowatt generators

PORTABLE VAN SPACE: Three 6.1-meter (20-foot) vans

COMPLEMENT: 52 (17 crew and 35 science operations)

FLAG: Saint Vincent and the Grenadines

CLASS: DNV (Det Norske Veritas) class vessel

AFT DECK

AREA: 19 meters long (62.3 feet) x 10 meters wide (32.8 feet)

EQUIPMENT:

- Dynacon 369i ROV winch with 7,000 meters (23,000 feet) of 1.73 centimeter (0.681 inch) diameter electro-optic Rochester cable
- DT Marine 210 winch with 2,000 pound line pull at 50–80 feet per minute and capacity for 1,000 meters of 0.322 wire (science-supplied)
- Bonfiglioli P30500XL/4Si knuckle-boom crane, 2–4 metric tons capacity with two extensions
- Guerra M660.24A knuckle-boom crane, 4.5 metric tons-safe working load at 8.3 meters
- Hawbolt painter boom with winch, 1.5 metric tons safe working load with 7-meter reach off starboard side
- Two airtuggers, 900 pounds safe working load each
- A-frame, 8 metric tons safe working load
- Schat-Harding davit (bridge deck), 0.9 metric tons safe working load to deploy rescue boat

SMALL BOATS

Zodiac Pro 5.5 EPA/ABYC with Yamaha F150LB outboard motor

- **LENGTH:** 5.4 meters (17.75 feet)
- **CAPACITY:** 12 Person
- **MAX LOAD:** 1,540 kilograms (people and equipment)

Zodiac MOB Rescue boat (emergency use only)

- **LENGTH:** 4.5 meters
- **CAPACITY:** 6 Person
- **MAX LOAD:** 990 kilogram

TELEPRESENCE TECHNOLOGY

VSAT: 2.4-meter stabilized Sea Tel 9711 uplink antenna capable of C- and Ku-band operation of up to 20 megabits per second (C-band circular or linear) bi-directional

REAL-TIME VIDEO STREAMING: Six Haivison Makito X encoders streaming live video via satellite to the Inner Space Center in Rhode Island

CAMERAS: 26 high-definition cameras: aft port, amid and starboard (pan/zoom/tilt), 180° wide aft, transom, bow, command center (10), wet lab, ROV hangar, and winch hold (6)

COMMUNICATIONS:

- Ship-wide RTS Odin intercom system for shipboard communications and connection with shoreside participants
- Software audio connection for global participants using VLink multi-platform intercom client (Mac, Windows, Android, iOS); telephone interface is available through a Rhode Island exchange for real-time collaboration between teams on the ship and ashore
- Full Internet connectivity from shipboard LAN and Wi-Fi
- Starlink electronic phased array antenna providing supplemental IP connectivity

CONTROL VAN

AREA: 43 square meters (476 square feet)

WORKSTATIONS: Twelve workstations, typical configuration for ROV operations includes workstations for ROV pilot, co-pilot, navigator, video engineer, data logger, educator, and 2–4 for scientists

VIDEO RECORDING AND STORAGE: Two Cinedeck ZX85 video recorders that capture ROV footage in two simultaneous codecs, two Blackmagic Hyperdeck uncompressed 4K recorders, two AJA KiPro Go recorders, 4x LTO-8 archive media drives

PRODUCTION STUDIO

AREA: 12 square meters (130 square feet) lit and dressed for live shows

CAMERAS: 4k Panasonic BGH1 studio camera, Sony A1 camera kit for topside video with live broadcast capacity via Teradek 500, iPhone mobile production kit

PRODUCTION: RTS Odin audio intercom panels. 10-input video production ATEM switcher for live-produced ship-to-shore interactions from onboard playback media. Full production editing workstation for remote production needs. Mobile belt packs for dynamic connections from other parts of the ship.

DATA PROCESSING & VISUALIZATION LAB

AREA: 44.5 square meters (480 square feet)

WORKSTATIONS: Eight workstations for seafloor mapping and other data processing, including work space for science managers, data loggers, navigators, educators, data engineers, satellite engineers, and video engineers.

RACK ROOM

AREA: 17.3 square meters (185 square feet)

DATA STORAGE: 64 terabyte onboard storage for non-video data, 236 terabyte disk storage for video data

EMERGENCY COMMUNICATIONS: Iridium phone

ELECTRONICS WORKBENCH: 2.3 cubic meters (80 cubic feet) of storage

WET LAB

AREA: 19 square meters (204.5 square feet) with 5.3-meter-long (17.5-foot) stainless steel bench and 2.3-meter-long (7.6-foot) worktop

REFRIGERATION:

- Panasonic MDF-C8V1 ULT –80°C scientific freezer, 0.085 cubic meters (3 cubic feet)
- Scientific freezer, –20°C, 0.14 cubic meters (5 cubic feet)
- Two science refrigerators, 0.57 cubic meters (20 cubic feet) each

HAZMAT:

- 2247301 Labconco fume hood, 119.4 centimeters wide × 63.5 centimeters deep × 134.6 centimeters high (47 inches wide × 25 inches deep × 53 inches high)
- Two HAZMAT lockers for chemical and waste storage

MICROSCOPE: Zeiss Primo Star Binocular Microscope, 4x, 10x, 40x, 100x

DEIONIZED WATER SYSTEM: ZFDI00001 Milli-D water purification system capable of producing deionized water at 0.5-0.7 liters per minute, 40 liters per day

ROV HANGAR

AREA: 24 square meters (258.3 square feet)

POWER: 110/60 hertz and 220/50 hertz available

PERSONAL PROTECTIVE EQUIPMENT: Hard hats, personal flotation devices, high voltage gloves

LIFTS: 2 × 2-ton overhead manual chainfall lifts

STORAGE: Storage for spares and other equipment

ROV WORKSHOP

AREA: 18 square meters (193.8 square feet)

TOOLS: Hand tools, cordless tools, electrical and fiber optic test equipment, mill-drill combination machine

STORAGE: Dedicated ROV storage for spares and equipment

ACOUSTIC SYSTEMS

KONGSBERG EM 302 MULTIBEAM ECHOSOUNDER

The EM 302 is a hull-mounted 30-kilohertz multibeam echosounder composed of two long transducer arrays mounted in a T-shape on the hull of E/V *Nautilus*. The EM 302 can map the seafloor at ship speeds up to 12 knots.

FREQUENCY: 30 kilohertz

DEPTH RANGE: 10–7,000 meters (33–22,966 feet)

PULSE FORMS: CW and FM chirp

ANGULAR RESOLUTION: 1° × 1°

APPROXIMATE SWATH WIDTH: 1–5 times water depth, up to 8 kilometers (5 miles)

SOUNDINGS PER SWATH: Up to 423 in single swath mode, 864 in dual swath mode

APPROXIMATE GRID RESOLUTION: 1–5% water depth (e.g., 10–50 meters [33–164 feet] at 1,000 meters [3,281 feet] depth)

KNUDSEN 3260 SUB-BOTTOM PROFILER

The Knudsen 3260 is a sub-bottom echosounder mounted inside the hull of E/V *Nautilus*. It operates at low frequencies (3.5 and 15 kilohertz) so that emitted sound can penetrate layers of sediment to a maximum of about 80 meters below the seabed surface.

OPERATING FREQUENCY: Dual frequency, 3.5 and 15 kilohertz

POWER: 4 kilowatt on Channel 1 and up to 2 kilowatt on Channel 2

RANGE: 50–11,000 meters

KONGSBERG SIMRAD EC150-3C TRANSDUCER

The Kongsberg Simrad EC150-3C 150 kilohertz is a hull-mounted transducer on E/V *Nautilus* that combines an acoustic Doppler current profiler (ADCP) and an EK80 split-beam fisheries sonar into one instrument. The ADCP measures the speed and direction of currents underneath the ship, whereas the split-beam echosounder maps features found within the water column.

FREQUENCY: 150 kilohertz (130–170 kilohertz range)

MAX DEPTH RANGE: 130 meters (426 feet)

BEAMWIDTH: 3° at 150 kilohertz

PULSE FORMS: CW or FM

ADCP NUMBER OF BEAMS: 4

ADCP DEPTH BIN CELL SIZE: Customizable between 2–16 meters (6.5–52.5 feet)

R2SONIC SONIC 2020-V MULTIBEAM ECHOSOUNDER

The 2020-V is a highly portable multibeam echosounder that can be mounted on the side of a small boat or surface vessel via a poll mount. The 2020-V can map the seafloor at maximum depths of 200 meters at speeds up to 11 knots. This sonar is not used on E/V *Nautilus*, but rather deployed on smaller vessels of opportunity for shallow-water surveys.

FREQUENCY: 200–450 kilohertz and 700 kilohertz

DEPTH RANGE: Up to 200 meters (656 feet)

PULSE FORMS: CW and FM chirp

ANGULAR RESOLUTION: 4° × 4° (at 200 kilohertz) to 1° × 1° (at 700 kilohertz)

NORBIT WBMS MULTIBEAM SONAR

The Norbit WBMS multibeam sonar is a compact and light multibeam sonar that is depth-rated to 4,500 meters for collecting mapping data subsea from an ROV platform. This sonar is a shared asset between the Ocean Exploration Trust and the University of Rhode Island. The Norbit system is periodically deployed on E/V *Nautilus* expeditions to collect high-resolution mapping data near the seafloor directly from ROV *Hercules*.

FREQUENCY: 400 kilohertz (200–700 kilohertz possible), 80 kilohertz of bandwidth.

RANGE: 160 meters (525 feet)

ANGULAR RESOLUTION: 0.9° × 1.9° (at 400 kilohertz)

ULTRA-SHORT BASELINE NAVIGATION SYSTEM

The ultra-short baseline (USBL) navigation system helps track the position of the ROVs in the water. The system consists of a hull-mounted transceiver on E/V *Nautilus*. Each ROV is outfitted with a transponder beacon that produces acoustic signals from each vehicle to the ship's transceiver to determine their subsea positions.

SYSTEM: Sonardyne Ranger 2 with Lodestar Gyro USBL transceiver deployed from the moonpool

RANGE: Up to 7,000 meters (22,966 feet)

POSITIONING ACCURACY: 0.5% of slant range

OPERATIONAL COVERAGE: ±90°

OPERATING FREQUENCY: 19–34 kilohertz

TARGETS TRACKED: *Hercules*, *Atalanta*, and two additional transponders are available. More targets can be tracked with the addition of compatible Sonardyne transponders.

REMOTELY OPERATED VEHICLE *HERCULES*

ROV *Hercules* works in tandem with towsled *Atalanta* to explore the deep sea. *Hercules* is equipped with a high-definition video camera, several LED lights, two manipulator arms, and a variety of oceanographic sensors and samplers. High-resolution mapping tools can be mounted on the ROV upon request. *Hercules* can carry up to 113 kilograms (250 pounds) of samples or tools between the seafloor and the surface.

GENERAL

DEPTH CAPABILITY: 4,000 meters (13,123 feet)

TETHER: 30–45 meters (98.4–147.6 feet), 20 millimeters (0.79 inches) diameter, neutrally buoyant

SIZE: 3.9 meters long × 1.9 meters wide × 2.2 meters tall (12.8 feet long × 6.2 feet wide × 7.2 feet tall)

MASS: ~ 2,720 kilograms (6,000 pound) mass in air

PAYLOAD: Up to 113 kilograms (250 pounds)

MAXIMUM VEHICLE SPEED: 0.77 meters per second (1.5 knots) forward, 0.25 meters per second (0.5 knots) lateral, 0.5 meters per second (1 knot) vertical (on site, within tether range)

MAXIMUM TRANSIT SPEED: 1 meter per second (2 knots), no sampling, in layback mode

MAXIMUM ON-BOTTOM TRANSIT SPEED: 0.5 meters per second (1 knot), no sampling

MAXIMUM SAMPLING TRANSIT SPEED: 0.25 meters per second (0.5 knots) on flat seafloor, <0.13 meters per second (<0.25 knots) over featured terrain

ROV CLOSED LOOP POSITION CONTROL: Station Keep, X/Y step, Auto Depth, Auto Altitude, X/Y/Z step and hold velocity control

DESCENT/ASCENT RATE: 30 meters per minute (98.4 feet per minute), 15 meters per minute (49.2 feet per minute), or 20–22 meters per minute (65.6–7.2 feet per minute) average

PROPULSION

- Six hydraulic thrusters powered by 15 kilowatt (20 horsepower), 207 bar (3,000 pounds power square inch) hydraulic system
- Fore/Aft & Vertical – Four 27.94 centimeter (11 inch) ducted thrusters, each providing 900 newton (200 pounds of force) thrust
- Lateral – Two 22.86 centimeter (9 inch) ducted thrusters, each providing 450 newton (100 pounds of force) thrust

VEHICLE SENSORS & NAVIGATION

SYSTEM: NavEst integrated navigation system

HEADING AND ATTITUDE

- Primary Heading – IXSEA Octans III 7600 north-seeking fiber optic gyrocompass (0.1° secant latitude accuracy with 0.01° resolution)
- Secondary Heading – TCM2 solid state fluxgate compass

PRESSURE SENSOR: Paroscientific Digiquartz 8CB series

CTD: Sea-Bird FastCAT 49

OXYGEN OPTODE: Aanderaa 4831

TEMPERATURE PROBE: WHOI high-temperature probe (0–450°C, 0.1°C resolution)

DOPPLER NAVIGATION & ALTITUDE: RDI Workhorse Navigator Doppler Velocity Log 600 kilohertz, 0.7–90 meter range (2.3–295.3 feet)

FORWARD-LOOKING SONARS

- Kongsberg Mesotech 1071 scanning sonar, tunable from 400–1,000 kilohertz; range to 200 meter (656 feet) at 450 kilohertz; range resolution up to 3.75 millimeter (0.15 inch)
- 200 meter (656 feet) at 450 kilohertz; range resolution up to 3.75 millimeter (0.15 inch)
- TriTech Super SeaKing V7 scanning sonar, 325 or 675 kilohertz; range 0.4–300 meters (1.3–984 feet); range resolution 0.015 meter (0.05 feet)

IMAGING & LIGHTING

STANDARD IMAGING SUITE: One high-definition video channel on fiber optic, four standard definition video channels on coax, generally configured as:

- Insite Pacific, 6,000-meter rated, Zeus Plus with 10× zoom lens, Ikegami HDL-45A with zoom/pan/tilt/extend, 1080i SMPTE 292M output format
- Insite Pacific, 6,000-meter rated, Titan Rotate-Tilt standard definition camera (bubble camera) 480 line NTSC format
- Three Insite Pacific NOVA utility cameras, mounted to view the starboard sample box, port rail, and aft region, 480 line NTSC format
- One Insite Pacific Aurora utility camera to view the eight-jar suction sampler, NTSC format
- One DeepSea Power & Light Wide-i-SeaCam to view starboard side sample box, NTSC format

LIGHTING: Fifteen DeepSea Power & Light SeaLite Sphere LED lights, 6,000 lumens, mounting configurable

SCALING: Two green DeepSea Power & Light Micro Sea-Lasers, mounted 10 centimeters (3.94 inches) apart, HD camera only

STILLS IMAGING CAMERA: One low-light sensitive 24 megapixel 6k cinematic camera with a 16–35 millimeter lens controlled via ethernet. Fix mounted.

WIDEFIELD CAMERA ARRAY: Up to three synchronized low-light sensitive 24 megapixel 6k cinematic cameras controlled via ethernet. Two cameras are fixed mounted with a third camera available depending on requirements for photogrammetry or filming.

MANIPULATORS & SAMPLING

MANIPULATORS

- Kraft Predator: Hydraulic, seven-function spatially correspondent, 200 pounds lift
- Schilling Orion 7R: Hydraulic, seven-function rate arm, nominal lift 250 kilograms, 68 kilograms lift at full extension

SUCTION SYSTEMS

- Suction sampling system, eight 3-liter discrete samples
- Venturi dredge excavation system

SAMPLING TOOLS – Mission configurable:

- Up to five 6.35 centimeter (2.5 inch) inner diameter, 28 centimeter (11 inch) long push cores
- Up to six 5-liter Niskin bottles, manually triggered
- Custom tools and sensors can be integrated

SAMPLE STORAGE

- Forward sample tray (inboard): 45 × 33 × 25 centimeters (17.7 × 13 × 9.8 inches)
- Forward sample tray (outboard): 68 × 35 × 30 centimeters (26.8 × 13.8 × 11.8 inches)

- Starboard sample drawer: 65 × 50 × 30 centimeters (25.5 × 19.7 × 11.8 inches)
- Payload: Up to 113 kilograms (250 pounds) depending on sensor package
- Custom configuration of boxes, crates, and containers

SCIENTIFIC INSTRUMENT SUPPORT

SWITCHED POWER

- 110 volt, 60 hertz AC
- 24 VDC
- 12 VDC

DIGITAL DATA CHANNELS

- RS-232: 115 kilobaud
- RS-485/422: 2.5 megabaud
- Ethernet: 10/100/1,000 megabits per second links available
- TTL: one TTL link

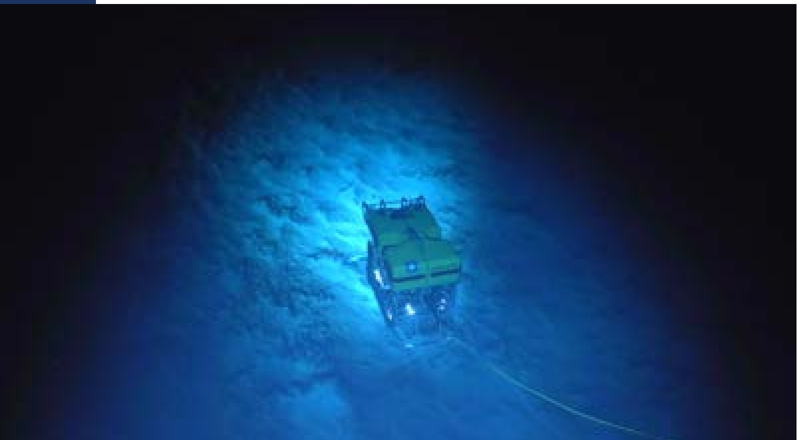
HYDRAULIC: Proportional and solenoid hydraulic functions

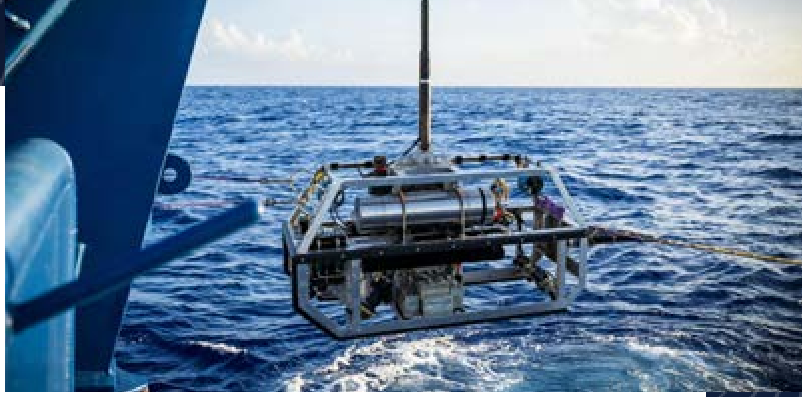
- 1,150 pounds per square inch at 5 gallons per minute
- 1,850 pounds per square inch at 5 gallons per minute
- 3,000 pounds per square inch at 5 gallons per minute (advance notice needed)

EXAMPLES OF GUEST TECHNOLOGIES ON ROV

Advance notice is required for custom solutions to engineering integration of user-provided sensors and equipment such as:

- *In situ* mass and laser spectrometers
- Fluorometer, pH sensor, eH sensor
- Kongsberg M3 multibeam sonar
- Norbit wideband multibeam sonar – forward or downward facing
- DeepSea Power & Light MxD SeaCam for 4K imaging
- 18 megapixel ethernet connected digital still camera
- Low-light camera
- Modular soft grippers





TOWSLED *ATALANTA*

Atalanta is used in tandem with ROVs *Hercules* or *Little Hercules*, hovering several meters above in order to provide a bird's-eye view of the ROV working on the seafloor. *Atalanta* is also capable of operating as a stand-alone system for deep-water survey missions.

GENERAL

DEPTH CAPABILITY: 6,000 meters (19,685 feet)

SIZE: 2.16 meters long × 1.0 meters wide × 1.2 meters tall (7 feet long × 3.28 feet wide × 3.94 feet tall)

WEIGHT: 1,000 kilograms (2,200 pounds) in air, 771 kilograms (1,700 pounds) in water

MAXIMUM TRANSIT SPEED: 2 knots

ASCENT/DESCENT RATE: 20–30 meters per minute (65–98 feet per minute)

PROPULSION: Two Tecnadyne Model 1020 1 HP thrusters for heading control

IMAGING & LIGHTING

CAMERAS

- One Insite Pacific Mini Zeus high-definition camera
- Two mini utility cameras (fixed mounted), 480 line NTSC format

LIGHTING: Eight DeepSea Power & Light LED SeaLite LSL-1000 sphere lights

VEHICLE SENSORS & NAVIGATION

HEADING: Lord Microstrain 3DM-GX5- 25 Attitude and Heading Reference System (AHRS)

PRESSURE SENSOR: Paroscientific Digiquartz 8CB series

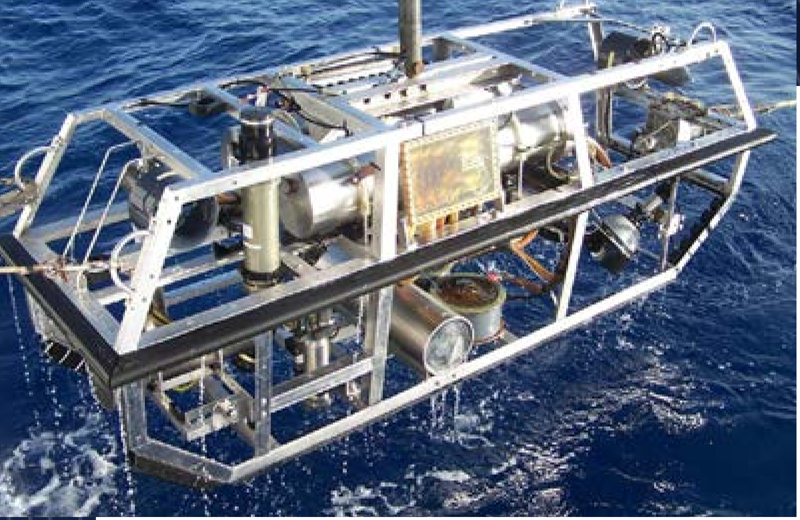
ALTIMETER: Valeport VA500 500 kilohertz altimeter

FORWARD-LOOKING SONAR: Mesotech 1071, 300 kilohertz, 0.5–100 meter range

SCIENTIFIC INSTRUMENT SUPPORT

POWER: 110 volt 60 hertz AC, 24 VDC and 12 VDC power options

DIGITAL DATA CHANNELS: Ethernet, RS-232



TOWSLED *ARGUS*

ROV *Argus* is a deep-tow system capable of diving to 6,000 meters. *Argus* is mainly used in tandem with ROV *Hercules*, where it hovers several meters above in order to provide a bird's-eye view of Hercules working on the seafloor. *Argus* is also capable of operating as a stand-alone system for deep-water survey missions.

GENERAL

DEPTH CAPABILITY: 6,000 meters (19,685 feet), currently limited to 4,000 meters (13,123 feet)

CABLE: 7,000 meters (23,000 feet) of 1.73 centimeter (0.681 inch) diameter electro-optic Rochester cable, 3x #11 conductors, 4x SM fibers

SIZE: 3.8 meters long × 1.2 meters wide × 1.3 meters high (12.5 feet long × 3.9 feet wide × 4.3 feet tall)

WEIGHT: 2,100 kilograms (4,700 pounds) in air, 1,360 kilograms (3,000 pounds) in water

MAXIMUM TRANSIT SPEED: 2 knots

ASCENT/DESCENT RATE: 30 meters per minute (98 feet per minute)

PROPULSION: Two Tecnadyne Model 1020 thrusters for heading control

IMAGING & LIGHTING

CAMERAS

- One Insite Pacific Zeus Plus high-definition camera with Ikegami HDL-45A head and Fujinon HA 10 × 5.2 lens, 1080i SMPTE 292M output format, 2 MP still image capable on tilt platform
- Three utility cameras (fixed mounted) 480 line NTSC format
- One DeepSea Power & Light Wide-i SeaCam, downward looking standard definition camera (fixed mounted)

LIGHTING

- Three CathX Aphos 16 LED lampheads, 28,000 lumens each
- Two DeepSea Power & Light 250 Watt incandescent lights

VEHICLE SENSORS & NAVIGATION

SYSTEM: NavEst integrated navigation system solution

USBL NAVIGATION: Sonardyne Ranger 2

PRIMARY HEADING: Crossbow high-resolution magnetic motion and attitude sensor

PRESSURE SENSOR: Paroscientific Digiquartz 8CB series

ALTIMETER: Benthos PSA-916

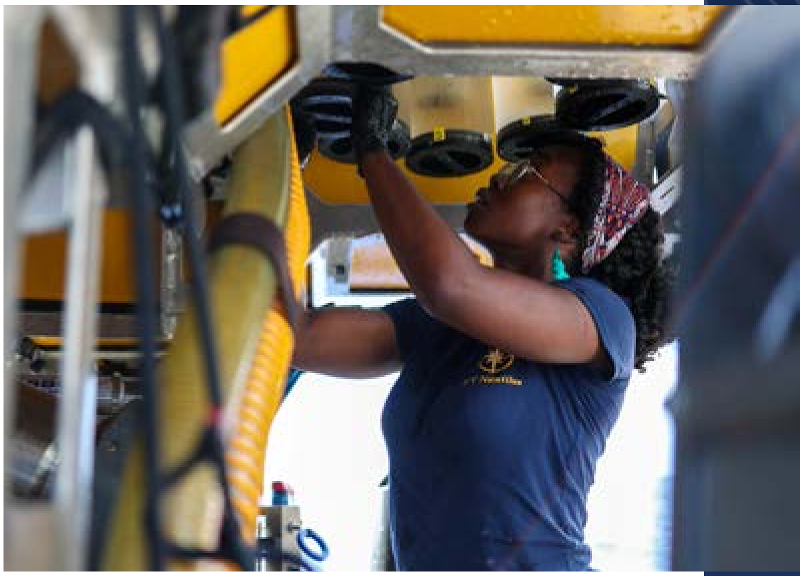
FORWARD-LOOKING SONAR: Mesotech 1071, 300 kilohertz, 0.5–100 meter (1.6–328.1 feet) range typical

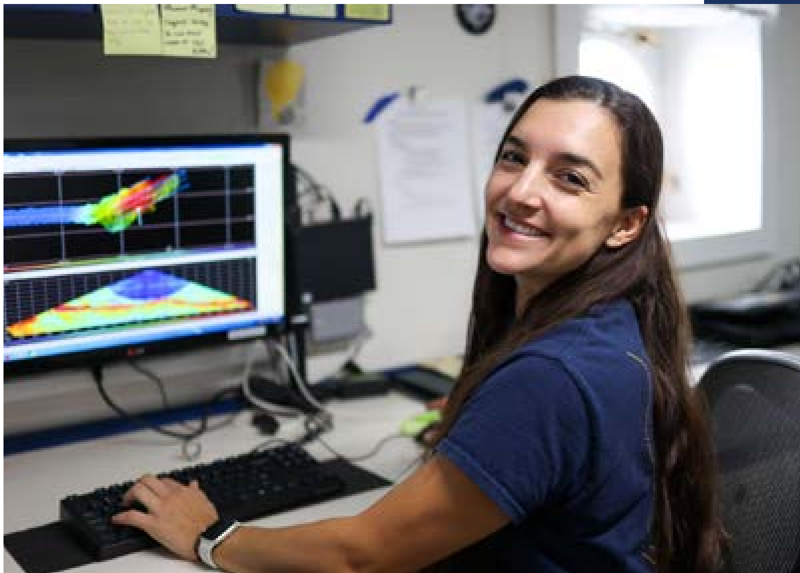
SUB-BOTTOM PROFILING SONAR: TriTech SeaKing Parametric Sub-bottom Profiler (10–30 kilohertz)

SCIENTIFIC INSTRUMENT SUPPORT

POWER: 110 volt 60 hertz AC, 24 VDC and 12 VDC power options

DIGITAL DATA CHANNELS: Ethernet





ROV *LITTLE HERCULES*

ROV *Little Hercules* is a smaller sister to *Hercules* with 6,000-meter capability, designed to function in tandem with *Atalanta*, but without the ability to collect physical samples. *Little Hercules* is equipped with a high-definition or 4K video camera, LED lights, and basic sensors for navigation and situational awareness.

GENERAL

DEPTH CAPABILITY: 6,000 meters (19,685 feet)

TETHER: 30–45 meters (98.4–147.6 feet), 20 millimeters (0.79 inches) diameter, neutrally buoyant

SIZE: 1.4 meters long × 1.0 meters wide × 1.2 meters tall (4.59 feet long × 3.28 feet wide × 3.93 feet tall)

WEIGHT: 400 kilograms (900 pounds) in air; 45.36 kilograms (100 pounds) payload

MAXIMUM TRANSIT SPEED: 2 knots

ASCENT/DESCENT RATE: 20–30 meters per minute, (65–98 feet per minute) max

PROPULSION: Four Tecnadyne Model 1020 thrusters for heading control

IMAGING & LIGHTING

CAMERAS

- High definition or ultra high definition
- Two mini utility cameras (fixed mounted), 480 line NTSC format

LIGHTING: Six Deepsea Power & Light LED sphere lights

VEHICLE SENSORS & NAVIGATION

HEADING: Lord Microstrain 3DM-GX5-25 Attitude and Heading Reference System (AHRS)

PRESSURE SENSOR: Paroscientific Digiquartz 8CB series

ALTIMETER: Valeport VA500 500 kilohertz altimeter

FORWARD-LOOKING SONAR: Kongsberg Mesotech 1071 scanning sonar, 675 kilohertz, 1–200 meter (3–656 feet) range typical

SCIENTIFIC INSTRUMENT SUPPORT

POWER: 110 volt 60 hertz AC, 24 VDC and 12 VDC power options

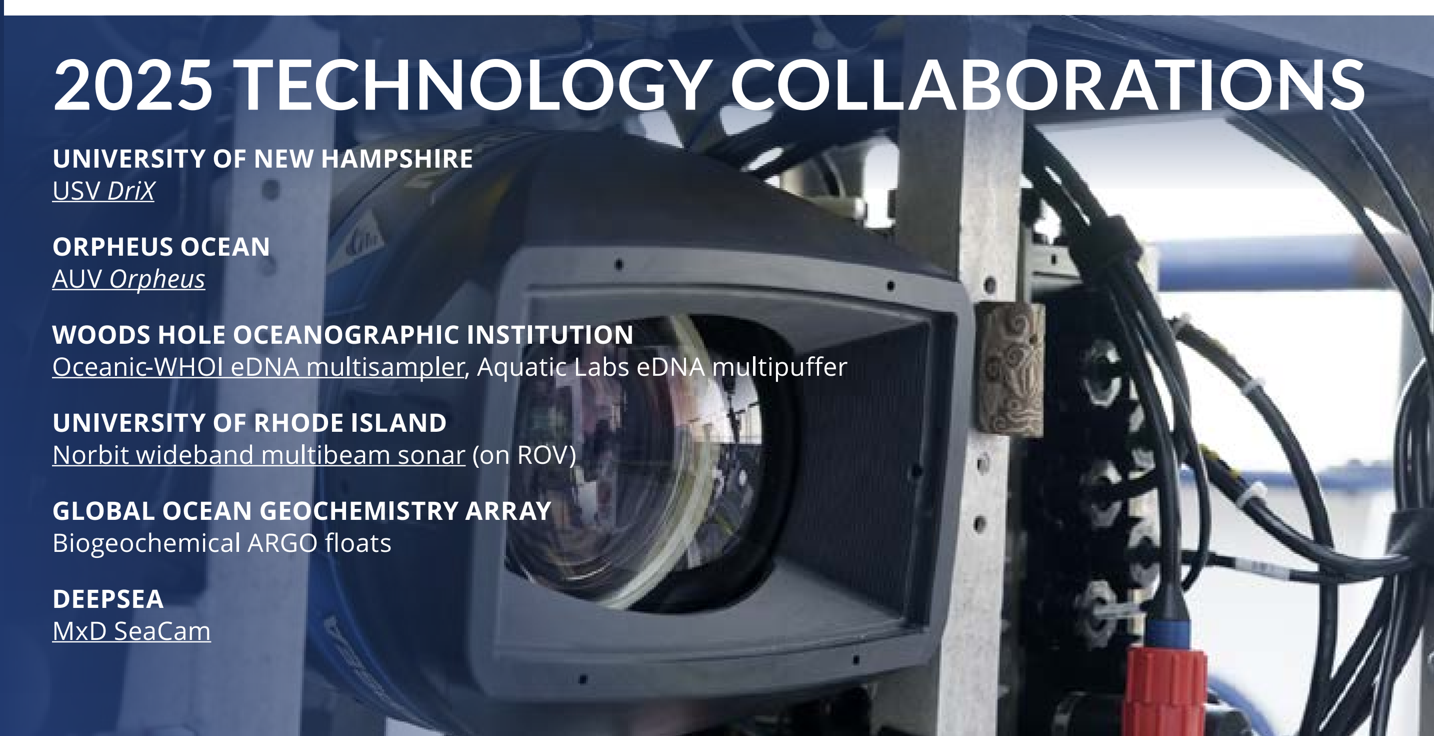
DIGITAL DATA CHANNELS

- RS-232 serial
- Ethernet: 10/100/1,000 mbps links available

ROV POSITIONING

The ROV systems are outfitted with an ultrashort baseline (USBL) navigation system compatible with the operational platform and scientific requirements.

USBL NAVIGATION: Sonardyne Ranger II.



2025 TECHNOLOGY COLLABORATIONS

UNIVERSITY OF NEW HAMPSHIRE
USV *DriX*

ORPHEUS OCEAN
AUV *Orpheus*

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Oceanic-WHOI eDNA multisampler, Aquatic Labs eDNA multipuffer

UNIVERSITY OF RHODE ISLAND
Norbit wideband multibeam sonar (on ROV)

GLOBAL OCEAN GEOCHEMISTRY ARRAY
Biogeochemical ARGO floats

DEEPSEA
MxD SeaCam

2025 FIELD SEASON OVERVIEW

Daniel Wagner, Allison Fundis, Megan Cook, Josh Chernov, Samantha Wishnak, Michael Labriola, Derek Sowers, and Noelle Helder

In 2025, E/V *Nautilus* successfully completed a seven-month field season consisting of seven multi-disciplinary expeditions that explored the Pacific for a total of 114 days at sea. The season began with a shakedown expedition in Guam to prepare for the fieldwork ahead, followed by others centered on exploring highly active submarine volcanoes in the Mariana Islands, maritime heritage sites associated with the Battles of Guadalcanal in the Solomon Islands, seamounts and other high biodiversity areas in the Marshall Islands, seafloor around Howland and Baker Islands, and abyssal plain habitats in the Cook Islands. Collectively, 2025 expeditions mapped over 106,000 square kilometers of seafloor, completed 36 successful ROV dives, 20 deployments of other vehicles, and engaged many millions of viewers around the world.

Figure 1. In preparation for the 2025 field season, the shakedown expedition included four dives to test various components of the ROV system.

SHAKEDOWN

Between April 26–May 2, E/V *Nautilus* conducted its annual shakedown expedition to prepare the ship's mapping, ROV, and telepresence systems for the 2025 field season. During this seven-day expedition around Guam, the team successfully completed annual quality assurance tests of E/V *Nautilus*' mapping and navigation systems, including a multibeam patch test, speed noise testing, accuracy surveys over a variety of seafloor depths, calibration of the subsea acoustic positioning system, and calibration of the acoustic Doppler current profiler. The expedition also included four test dives using our two-body ROV system in different configurations, for a total dive time of over 20.8 hours to get the vehicles ready for the fieldwork ahead.

Above. Map showing the locations of seafloor mapping, ROV dives, and other vehicle deployments conducted during the 2025 E/V *Nautilus* season.

MATTINGAN: MARIANA ARC VOLCANIC EXPLORATION (NA171)

Between May 7–28, E/V *Nautilus* supported an expedition that explored deep-sea habitats around the Mariana Islands. During 21 days at sea, the team mapped over 20,504 square kilometers of seafloor, in addition to completing nine successful ROV dives that explored a wide range of underwater features, including highly active underwater volcanoes, some of the oldest seamounts on Earth, and shallower coral reefs. At Ahyi Seamount, the ROVs explored a recently formed lava cone and found that it is still intensely degassing over a very large area. At Daikoku Seamount, the ROVs documented substantial changes since this feature was last surveyed in 2016, including that the molten sulfur pond near the summit was no longer present. ROV surveys of the Hafa Adai hydrothermal vent field discovered that its large black smoker chimney had toppled over since it was first discovered in 2016, and that a new, smaller chimney was re-growing in its place. Two shallower seamounts on the Western Mariana Ridge were also explored for the first time on this expedition, and here the ROVs discovered healthy coral reefs at depths between 50–100 meters, significantly expanding the known range of reef habitats in the region to far offshore seamounts. In addition to ROV surveys, the expedition also included six deployments using Orpheus Ocean's AUV, the majority of which focused on exploring abyssal plain habitats in a large previously unsurveyed area east of the Mariana Trench.

Figure 3. In June 2025, E/V *Nautilus* conducted a transit expedition that mapped the seafloor between Guam and the Solomon Islands.

Figure 2. In addition to ROV dives and seafloor mapping using the E/V *Nautilus* systems, the Mattingan expedition included surveys using Orpheus Ocean AUV focused on exploring abyssal plain habitats east of the Mariana Trench.

EXPLORING THE OFFSHORE MARIANAS (NA172)

From June 21–28, 2025, E/V *Nautilus* conducted an expedition to map seafloor in the Western Pacific. While the original goal was to explore the Mariana Trench and adjacent mud volcanoes through the use of multiple technologies, the expedition start date had to be delayed significantly due to unforeseen ship repairs. As a result, the expedition shifted its primary focus to transit mapping operations. A total of 13,691 square kilometers of seafloor were mapped over the course of the expedition around Guam, the Federated States of Micronesia, and the Solomon Islands. In addition to mapping, the expedition included visual faunal surveys from the observation deck on E/V *Nautilus*, which documented 631 individuals from 11 species of seabirds and several species of cetaceans, including sperm and short-finned pilot whales. Furthermore, the expedition included the successful deployment of six biogeochemical Argo floats from the Scripps Institution of Oceanography, adding important Western Pacific coverage to the over 4,000 Argo floats that are currently operational globally in support of large-scale oceanographic monitoring.

MARITIME ARCHAEOLOGY OF GUADALCANAL: IRON BOTTOM SOUND (NA173)

Between July 2–23, E/V *Nautilus* conducted an expedition that explored historically-significant maritime heritage sites associated with the Battles of Guadalcanal in Iron Bottom Sound. The expedition included deployments of the University of New Hampshire's uncrewed surface vehicle *DriX*, with operators controlling the vehicle remotely both from shore, as well as from onboard E/V *Nautilus*. *DriX* was deployed 12 times for a total of 380 hours over the course of the expedition, during which it mapped 979 square kilometers of seafloor, and recorded 112 potential targets, several of which were then surveyed via E/V *Nautilus*' ROVs. The mission completed six successful ROV dives for a total dive time of 138 hours, during which the ROVs surveyed a linear distance of over 56 kilometers. A total of 13 different maritime heritage sites were documented via these ROV surveys, including two that were found for the first time (USS *New Orleans* and IJN *Teruzuki*), one that was imaged for the first time (USS *Walke*), and ten that had only partially been imaged prior to this expedition (USS *Vincennes*, USS *Astoria*, USS *Quincy*, USS *Northampton*, USS *DeHaven*, USS *Laffey*, USS *Preston*, IJN *Yūdachi*, HMAS *Canberra*, and an unidentified small pontoon boat). All maritime heritage sites were systematically and comprehensively surveyed; this included creating a high-resolution map of each wreck using multibeam data collected using a Norbit wideband sonar mounted on ROV *Hercules*, followed by a systematic close-up visual survey to image the main wreck features, debris field, as well as diagnostic features.

Figure 4. In July 2025, E/V *Nautilus* supported an expedition that used the mapping capabilities of University of New Hampshire's uncrewed surface surface vehicle *DriX* in combination with the ship's ROVs to explore historically-significant maritime heritage sites in the Solomon Islands.

DEEP-SEA HABITATS OF THE MARSHALL ISLANDS (NA174)

Between July 27–August 17, E/V *Nautilus* conducted an expedition focused on exploring deep-sea habitats around the Marshall Islands. In addition to mapping 31,421 square kilometers of seafloor and 15 seamounts, the expedition completed 10 successful ROV dives. Noteworthy ROV observations included thriving deep-sea communities of high density and diversity in the recently-designated National Marine Sanctuary of Bikar and Bokak, discovery of at least two new species of octocorals, and multiple new invertebrate records for the region. In addition to its standard sensors, an autonomous eDNA sampler was integrated onto ROV *Hercules*, which was used to filter over 20,000 liters of seawater and collect 161 environmental DNA samples. An additional 77 biological and 30 rock samples were collected during ROV dives to support studies on the biodiversity, coral reproductive biology, biogeography, and geological context of the region. Throughout the planning and execution of the mission, the team worked closely with stakeholders in the Marshall Islands to ensure that expedition activities addressed local management, science, and education needs. A planning workshop was held in the Marshall Islands prior to the start of the expedition, and several Marshall Island-based scientists sailed on the expedition to facilitate this process.

Figure 5. In July–August 2025, the Ocean Exploration Trust conducted an expedition that used the ROV and mapping systems of E/V *Nautilus* to explore deep-sea habitats around the Marshall Islands. This included the deployment of an ROV-mounted automated eDNA sampler, which collected 161 samples to support biodiversity assessments in this largely unexplored region.

SEAFLOOR MAPPING OFFSHORE HOWLAND & BAKER ISLANDS (NA175)

From August 20–September 5, E/V *Nautilus* conducted an expedition focused on seafloor mapping in the US Exclusive Economic Zone around the islands of Howland and Baker, as well as other unmapped areas along the transit route between the Marshall Islands and American Samoa. Over 18,003 square kilometers of seafloor were mapped over the course of the expedition, including 11,192 square kilometers in the US Exclusive Economic Zone around Howland and Baker Islands, where four larger seamounts were mapped in their entirety. In addition to mapping operations, the expedition included topside surveys on the abundance and diversity of marine fauna. Over 8,000 individual birds were recorded in at least 27 species, including 24 seabird species and two migratory shorebird species. Highlights included observations of Phoenix Petrel, Tahiti Petrel, Nazca Booby, Buller's Shearwaters, Christmas Shearwater, Leach's Storm-Petrel, Blue-gray Noddy, Gray-backed Tern, and thousands of individuals of Sooty Terns. Furthermore, at least nine individual cetaceans were observed, including confirmed records of Short-finned Pilot Whale and Cuvier's Beaked Whale.

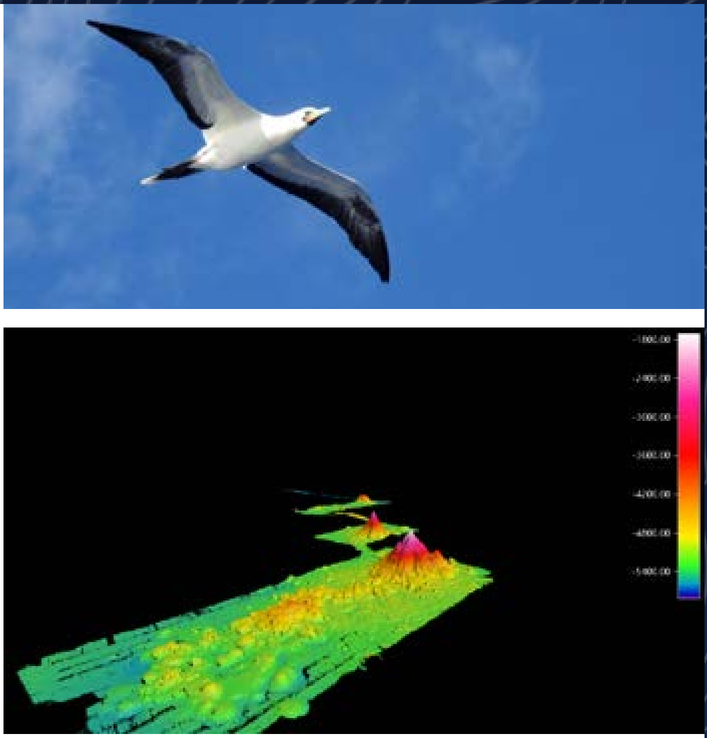


Figure 6. In August–September 2025, E/V *Nautilus* conducted an expedition focused on mapping the seafloor around the islands of Howland and Baker, where four larger seamounts were mapped for the first time. The expedition also included topside surveys for seabirds and other marine fauna.

Figure 7. In August–September 2025, E/V *Nautilus* conducted an expedition focused on mapping the seafloor around the islands of Howland and Baker, where four larger seamounts were mapped for the first time.

DEEP-SEA HABITATS OF THE COOK ISLANDS (NA176)

Between October 1–21, E/V *Nautilus* supported an expedition focused on mapping and ROV surveys of abyssal plain habitats around the Cook Islands. The expedition collected seafloor mapping data over 14,145 square kilometers of seafloor, in addition to seven ROV dives that reached the seafloor at depths down to 5,200 meters. In contrast to other 2025 expeditions, these dives all surveyed much deeper environments and therefore required the use of the 6,000-meter-rated ROV *Little Hercules* as opposed to the 4,000-meter-rated ROV *Hercules*. In addition to its standard sensors, ROV *Little Hercules* was equipped with an MxD SeaCam from DeepSea during this expedition. This recently developed camera provided very detailed imagery of the seafloor, including of over 400 unique species, the vast majority of which were recorded for the first time from the Cook Islands, including the very rare *Magnapinna* deep-sea squid. Furthermore, the expedition included the successful deployment of two autonomous benthic landers at depths of 4,800 and 5,000 meters, which will collect continuous acoustic and environmental data for the next several months, thereby supporting oceanographic monitoring across the region.

2025 REMOTELY OPERATED VEHICLE FIELD SEASON OVERVIEW

Josh Chernov, Jon Zand, Rhye DeWolfe, Robert Waters, Dan Cormany, and Jake Bonney

The 2025 E/V *Nautilus* field season represented a year of operational consolidation for Ocean Exploration Trust's remotely operated vehicle (ROV) program. Building on the major structural upgrades to ROV *Hercules* completed in 2023 and the targeted mechanical and hydraulic improvements implemented in 2024, in 2025 the ROV team focused on system reliability, performance refinement, and sustaining high-tempo deep-sea operations. These efforts supported a productive field season and enabled complex, repeatable dive operations in support of a wide range of scientific and technical objectives.

Throughout the season, Ocean Exploration Trust's ROVs logged extensive bottom time while delivering stable, high-resolution video imagery, precise manipulator performance, and dependable platform control. In parallel with continued operations using ROV *Hercules*, the 2025 season also marked a significant expansion of deep-diving capabilities through the successful deployment of the inspection-class ROV *Little Hercules*. Rated to 6,000 meters, ROV *Little Hercules* supported sustained operations at abyssal depths, broadening both the flexibility and reach of Ocean Exploration Trust's exploration toolkit.

ROV *HERCULES* OPERATIONS AND PERFORMANCE

Throughout the 2025 field season, ROV *Hercules* continued to serve as the primary science vehicle supporting Ocean Exploration Trust's exploration program. Following two years of significant modifications to its structural and hydraulic systems, the vehicle demonstrated a high degree of operational reliability across a broad range of mission profiles. These improvements enabled the ROV team to maintain consistent dive schedules while supporting complex scientific objectives across multiple disciplines.

A notable milestone during the 2025 season was the installation of a new Kraft manipulator arm, replacing an earlier-generation arm of the same model that

Figure 1. A passing of the torch for ROV *Hercules*. The legacy Kraft manipulator arm (left), which had been in continuous service since ROV *Hercules* was commissioned in 2002, is shown alongside its newly installed replacement (right). Over more than two decades of operations, the original arm supported thousands of scientific sample collections and seafloor interactions. After more than 20 years of dependable service, it has been retired, making way for a new Kraft arm that will continue supporting deep-sea science for years to come.

had been in continuous service since ROV *Hercules* was commissioned in 2002 (Figure 1). Over more than two decades of operations, the original Kraft arm played a central role in thousands of scientific sample collections and seafloor interaction tasks, becoming one of the most-heavily utilized scientific instruments of the vehicle. Its replacement marked the conclusion of an exceptional service life and the beginning of a new chapter in ROV *Hercules*' operational capability.

The new Kraft arm, together with the Schilling Orion manipulator and upgraded hydraulic manifolds introduced in 2024, provided pilots with more robust and precise control during seafloor interactions. Operator-controlled hydraulic functions proved particularly valuable during operations requiring delicate sample collection, instrument handling, and improved video stability, where smooth and predictable motion directly impacts data quality and mission efficiency.

In addition to mechanical performance, refinements to operational procedures and maintenance practices contributed significantly to vehicle reliability throughout the season. Preventive maintenance schedules, informed by lessons learned during previous field years, helped reduce unplanned downtime and allowed the team to focus on maximizing productive dive time. Collectively, these factors underscore the growing maturity of ROV *Hercules* as a stable and capable platform for deep-sea exploration.

ROV *LITTLE HERCULES* DEEP-DIVING OPERATIONS IN THE COOK ISLANDS

The 2025 field season also marked a major operational milestone for Ocean Exploration Trust's inspection-class ROV, *Little Hercules*. This vehicle was deployed extensively during a dedicated expedition in the waters surrounding the Cook Islands (see Soule et al. in this report). Over the course of the NA176 expedition, the vehicle accumulated over 199 hours of dive time while

Figure 2. The UHD MxD camera mounted on ROV *Little Hercules* during integration ahead of the 2025 Cook Islands expedition. This close-up photo captures the first deployment of the system on ROV *Little Hercules*—and its first journey to abyssal depths—marking a milestone for both the camera and the vehicle as they ventured deeper than ever before.

Figure 3. Examples of marine life observed during ROV *Little Hercules* dives in the Cook Islands, captured using the UHD MxD camera system. A close-up shot of a colorful shrimp on the seafloor, spotted at 3,133 meters (above) and a solitary black coral observed at 5,034 meters, its white tentacles extending into the current (below).

conducting dives to depths reaching 5,200 meters, demonstrating both system reliability and the team's ability to sustain operations at abyssal depths.

A key achievement of the Cook Islands expedition was the successful integration and deployment of the UHD MxD camera system developed by DeepSea (Figure 2; see Steiner and Rossoshanskiy in this report). Through close collaboration between OET's operations team and engineers from DeepSea, the camera was installed on *Little Hercules* and operated reliably under extreme pressure conditions (Figure 3). This deployment marked the deepest operation of the MxD camera to date.

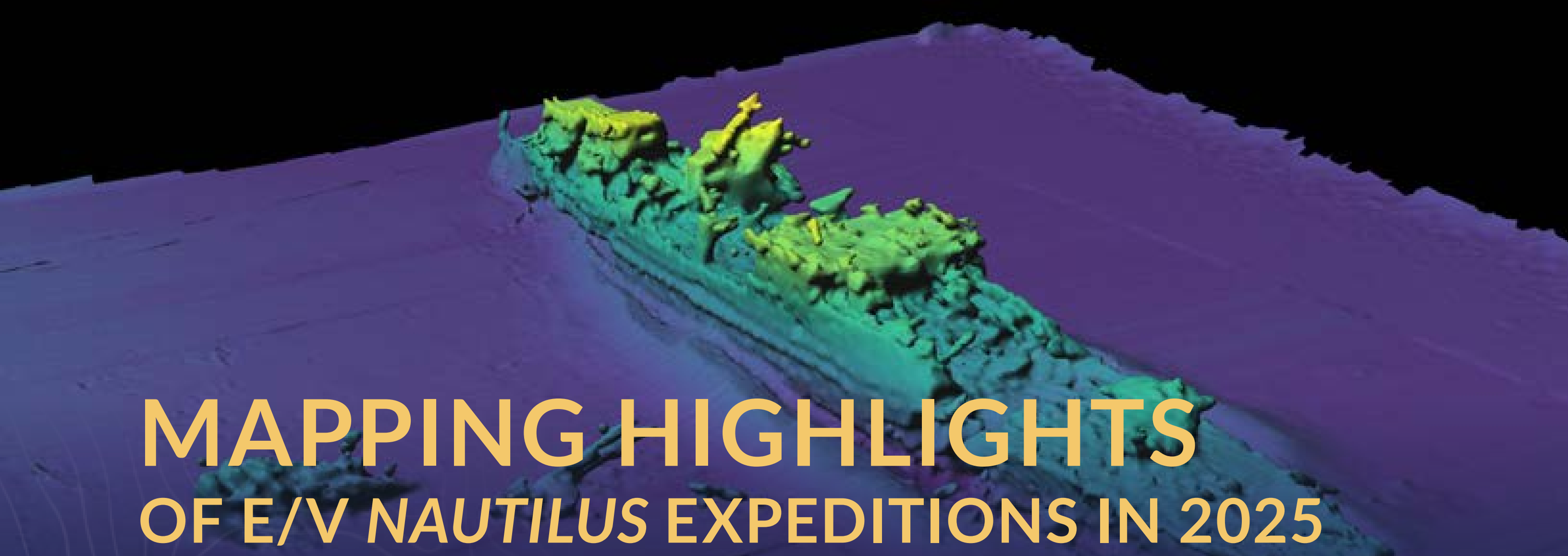
Throughout the expedition, the MxD camera system consistently delivered high-quality 4K video and still imagery, providing unprecedented visual documentation of deep-sea environments. The success of this collaboration highlights the growing role of *Little Hercules* as a flexible platform for technology development and deep-ocean imaging in support of Ocean Exploration Trust's exploration objectives.

CONCLUSION AND LOOKING AHEAD

The 2025 ROV field season reflects the cumulative impact of several years of sustained investment in vehicle capability, operational practices, and team expertise. Across Ocean Exploration Trust's science-focused ROV platforms, the program demonstrated a high degree of reliability and flexibility, enabling sustained operations across a wide range of depths, environments, and scientific objectives. Rather than being defined by a single transformative upgrade, the 2025 season was characterized by steady performance, successful technology integration, and the consistent execution of complex missions.

Operations with ROV *Hercules* highlighted the maturity of the platform following recent structural and hydraulic upgrades, while the successful deep-diving deployment of ROV *Little Hercules* expanded Ocean Exploration Trust's operational reach into abyssal environments. Together, these efforts underscore the value of a multi-vehicle approach and the close collaboration between engineers, pilots, scientists, and external partners that underpins Ocean Exploration Trust's exploration program.

Looking ahead, the performance of the ROV systems during the 2025 season provides a strong foundation for future development. Incremental evaluation of electronics and control system components continued throughout the year, informing longer-term planning without disrupting ongoing operations. As these efforts progress, the ROV program remains focused on maintaining reliability and scientific effectiveness while thoughtfully preparing for the next phase of system evolution.



MAPPING HIGHLIGHTS
OF E/V *NAUTILUS* EXPEDITIONS IN 2025

Derek Sowers, Renato Kane, Lynette Davis, Kristopher Krasnosky, John Smith, Johann Becker, Miles Saunders, Isabella Monaco, and Daniel Wagner

E/V *Nautilus* mapping operations in 2025 were completed as part of seven multidisciplinary expeditions that spanned the Western Pacific on both sides of the Equator, focusing on high-priority areas in the Mariana Islands, Solomon Islands, Marshall Islands, Howland and Baker Islands, and Cook Islands (Figure 1). Seafloor mapping was also completed while transiting through international waters between these destinations, as well as through the exclusive economic zones of the Federated States of Micronesia and the Republic of Kiribati. Using the vessel's Kongsberg EM 302 multibeam sonar, the Ocean Exploration Trust mapped a total of 106,591 square kilometers of seafloor during 2025, an area that is comparable in size to the US state of Kentucky.

The field season began in April 2025 with a week-long shakedown expedition conducted in the waters off Guam (NA170). The team successfully completed annual quality assurance tests of E/V *Nautilus*' mapping and ancillary navigation systems, including a multibeam patch test, an evaluation of swath extinction over a variety of depths, speed noise testing, accuracy surveys, calibration of the subsea acoustic positioning system and the acoustic Doppler current profiler.

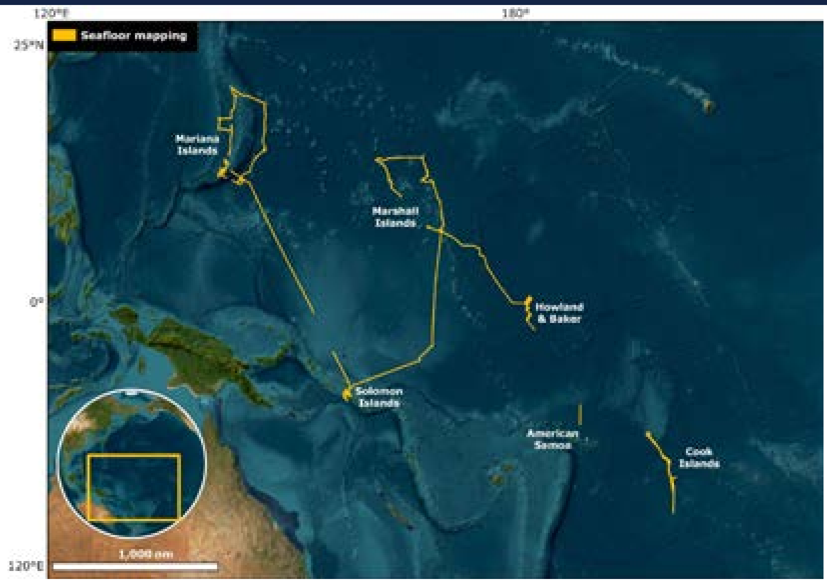


Figure 1. Map showing areas mapped using the multibeam sonar on E/V *Nautilus* during expeditions in 2025.

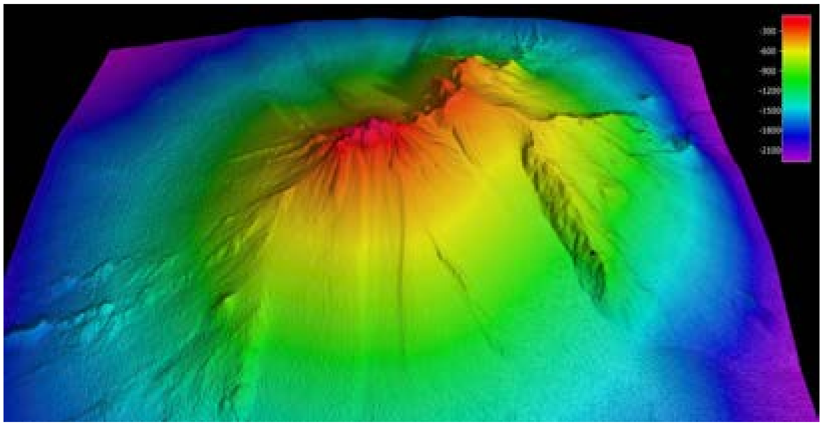


Figure 2. Three-dimensional view of Ahyi Seamount mapped during the Mattingan expedition NA171. The color ramp represents depth in meters. Image created with QPS Fledermaus software with a two-times vertical exaggeration.

Above. Three-dimensional image of the wreck of USS *Northampton*, generated from high-resolution multibeam data collected by the Norbit Wideband Multibeam Sonar mounted on ROV *Hercules*. Image created using CloudCompare software (image credit: Kristopher Krasnosky, Seaward Science).

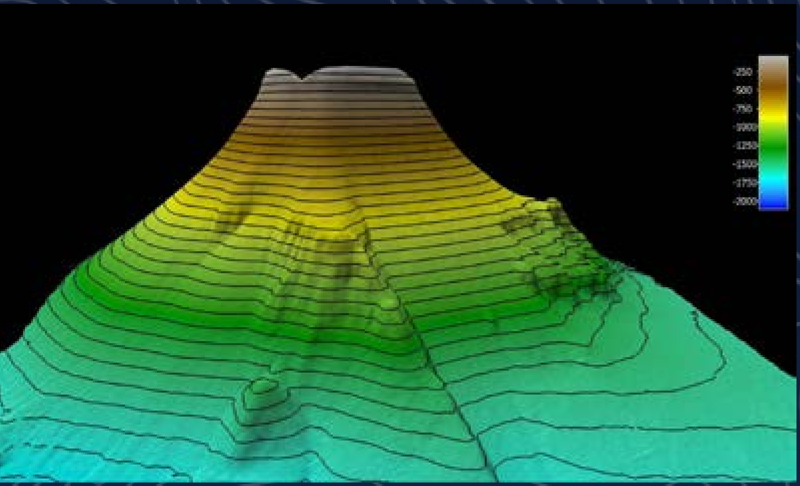


Figure 3. Three-dimensional view of an unnamed shallow seamount mapped within the remnant-arc region of the Mariana Islands. The color ramp represents depth in meters, and the black lines are 50-meter contours. Image created with QPS Fledermaus software with a two-times vertical exaggeration.

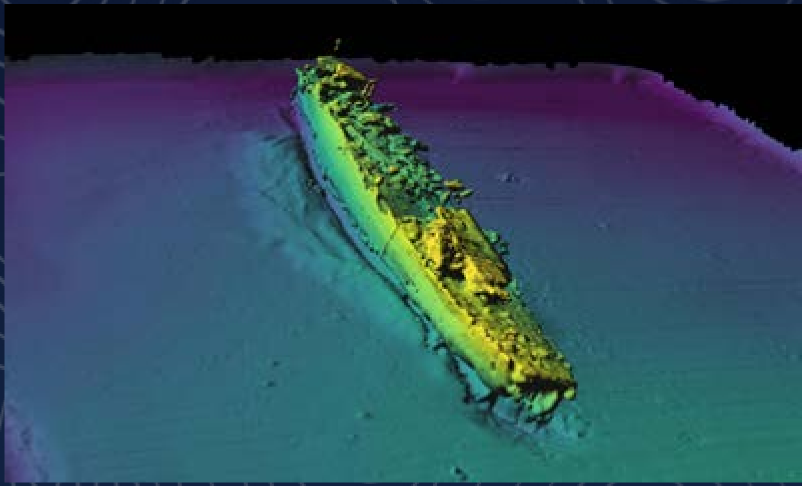


Figure 4. Three-dimensional view of the World War II wreck of the USS *Astoria*, a 175-meter-long New Orleans-class heavy cruiser lost during the Battle of Savo Island. Mapping data were collected using a Norbit Wideband Multibeam Sonar mounted on ROV *Hercules*. Image created using CloudCompare software (image credit: Kristopher Krasnosky, Seaward Science).

Following the shakedown mission, E/V *Nautilus* completed the 21-day Mattingan expedition in the Mariana Islands (NA171), mapping over 20,504 square kilometers of seafloor. Mapping highlights included documenting substantial bathymetric changes at Ahyi Seamount (Figure 2) and NW Rota-1 Seamount due to volcanic activity since they were last mapped, and mapping active bubble plumes over Daikoku Seamount, Ahyi Seamount, and NW Rota-1 (see Chadwick et al. in this report).

Another highlight was gathering the first multibeam data ever collected over portions of two shallow seamounts in the remnant-arc region of the Marianas (Figure 3). These remote seamounts with shallow summits were further explored with the ROVs to reveal vibrant mesophotic coral reef habitats supporting abundant marine life. An additional 13,691 square kilometers of seafloor were mapped in the waters around Guam, the Federated States of Micronesia, and the Solomon Islands during the following NA172 expedition's transit from Guam to the Solomon Islands.

In July, the NA173 expedition explored maritime heritage sites associated with the Battles of Guadalcanal in Iron Bottom Sound. The expedition included extensive mapping by both E/V *Nautilus* and the University of New Hampshire's uncrewed surface vehicle *DriX*, mapping 112 potential targets of interest (see Schmidt et al. in this report). Numerous maritime heritage sites were mapped in very high resolution using a Norbit Wideband Multibeam Sonar mounted on ROV *Hercules* (Figure 4), followed by thorough imagery documentation via ROV video surveys (see Ballard et al. in this report). Complementing the E/V *Nautilus* expedition to Iron Bottom Sound, adjacent shallow-water environments were mapped in high-resolution using a R2Sonic 2020 multibeam sonar mounted on M/V *Berry Ferry*, followed by close-range imaging by high-resolution cameras carried by SCUBA divers (see Krasnosky et al. in this report).

E/V *Nautilus* expedition NA174 explored deep-sea habitats around the Marshall Islands, mapping 31,421 square kilometers of seafloor and revealing details of 15 newly-mapped seamounts (Figure 5). New

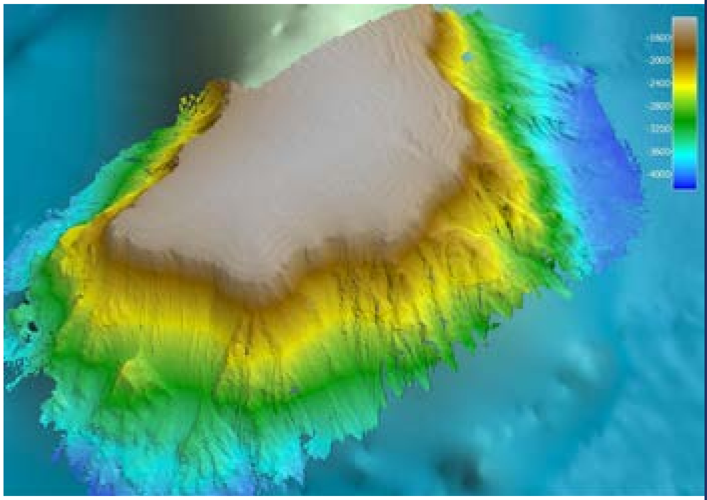


Figure 5. Three-dimensional view of an unnamed flat-topped seamount (7.49° N, 169.77° E) mapped near the Marshall Islands. The color ramp represents depth in meters. Image created with QPS Fledermaus software with a three-times vertical exaggeration.

multibeam coverage included areas within the National Marine Sanctuary of Bikar and Bokak, established by the Marshall Islands in January 2025, within the main shipping approach lane to the port in Majuro, as well as three seamounts located in international waters of the Ontong Java Plateau.

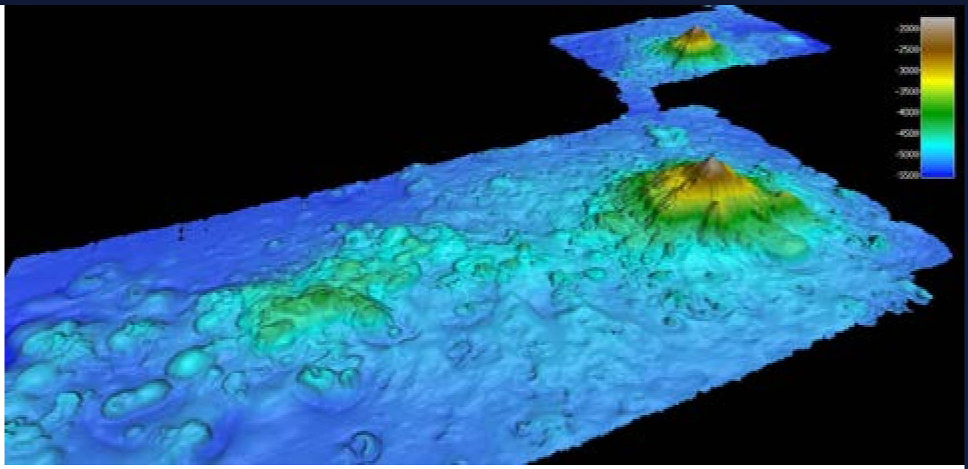


Figure 6. Three-dimensional view of unnamed seamounts mapped near Howland and Baker Islands. The color ramp represents depth in meters. Image created with QPS Fledermaus software with a two-times vertical exaggeration.

NA175 was a dedicated mapping expedition, with no ROV operations. E/V *Nautilus* completed 18,003 square kilometers of new seafloor mapping, including 11,192 square kilometers in the US Exclusive Economic Zone around Howland and Baker Islands, where four large seamounts were mapped in their entirety (Figure 6). The expedition included the participation of students and educators via the OET Seafloor Mapping Internship Program and the OET Science Communication Fellowship Program (Figure 7).

NA176 was the final expedition of the 2025 field season, with E/V *Nautilus* partnering with the Cook Islands Seabed Mineral Authority to explore abyssal plain and deep slope habitats in the Cook Islands. The expedition collected mapping data over 14,145 square kilometers of seafloor, contributing important new data to the Cook Islands compilation of multibeam data.

As in previous years, mapping data collected during 2025 expeditions were submitted to the Rolling Deck to Repository, the Marine Geoscience Data System, the NOAA National Center of Environmental Information, the Global Multi-Resolution Topography data synthesis, and the GEBCO Seabed 2030 data centers, and thereby provide a publicly-accessible foundation to stimulate future explorations throughout the Pacific. For 2026, E/V *Nautilus*' mapping capabilities will be substantially enhanced by upgrading our 13-year old workhorse EM 302 multibeam sonar to the next generation EM 304 MKII—stay tuned.

The accomplishments summarized in this article were made possible through the hard work of the entire dedicated team of navigation and mapping experts that participated in 2025 E/V *Nautilus* expeditions, which included Renato Kane, Lynette Davis, Kris Krasnosky, John Smith, Johann Becker, Miles Saunders, Isabella Monaco, Paul Johnson, Anna Coulson, Gabriela Espino, Amanda Bittinger, Samantha Wishnak, Jacob Stock, Meagan Putts, Francesca Dellacqua, Deb Smith, Matt Hommeyer, Lexie DelViscio, Ella Magrum-Stanley, Diego Johansen, and Derek Sowers.

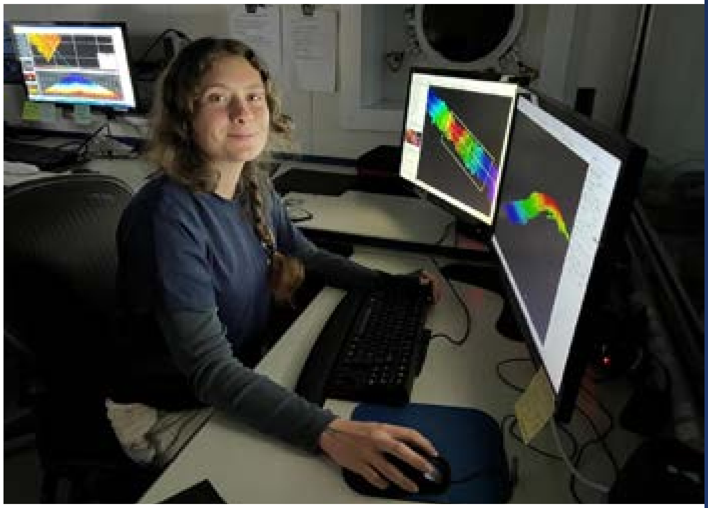


Figure 7. Seafloor Mapping Intern Lexie DelViscio (left) ready to deploy an expendable bathythermograph probe to support mapping operations and Seafloor Mapping Intern Ella Magrum-Stanley (right) processing multibeam data in the E/V *Nautilus* Data Lab.

FORGING A NEW PARTNERSHIP: LEEWAY MARINE'S MANAGEMENT OF E/V *NAUTILUS*

Bill Sanson, Greg Veinott, Mark Decker, and Jamie Sangster

Leeway Marine assumed vessel management responsibility for E/V *Nautilus* in December 2024, supporting the Ocean Exploration Trust's work in ocean exploration, research, and public engagement. The transition brought together two organizations with aligned priorities: safe operations, reliable performance, and a shared respect for the people who make complex missions possible at sea.

Leeway Marine's approach to vessel management is grounded in long-term stewardship. Whether operating owned or managed vessels, we emphasize practical decision-making, transparency, and accountability. This mindset proved well suited to E/V *Nautilus*, a vessel that supports technically demanding scientific expeditions while also serving as a highly visible platform for education and outreach.

Early efforts focused on maintaining continuity while building trust across shipboard and shoreside teams. Leeway Marine worked closely with leadership of the Ocean Exploration Trust as well as vessel crew to understand established practices, operational constraints, and seasonal demands. The objective was not to introduce unnecessary change, but to support the vessel in a way that preserved what was working, while strengthening areas that affected reliability and risk.

Figure 1. Based in Halifax, Nova Scotia, Canada, Leeway Marine operates and manages vessels around the world, focusing on the locations marked on this map.

Regular coordination between Leeway Marine and the Ocean Exploration Trust became central to this relationship. Shared planning cycles and open communication allowed both organizations to stay aligned on priorities and respond effectively when challenges arose. This collaborative rhythm supported smoother operations across expedition planning, maintenance scheduling, and crew logistics, particularly during periods of high activity or compressed timelines.

Figure 2. Crew members aboard E/V *Nautilus*, whose efforts ensure safe and efficient deep-sea exploration.

The working relationship between Leeway Marine and the Ocean Exploration Trust has been characterized by openness and shared responsibility. Financial reporting, operational updates, and technical planning were handled in a transparent manner, allowing both organizations to identify issues early and address them collaboratively. This approach reinforced confidence on both sides and supported steady progress through complex operational seasons.

Crew experience and stability were treated as operational essentials. E/V *Nautilus* operates for extended periods in remote regions, where fatigue, uncertainty, and logistical complexity can quickly affect performance. Leeway Marine placed emphasis on clear communication, consistent planning, and responsive shoreside support to reduce unnecessary friction for those onboard. This focus helped reinforce a working environment where crew members could concentrate on safe operations and mission execution.

Maintaining technical readiness was equally important. The vessel's ability to support exploration depends on the reliable performance of propulsion, navigation, and mission-support systems. Leeway Marine strengthened preventative maintenance planning and improved coordination with technical partners to reduce the impact of in-season repairs. These efforts were aimed at protecting expedition continuity to the extent possible.

Operational decisions were made with Ocean Exploration Trust's broader mission in mind. E/V *Nautilus* is unique in connecting scientific exploration with public audiences around the world. Choices related to maintenance timing, crew movements, and operational planning directly affect the vessel's ability to support live exploration and educational programming. Close coordination between Leeway Marine and the Ocean Exploration Trust staff helped ensure that operational considerations remained aligned with mission objectives.

The experience of managing E/V *Nautilus* reflects Leeway Marine's broader commitment to partnership-based vessel management. By focusing on people, planning, and reliability, the management team has supported the vessel as a stable and capable platform for exploration. The results achieved to date are the product of sustained effort by shipboard crews and shoreside staff at both Leeway Marine and the Ocean Exploration Trust, working toward a common goal of enabling safe, effective ocean exploration.

Figure 3. Leeway Marine's Chief Technical Officer Mark Decker, and Fleet Maintenance Manager Jamie Fitzgerald, with Chief Engineer Lino Gutierrez Portugal, and the Engineering staff onboard E/V *Nautilus* in early 2025.

MATTINGAN:
EXPLORATION OF DYNAMIC UNDERWATER LANDSCAPES IN THE MARIANA REGION

William W. Chadwick Jr., Verena Tunnicliffe, Jeffrey Beeson, and Derek Sowers

TECTONIC SETTING AND EXPLORATION GOALS

The first operational expedition of the 2025 E/V *Nautilus* season was a 21-day mission to the Mariana Archipelago in the Western Pacific. The Mattingan (NA171) expedition explored the seafloor in the Mariana region: one of the most dynamic parts of our planet. This region contains a subduction zone where two tectonic plates are colliding, forcing one plate under the other along the curved, north-to-south oriented boundary (Figure 1). This process creates five distinctive tectonic settings, which from east to west include: (1) A deep abyssal plain studded with ancient seamounts, located east of the Mariana Trench, which contains some of the oldest seafloor on the planet. (2) The Mariana Trench where the Pacific plate dives beneath the Philippine plate, causing frequent earthquakes as the two plates grind past each other, and generating magmas that rise to the surface in the overriding plate. (3) The volcanic arc, which consists of over 60 submarine volcanoes in addition to the nine northernmost islands of the Mariana Archipelago, all of which once started as smaller underwater mountains but have since grown large enough for their summits to reach above sea level. (4) The back arc, which is a zone of deep basins where the upper plate is rifting and spreading apart, creating another zone of submarine volcanic and hydrothermal activity, but in a setting that is very different and distinct from the one in the volcanic arc. (5) And finally, the remnant arc, also known as the West Mariana Ridge, which formed millions of years ago when it was part of the active volcanic arc, but has since rifted far to the west by millions of years of back-arc spreading.

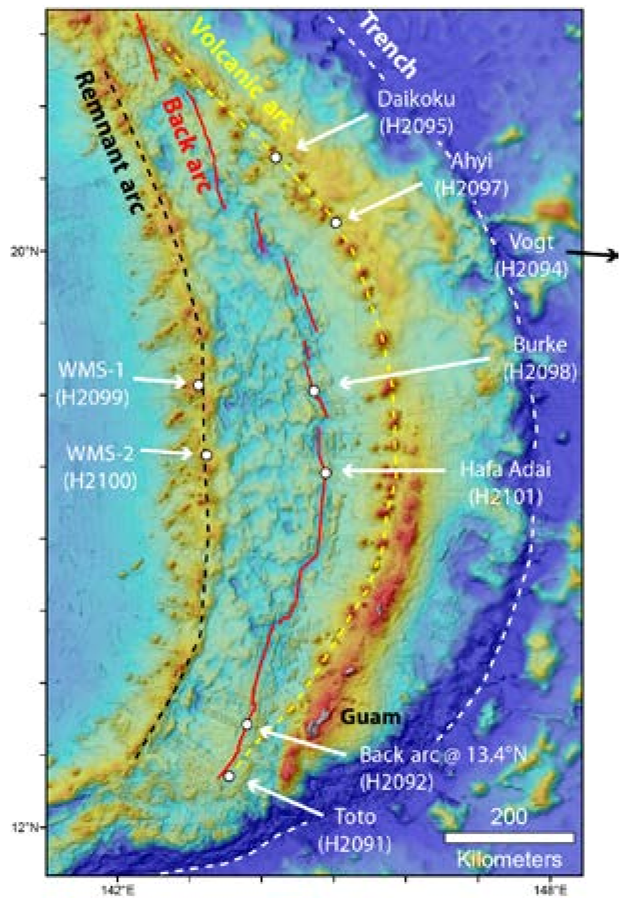


Figure 1. Map of the Mariana Trench, volcanic arc, back arc, and remnant arc, showing ROV dive locations during NA171 (image credit: William Chadwick, Oregon State University).

Above. ROV *Hercules* illuminates a sulfur-rich particle plume in the summit crater at Daikoku Seamount during dive H2095.

Figure 2. Shrimp swarm at an active hydrothermal vent chimney in Toto Caldera imaged during ROV *Hercules* dive H2091.

Figure 3. Carbon dioxide bubbles streamed out of the newly erupted lava dome near the summit of Ahyi Seamount during ROV *Hercules* dive H2097.

During the Mattingan expedition, we completed nine successful dives with ROV *Hercules* across all of the tectonic settings described above with the exception of the Mariana Trench. In addition, we made six dives with an Orpheus Ocean AUV, including two engineering test dives and four dives that explored abyssal plains (see Machado et al. in this report). The overall goals of the NA171 expedition were a combination of exploring new areas that had not been visited before, and returning to previously visited sites that were suspected of having experienced significant changes since they were last visited. Documenting change helps us better understand the dynamic nature of this extraordinary underwater tectonic landscape.

DEEP ABYSSAL PLAIN AND ANCIENT SEAMOUNT

We made all four exploration dives with the Orpheus Ocean AUV east of the trench down to depths of 6,000 meters (beyond the 4,000-meter depth limit of ROV *Hercules*) to characterize areas within the US Exclusive Economic Zone that may contain polymetallic nodules. We also made one ROV *Hercules* dive (H2094) at Vogt Seamount, which rises above the deep abyssal plain to shallower depths. At 2,000 meters depth, the ROVs documented abundant glass sponges, crinoids, and echinoderms. Here, sediment ponds hosted manganese nodules while the host rock of the seamount was coated with ferromanganese crusts. The dive crested the seamount summit at a depth around 1,870 meters where biodiversity was high. Incredibly, the flat top of the seamount shows that it was previously eroded near sea level, and since then the seafloor has subsided by over a mile.

VOLCANIC ARC

ROV dives in the volcanic arc surveyed the Toto Caldera, Daikoku Seamount, and Ahyi Seamount. The dive at Toto (H2091) provided the opportunity to observe and sample the biological communities at the hydrothermal vents in the floor of the caldera (Figure 2), which seem to be a key stepping stone for vent species between the Mariana region and other sites in the Southwest Pacific based on recent genetic evidence. The dive at Daikoku (H2095) was a chance to revisit this remarkable site where sulfur-rich hydrothermal vents support unique volcano-adapted flat fish populations and large tubeworm bushes. Bubbling ponds of molten sulfur seen on previous visits had become inactive, but the large summit crater was still vigorously venting warm fluids and volcanic gases, producing carbon dioxide bubble streams and cloudy sulfur-laden particle plumes.

The dive at Ahyi (H2097) was particularly exciting, because we were able to document a new blocky lava dome that had erupted recently, probably during remotely-detected unrest starting in 2022. Resurveying the seamount with E/V *Nautilus*' multibeam sonar revealed major depth changes since previous surveys in 2014 and 2022. Guided by the new map, ROV *Hercules* sampled the new lava flow and found an incredible scene at the top of the new dome, with vast areas emitting warm shimmering fluids, streams of carbon dioxide bubbles, and sulfur-rich particle plumes from sulfur dioxide emission (Figure 3). Around the rest of the shallow summit of Ahyi, coral reef communities were thriving despite the recent eruption.

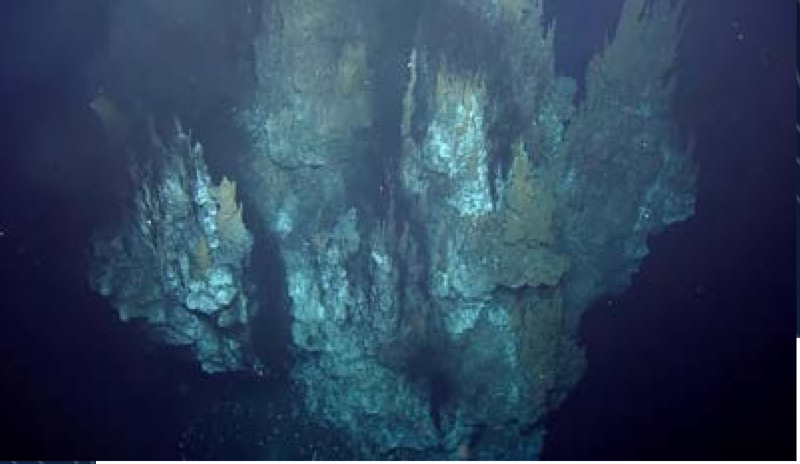
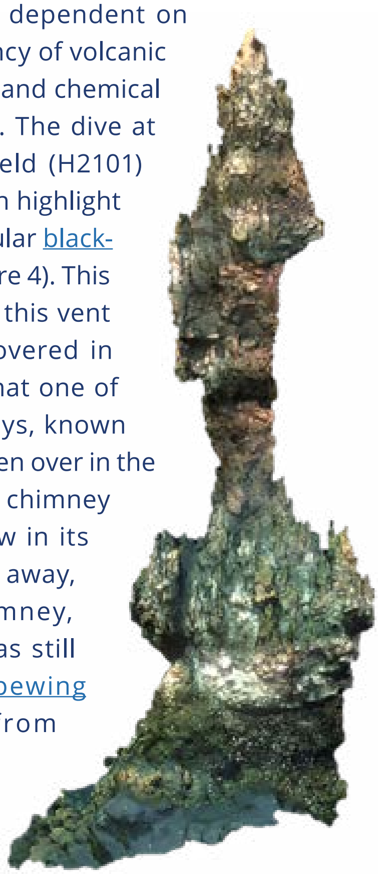


Figure 4. View of the base of the 35-m high Sequoia black smoker chimney at the Hafa Adai hydrothermal vent field during ROV *Hercules* dive H2101 (left). Three-dimensional model of the Sequoia chimney created by ROV *Hercules* pilot Ben Erwin (below left).

BACK ARC

ROV dives in the back arc targeted several locations along the axis of the spreading center, including an unnamed area at 13.4°N latitude, the Burke hydrothermal vent field, and the Hafa Adai hydrothermal vent field. The first of these dives (H2902) targeted a part of the back arc that had not been visited before and collected rock samples for later geochemical analysis to fill a gap in existing coverage. The dive at Burke (H2098) documented the continued decline at this hydrothermal site that was originally discovered by the manned submersible *Alvin* back in 1987 with high-temperature hydrothermal vents and robust biological communities, but now has no visible venting and just a scattering of vent animals still eking out a living there. This shows that hydrothermal vents do not last forever and their longevity is dependent on the timing and frequency of volcanic events that bring heat and chemical energy to the surface. The dive at the Hafa Adai vent field (H2101) was another expedition highlight because of its spectacular black-smoker chimneys (Figure 4). This was the first revisit to this vent site since it was discovered in 2016, and we found that one of the big sulfide chimneys, known as Two Towers, had fallen over in the meantime, and a new chimney had started to re-grow in its place. Just 50 meters away, an even larger chimney, known as Sequoia, was still standing tall and spewing out black smoke from multiple vents in all its 35-meter-high glory (three-dimensional model on right).



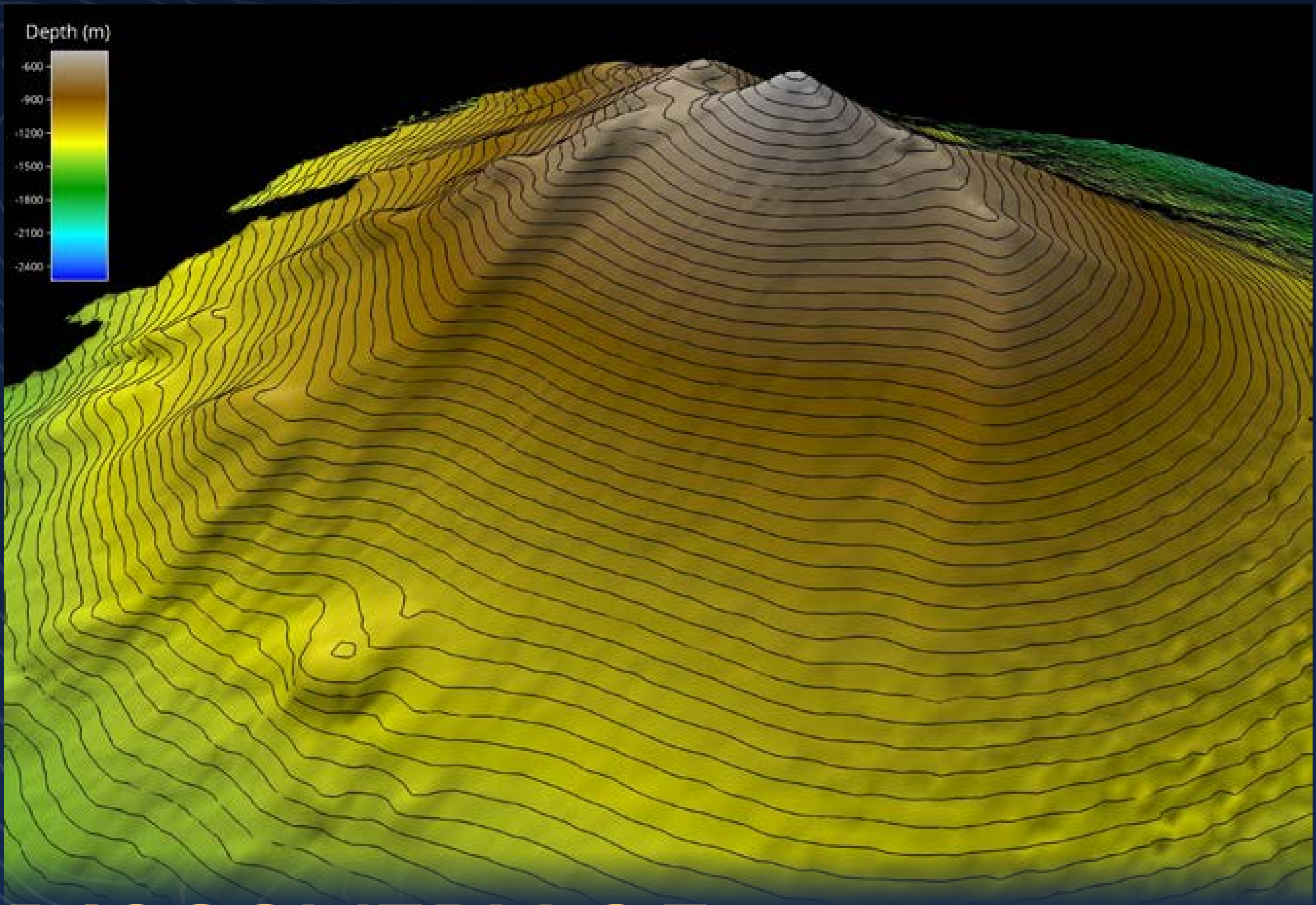
REMNANT ARC

The expedition also made two ROV dives (H2099 and H2100) on the remnant arc, located further to the west. We chose two shallow locations on the Western Mariana Ridge to characterize the healthy Mariana coral reef biological communities in a relatively undisturbed location, far from the inhabited islands. These dives provided quite a contrast to ones at the deep hydrothermal vents and the active volcanic seamounts, with a riot of colors in the vibrant coral reef communities teeming with life (Figure 5).

SUMMARY

There were a few other sites that we had hoped to survey during the NA171 expedition, but we were not able to, due to problems that developed with the ship propulsion system late in the mission. Despite these logistical challenges, the NA171 expedition made several significant new findings, including the first visual surveys of abyssal plain habitats in the region, substantial changes in seafloor morphology and benthic communities on volcanically active sites of the arc and back arc, as well as expanding the known range of coral reef habitats in the region to far offshore seamounts located west of the Mariana Islands. These accomplishments could have not been possible without the contributions of many team members, both on the ship and on shore, who worked collaboratively and tirelessly to make the mission a success.

Figure 5. Healthy coral reef on an unnamed seamount on the West Mariana Ridge during ROV *Hercules* dive H2100.



DISCOVERY OF REJUVENATED ERUPTIVE ACTIVITY AT NW ROTA-1 SEAMOUNT

William W. Chadwick Jr., Jeffrey W. Beeson, Jeremy Powell, and Derek Sowers

NW Rota-1 Seamount is an active submarine volcano in the Mariana volcanic arc that was discovered to be erupting almost continuously between 2003–2010. However, the volcano apparently stopped erupting soon after 2010, and opportunistic remapping in subsequent years suggests that the hiatus in activity lasted until at least June 2019. The NA171 expedition aboard E/V *Nautilus* in May 2025 (see Chadwick et al. in this report) provided the opportunity to resurvey NW Rota-1. While no ROV or AUV dives were conducted at this site due to time constraints, multibeam mapping data was collected right over its summit during the transit back into port. Comparing the survey data collected on NA171 with ones collected on previous expeditions by other vessels shows major morphologic changes, and clear evidence of significant constructional volcanism (Figure 1).

In addition, the presence of a strong bubble plume detected by E/V *Nautilus*' sonars in the water-column over the summit (Figure 1d) is evidence of active eruptive activity, because such plumes are absent during dormant periods.

When compared with survey data collected during a R/V *Revelle* expedition in 2014, the bathymetry data collected on NA171 shows that a large new cone has grown at the summit of the volcano, completely burying the previous topography and shedding new material approximately 2 kilometers down the south flank and 1 kilometer down the north flank. The

Above. New bathymetric data collected by E/V *Nautilus* during NA171 found a new cone has grown at the summit of NW Rota-1 Seamount. Feature shown with no vertical exaggeration and 20 meter contour lines.

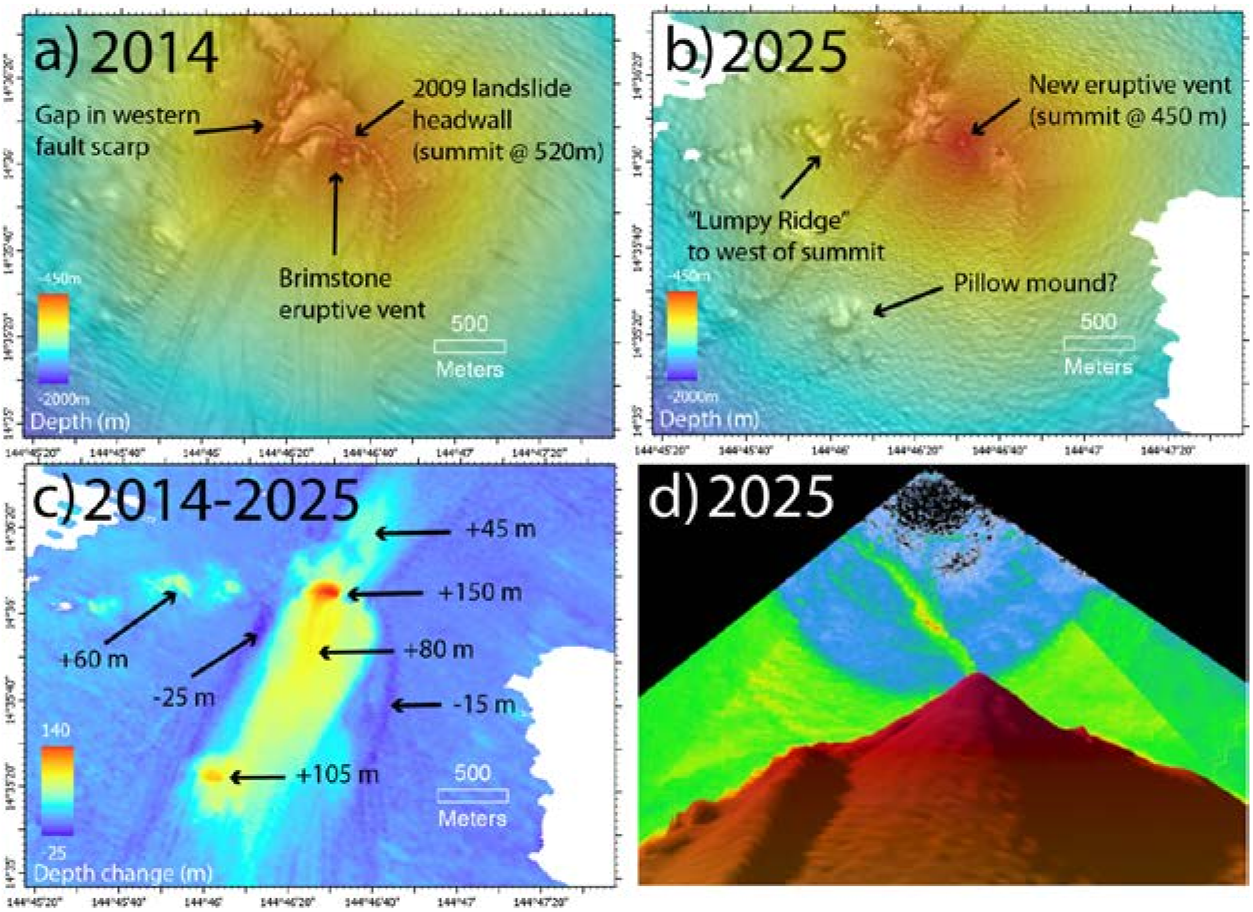


Figure 1. (a) Bathymetric map of the summit area of NW Rota-1 surveyed by an expedition aboard R/V *Revelle* in 2014. (b) The same area mapped by E/V *Nautilus* in May 2025 showing most of the summit area buried by new eruptive deposits. (c) Map of depth changes between 2014–2025 surveys. (d) Three-dimensional oblique view of a bubble plume above the summit of NW Rota-1, imaged by the E/V *Nautilus* multibeam sonar in 2025.

summit depth has decreased from approximately 525 to 455 meters over this time span, but the maximum positive depth change between the surveys is roughly 150 meters, at a location that is about 100 meters west of the old summit where a landslide scar from 2009 has been filled in. Previously, the eruptive vent was located just south of the summit and the eruptive deposits accumulated only on the upper south flank of the volcano.

The new cone, however, has grown high enough to shed material down both the north and south flanks. The net volume of the 2014–2025 depth changes is 116 million cubic meters, which is 3.4 times larger than the volume change observed between 2003 and 2009, indicating a significantly higher eruption rate. The areas of positive depth change are up to 45 meters on the north flank and up to 80 meters on the south flank, with narrow zones of negative depth change (up to 25 meters) to the east and west, apparently due to erosion and widening of landslide chutes by repeated cascades of erupted debris down the flanks.

An unusual feature in the new depth change map is the large oval mound-shaped area of positive depth change that is 100–200 meters in diameter, 105 meters in thickness, and located about 1.5 kilometers south of the summit. This mound could be constructed of pillow lava fed downslope from the summit eruptive vent, and if so would be the first observation of effusive lava flows erupted at NW Rota-1. Similarly, the lumpy ridge of positive depth changes (up to 60 meters) that extends 1.8 kilometers down the southwest flank from the summit could have formed from lava flows fed through a pre-existing topographic gap in the fault scarp west of the summit, after the new cone had grown large enough to reach it. Higher-resolution bathymetry and ROV visual observations will be required to confirm these interpretations. In summary, the pattern and distribution of the new 2014–2025 eruptive deposits are substantially different from previous ones and indicate more energetic eruptive activity, increased eruption rates, and may portend increasing levels of activity at NW Rota-1.

ILLUMINATING THE DEEP WITH THE ORPHEUS AUV

Casey Machado, Francesca Daszak, Ishani Narwankar, and Jake Russell

In May 2025, Orpheus Ocean Inc. joined E/V *Nautilus* on the Mattingan expedition (NA171), a 21-day mission that marked both a milestone in ocean exploration and a new chapter for a technology born from scientific innovation. Over the course of this three-week expedition, the Orpheus team deployed its autonomous underwater vehicle (AUV) in the deep waters surrounding the Mariana Islands, one of the most tectonically dynamic regions on Earth (Figure 1). The expedition represented the first commercial demonstration of the Orpheus AUV and showcased a new era of agile, scalable, and affordable deep-sea access.

FROM LAB TO MARKET

Originally conceived at the Woods Hole Oceanographic Institution in collaboration with NASA's Jet Propulsion Laboratory, the Orpheus AUV was designed to make deep-sea access routine rather than exceptional. Its development was supported by NOAA Ocean Exploration through the Ocean Exploration Cooperative Institute, with the goal of enabling the collection of data from the most remote parts of our ocean.

In 2024, the technology transitioned from research to commercialization under the newly formed Orpheus Ocean Inc., a venture-backed startup based in New Bedford, Massachusetts. The NA171 expedition marked the AUV's first deployment under this new banner, demonstrating not only its technical capabilities, but also the power of collaboration between public science institutions and the private enterprise.

MISSION GOALS

The NA171 expedition aimed to explore priority deep-sea areas identified by the science and resource management community, including sites showing evidence of recent volcanic activity, abyssal plain habitats, and other areas within and around the Mariana Trench Marine National Monument (see Chadwick et al. in this report). Orpheus AUV joined E/V *Nautilus*' ROVs and mapping systems in conducting high-resolution seafloor surveys, efforts that support broader federal initiatives for ocean mapping and characterization.

SIX DIVES INTO THE UNKNOWN

During the 21-day expedition, Orpheus AUV conducted six dives reaching depths up to 5,700 meters, including surveys of the abyssal plain and tests of its sediment coring system (Figure 2). Over the course of these dives, the AUV logged 68 hours in the water, with 16 hours on the seafloor, and captured more than 10 hours of high-definition video footage covering nearly 8 kilometers of seabed terrain. Each dive provided valuable data on seafloor conditions and offered an opportunity to test the vehicle's subsystems in the field. The team successfully integrated a conductivity-temperature-depth (CTD) sensor, validated the AUV's terrain-following capabilities, and demonstrated fully autonomous operations in one of the world's most challenging environments.

Above. Polymetallic nodules imaged by the Orpheus AUV on the abyssal plain at a depth of 5,683 meters during the fourth of six dives conducted during the NA171 expedition.

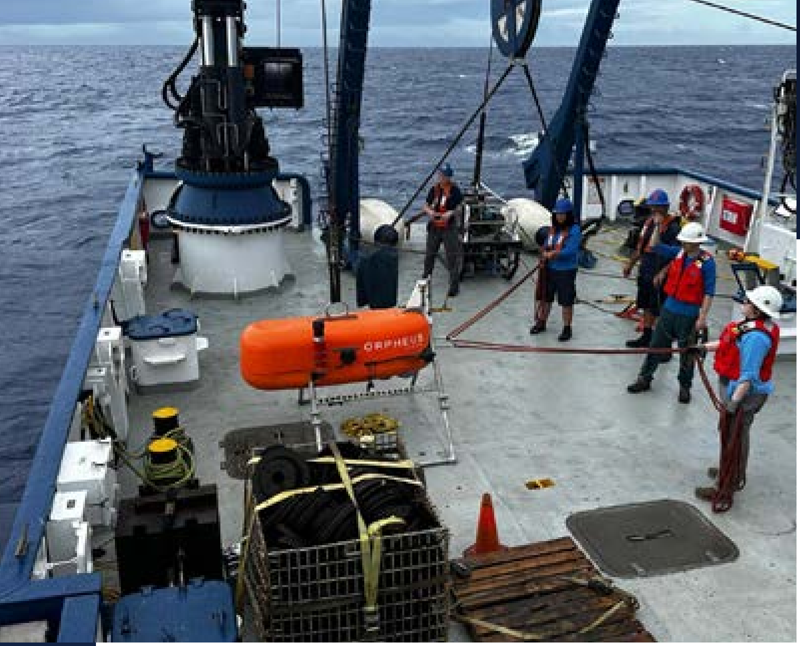


Figure 1. The team preparing the Orpheus AUV for deployment during the NA171 expedition.

OVERCOMING CHALLENGES

No first voyage is without challenges. During initial mobilization, the team encountered an electrical issue with the vehicle's main power switch that forced early repairs. Later, interference from thrusters affected acoustic tracking, and anomalies in the altimeter data created navigation challenges. Each issue became an opportunity for rapid learning. Orpheus Ocean engineers applied real-time fixes, adjusted mission profiles, and refined onboard software, ultimately achieving successful operations. This iterative, at-sea problem-solving is a hallmark of ocean technology development. It is one thing to build a vehicle that works in the laboratory, but having it operate thousands of meters below the surface is entirely different. The challenges encountered during the NA171 expedition made the vehicle stronger for its next missions.

A DEEP OCEAN PLATFORM FOR THE FUTURE

Beyond the technical validation, the expedition demonstrated the potential of Orpheus AUV as a new class of ocean exploration tool. Unlike traditional ROVs, which require tethered connections and large ship-based infrastructure, the Orpheus AUV is light, small, and fully autonomous. It can be launched over the side of smaller vessels, operated in swarms, and equipped with a range of payloads, from hyperspectral imaging cameras to environmental DNA samplers and magnetic tracking systems. This flexibility allows Orpheus AUV to support not only scientific research, but also emerging industries such as offshore wind, seabed minerals, and carbon sequestration, all of which require scalable, low-impact methods for understanding the deep ocean environment.

ONWARDS AND DOWNWARDS

The success of NA171 underscores the value of partnerships between innovative startups and established scientific organizations. For the Ocean Exploration Trust, Orpheus Ocean's participation in the NA171 mission expanded its toolkit for exploring depths approaching 6,000 meters. For Orpheus Ocean, it was a proving ground, validating years of research and setting the stage for commercial deployment.

Collaborating with the Ocean Exploration Trust and E/V *Nautilus* was a real honor for Orpheus Ocean. The mission of Orpheus Ocean is to democratize deep ocean access, and the NA171 expedition was a perfect illustration of how novel technology can complement traditional ocean exploration approaches. Following the success of this mission, Orpheus Ocean is planning to rapidly scale up its capabilities in 2026, including continued work with NOAA and the Bureau of Ocean Energy Management, as well as new partnerships with offshore wind developers, seabed mineral companies, and environmental consultancies. The company's long-term vision, fleets of Orpheus AUVs deployed from uncrewed surface vessels to dramatically reduce the cost of access to the deep seabed, will dramatically expand the reach of ocean science and stewardship.

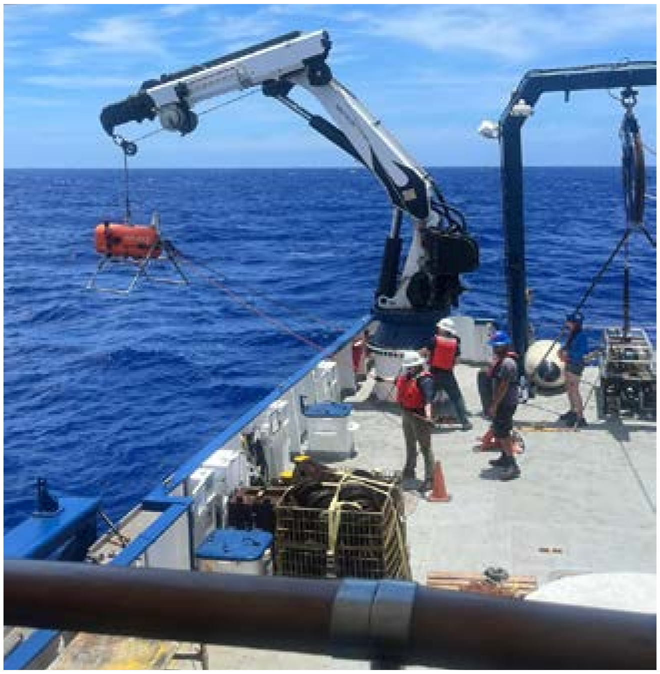


Figure 2. The Orpheus AUV being launched over the side of E/V *Nautilus* for a dive to a depth of 5,700 meters.

DEPLOYING BIOGEOCHEMICAL ARGO FLOATS
IN THE WESTERN PACIFIC

Melissa T. Miller

Figure 1. NA172 Deck Chief TJ Scanlon deploying an Argo float over the side of E/V *Nautilus* during NA172 (image credit: Melissa Miller, Scripps Institution of Oceanography).

Drifting across the world's oceans is a network of more than 4,000 robotic floats measuring temperature and various other ocean environmental variables in near-real time. This program, called the Argo float program, is an international collaboration that brings together partners from around the world to autonomously monitor changing ocean conditions. Building onto this rich dataset, the National Science Foundation is funding the Global Ocean Biogeochemical Array, contributing 500 floats outfitted with extra biogeochemical sensors. Scripps Institution of Oceanography is one of many organizations that contributes data to this Argo network, and Scripps technician Melissa Miller joined E/V *Nautilus* during the NA172 transit expedition between Guam and the Solomon Islands to oversee six float deployments. Thanks to the dedicated E/V *Nautilus* team and collaborators, all floats were deployed successfully (Figure 1) and are now contributing important oceanography data across the Pacific to this global monitoring network.

Each autonomous float is equipped with a suite of biogeochemical sensors and is on a mission to collect data along a vertical profile extending from the ocean surface to 2,000 meters depth. Each float includes sensors that measure temperature, conductivity (salinity), pH, nitrate, dissolved oxygen, chlorophyll, and irradiance (light levels at multiple wavelengths). Every 10 days, the floats return to the surface and transmit all of that data back to shore via satellite, giving near real-time information on ocean biogeochemistry that is made available publicly (Figure 2). Each float will continue on its mission drifting with the currents for 5–7 years, depending on battery life. Of the six floats deployed by E/V *Nautilus* in 2025, some are still relatively close to their deployment location, while others are nearly 1,000 miles away after only five months (Figure 3).

The program relies on ships of opportunity to facilitate float deployments that build and maintain a sensor array in every region of the ocean. Often piggy-backing on expeditions with the US academic research fleet, the program has also deployed floats from private research vessels, yachts, and cruise ships. The partnership with E/V *Nautilus* will provide crucial coverage in the Western Pacific for years to come. They are invaluable instruments, reporting year-round and in all weather conditions. Floats that are deployed in the Southern Ocean are even capable of detecting ice and stay under the surface, only reporting once they are in open water again—sometimes months or even years after their last transmission.

Figure 4. Melissa Miller (center) joined OET Science Communication Fellows Shel Alokoa (left) and Emily Jones (right) during a ship to shore interaction with a classroom that adopted an Argo float deployed on NA172.

The E/V *Nautilus* team loaded the Argo floats onto the ship in Guam after the conclusion of the NA171 expedition (see Chadwick et al. in this report) and deployed them during the transit to the Solomon Islands for the NA173 expedition (see Ballard et al. in this report). Transit expeditions like this are ideal for float deployments as there is often equipment storage space onboard, as well as berths available for technicians to join the mission at sea, something that is rare on other scientific expeditions. Transit deployments require no deviations from the ship's transit route, simply requiring the ship to slow down briefly to allow for a safe deployment. When all goes well, as it did on NA172, each deployment only adds about 10 minutes to the ship's overall journey.

The open-access datasets from the Argo network are used by researchers for monitoring ocean warming, sea level rise, ocean deoxygenation, and changes to ocean biogeochemistry as well as weather forecasting. In addition, the data is used for myriads of scientific publications covering physical, chemical, biological, and geological oceanography, among other scientific disciplines. School teachers also use the float program to educate kids of all ages about science, technology, engineering, and math concepts. Classrooms can adopt a float, name it, and follow its journey. All six of the floats deployed from E/V *Nautilus* this year were adopted and, thanks to the ship's amazing telepresence capabilities, some of those classrooms were able to connect with the team onboard during the NA172 expedition (Figure 4). The team onboard was even able to answer questions from a summer camp held at Ocean Discovery Institute, which was over 6,000 miles away from the ship at the time. The kids were eager to learn about life at sea and how to get more involved in ocean science projects. Their curiosity provides hope that the effects of this mission will be felt long after the floats stop transmitting data.

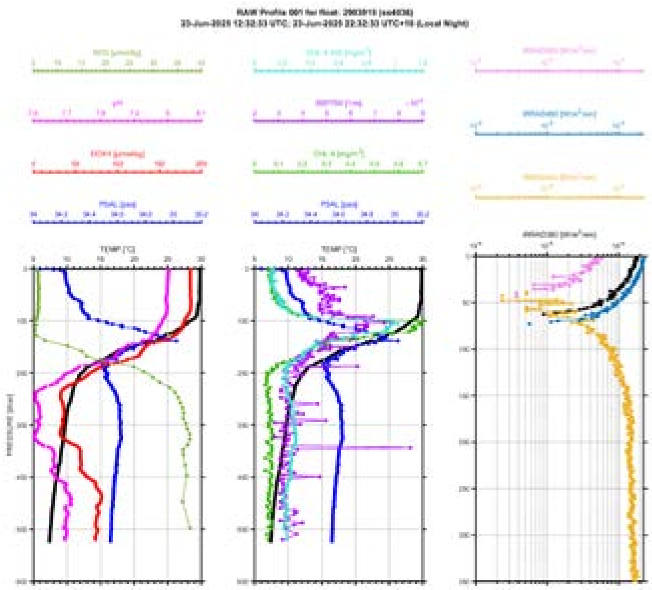


Figure 2. Plots of environmental data collected during the first profile of one of the Argo floats deployed during the NA172 expedition. Environmental data includes 14 different parameters, each of which was measured between the ocean surface and a depth of 520 meters (image credit: Global Ocean Biogeochemical Array).

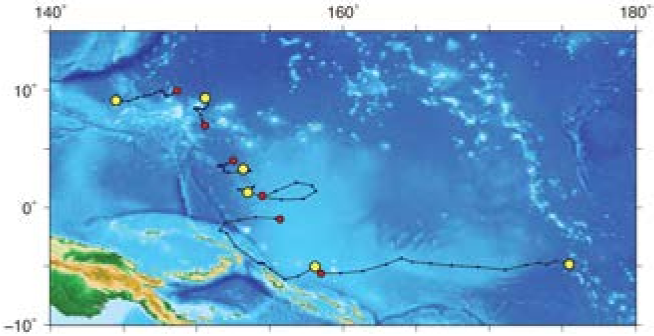


Figure 3. Map showing the location of the six Argo floats deployed during the NA172 expedition, which transited from Guam to Honiara. Red dots show the location each float was deployed in late June 2025, and yellow dots show the location of those floats by November 24, 2025 (image credit: Global Ocean Biogeochemical Array).

THE OCEAN THAT CONNECTS US:

THE VALUE OF RECORDING SEABIRD AND SURFACE MARINE ACTIVITY AT SEA

Chris Gaskin and Karen Baird

While E/V *Nautilus* is dedicated to mapping and exploring the deep sea, transit operations between expedition ports offer a unique opportunity to monitor oceanic activity at the sea surface. In response to just how little we know about at-sea distributions of many seabird species, two trained seabird observers participated in dedicated observational research during E/V *Nautilus* transit operations both during the 2024 and 2025 E/V *Nautilus* seasons. The resulting observations highlight that observational data can be extremely useful, provided that sufficient detail is collected to ensure accurate identification of species. Most seabird researchers focus on tracking seabirds using remote technologies; however, at-sea surveys have the added value of observing the seabirds themselves, their foraging associations and behaviours (Figure 1), and linking that with their exact place and time of observation.

Figure 1. Red-footed booby in pursuit (and catching) a flying fish (image credit: Karen Baird).

Above. Dark and light morph Wedge-tailed Shearwaters documented during the NA172 expedition (image credit: Karen Baird).

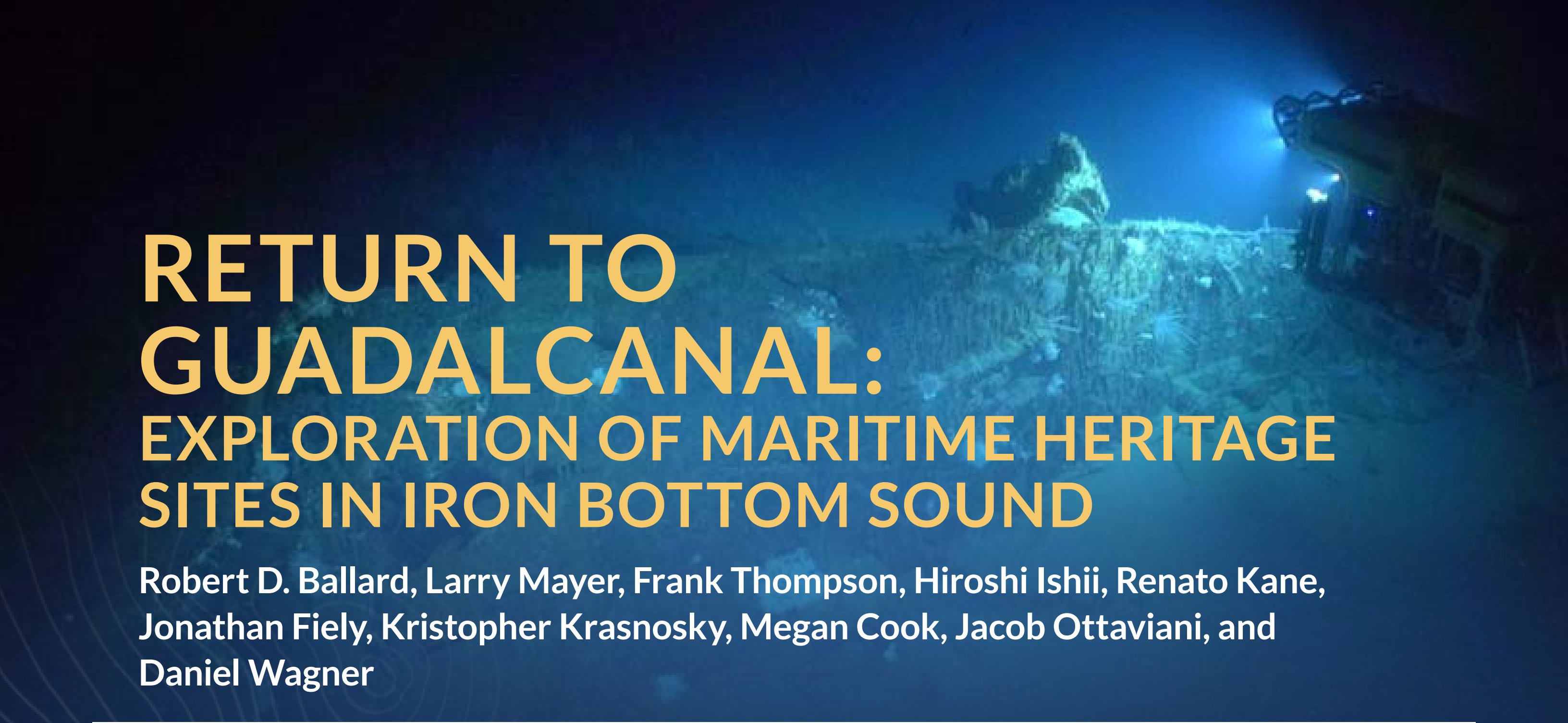
Figure 2. Crested tern and flying fish documented while E/V *Nautilus* transited through the waters of the Solomon Islands (image credit: Chris Gaskin).

In addition to seafloor mapping and Argo float deployments (see Miller in this report), the seven-day transit from Guam to the Solomon Islands during the NA172 expedition included topside surveys on the abundance and diversity of seabirds and other marine animals. Surveys were conducted during daylight hours for a cumulative time of 90 hours, during which we documented over 631 individuals from 11 species of seabirds.

Noteworthy records included Bulwer's Petrels venturing south from islands to the north and west of Guam; large numbers of Wedge-tailed Shearwaters with two colour morphs mixing together indicating origins north and south of the region; and tropical species from islands within the region—frigatebirds, boobies, tropicbirds, noddies, and terns (Figures 2–3). Furthermore, the topside fauna surveys documented cetaceans including sperm and short-finned pilot whales, and large schools of tuna.

At-sea observations play an important role in improving understanding of seabird distribution and behavior, particularly in remote oceanic regions where data are limited. Accurate identification is essential, and observers are encouraged to document sightings with as much detail as possible, including physical characteristics, behavior, and environmental context. When feasible, photographs provide valuable records that can be examined and verified after the expedition. Sharing these observations further increases their scientific value by allowing them to contribute to broader datasets. Platforms such as eBird and iNaturalist enable sightings collected at sea to be archived, validated, and made accessible to researchers and resource managers worldwide, helping to strengthen long-term monitoring and conservation efforts.

Figure 3. White-tailed tropicbird documented while E/V *Nautilus* transited through the waters of the Federated States of Micronesia (image credit: Karen Baird).



RETURN TO GUADALCANAL:

EXPLORATION OF MARITIME HERITAGE SITES IN IRON BOTTOM SOUND

Robert D. Ballard, Larry Mayer, Frank Thompson, Hiroshi Ishii, Renato Kane, Jonathan Fiely, Kristopher Krasnosky, Megan Cook, Jacob Ottaviani, and Daniel Wagner

BACKGROUND

In 1991–1992, the senior author of this article carried out two expeditions to Iron Bottom Sound off the Solomon Island of Guadalcanal to search for warships lost during the naval battles that took place between August 7, 1942–February 9, 1943. The first of these expeditions was exploratory in nature using a chartered Australian transport ship named the *Restless M*, which was outfitted with a towed side-sonar and a crude 35-millimeter camera sled with lights. The expedition took place during three weeks in 1991 and successfully located 10 warships, three of which were also imaged, including the Australian heavy cruiser HMAS *Canberra*, the Japanese destroyer IJN *Yūdachi* and the American light cruiser USS *Atalanta*.

The second expedition took place between July 22–August 9, 1992 using the US Navy deep submersible *SEA CLIFF*, its ROV *SCORPIO*, and its deep-towed side-scan sonar, all of which were deployed by their support boat M/V *Laney Chouest*. Using these assets, we were able to relocate, image, and identify the ten warships found the previous year, including HMAS *Canberra*, IJN *Yūdachi*, USS *Atalanta*, USS *Quincy*, USS *Northampton*, USS *Cushing*, USS *Barton*, USS *Monssen*, USS *Laffey*, and USS *DeHaven*. Furthermore, we were also able to find two additional warships, including the Japanese battleship IJN *Kirishima* and an American destroyer that was either USS *Little* or USS *Gregory*.

In February of 2015, a subsea operations team of Paul Allen's company, Vulcan Inc., conducted an expedition aboard the yacht *Octopus* to Iron Bottom Sound. Using a Bluefin AUV equipped with an EdgeTech 2205 side-scan sonar, as well as the ship's ROV system, the team relocated many of the ships that were imaged previously, as well as found USS *Vincennes* and USS *Astoria* for the first time. In 2018, the Vulcan team returned to the Solomon Islands, this time aboard R/V *Petrel*, locating the wrecks of the IJN *Hiei* and IJN *Furutaka* in Iron Bottom Sound, as well as several other warships in other areas of the Solomon Islands. Despite these historic surveys, several dozen warships lost in the deep waters of the Iron Bottom Sound during the Battles of Guadalcanal remained to be found.

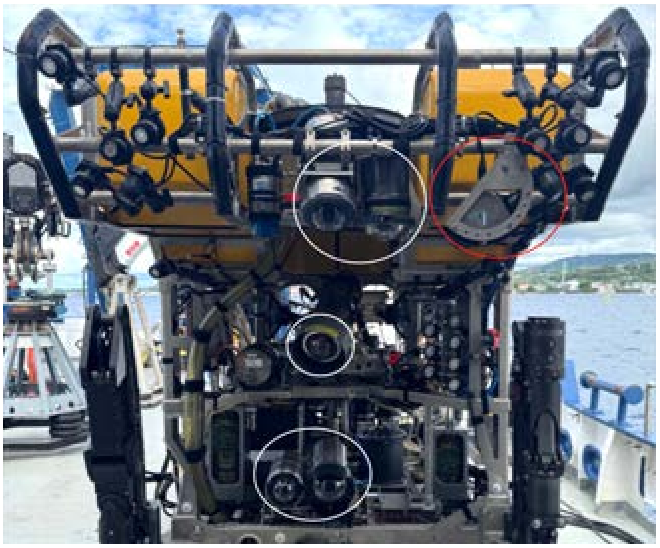


Figure 1. The front of ROV *Hercules* showing its many cameras, video lights, and sensors. Its high-resolution imaging systems are highlighted with white circles and the Norbit multibeam sonar is shown with a red circle.

Above. Photograph of the bow section of the USS *New Orleans*, which was discovered during the NA173 expedition for the first time.

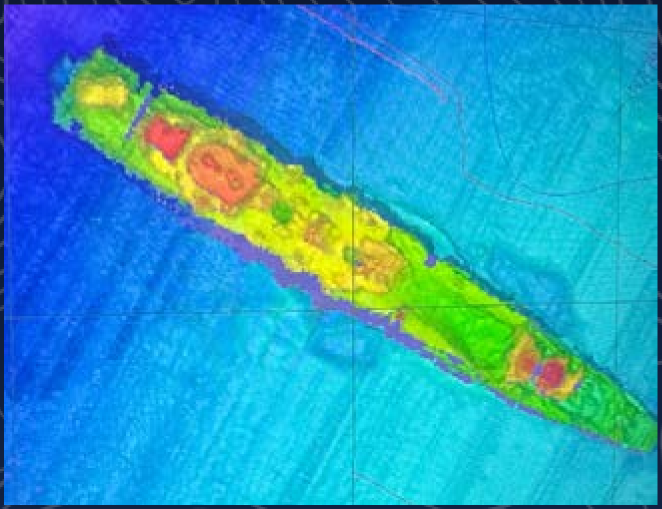


Figure 2. High-resolution multibeam data collected by the Norbit Wideband Multibeam Sonar mounted on ROV *Hercules* over the wreck of the USS *Vincennes*.

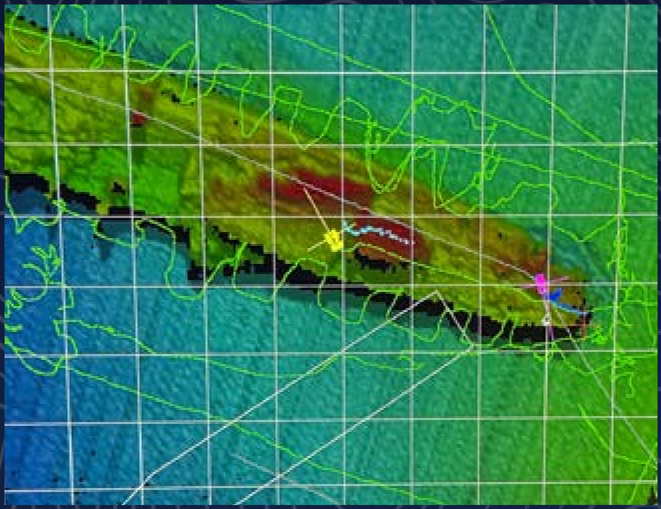


Figure 3. Map showing the typical ROV *Hercules* tracks (green lines) conducted to complete systematic imaging surveys of warships in Iron Bottom Sound during the NA173 expedition.

E/V *NAUTILUS* EXPEDITION NA173

In July 2025, the Ocean Exploration Trust and the University of New Hampshire Center for Coastal Ocean Mapping led an expedition to Iron Bottom Sound with funding support from the NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute. The primary purpose was to continue the documentation of the warships that had already been found, as well as locate additional shipwrecks. The main asset used to locate the potential maritime heritage sites was the autonomous surface vehicle *DriX* from the University of New Hampshire Center for Coastal and Ocean Mapping (see Schmidt et al. in this report). Using the data collected by the EM 712 multibeam sonar of *DriX*, 112 potential targets were identified, about a quarter of which were visually surveyed via ROV.

Once particularly promising targets were identified in the mapping data collected by *DriX*, ROV-based surveys were conducted using E/V *Nautilus*' dual-body ROV system, consisting of the main ROV *Hercules* and Towsled *Atalanta*. For this purpose, ROV *Hercules* was equipped with all of its standard sensors, in addition to various acoustical and optical imaging systems, including the Norbit Wideband Multibeam Sonar, and several high-resolution video cameras (Figure 1).

Six ROV dives were conducted during the NA173 expedition totaling 138 hours, during which over 56 kilometers of seafloor were surveyed to maximum depths of 1,030 meters. ROV surveys began with a 50 meter altitude survey during which targets were mapped using the ROV-mounted Norbit multibeam sonar (Figure 2), followed by close-up imaging surveys using the ROV's video cameras. During these imaging surveys, ROV *Hercules* was systematically moved across the entire periphery of each wreck using the overhead view provided by Towsled *Atalanta*, as well as the previously-collected Norbit multibeam data, for obstacle avoidance. Once the entire periphery of each wreck was imaged, ROV *Hercules* ran a series of camera runs down the axis of the ship to complete the imaging survey (Figure 3).

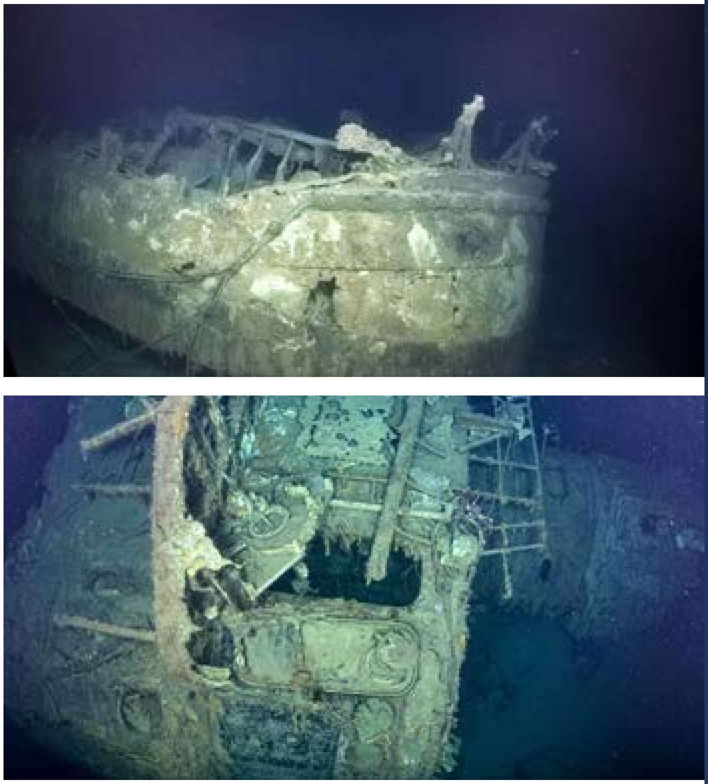


Figure 4. World War II shipwrecks in Iron Bottom Sound that were imaged for the first time as part of the NA173 expedition, including the IJN *Teruzuki* (above) and USS *Walke* (below).

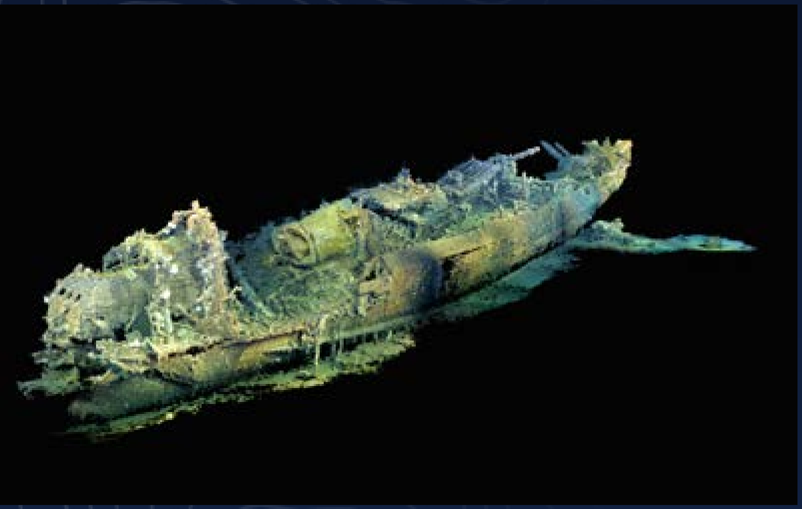


Figure 5. Three-dimensional reconstruction of the USS *DeHaven*, one of the 13 shipwrecks that was imaged during the NA173 expedition to Iron Bottom Sound.

Figure 7. NA173 Communications lead Megan Cook and Expedition Lead Scientist Dr. Robert Ballard hosting a ship-to-shore interaction from the broadcast studio on the E/V *Nautilus*.

Using these methods, 13 maritime heritage sites were comprehensively surveyed during the NA173 expedition (Figure 4), including two that were found for the first time (bow section of USS *New Orleans* and IJN *Teruzuki*), one that was imaged for the first time (USS *Walke*) and ten that had only partially been imaged prior to this expedition (USS *Vincennes*, USS *Astoria*, USS *Quincy*, USS *Northampton*, USS *DeHaven*, USS *Laffey*, USS *Preston*, IJN *Yūdachi*, HMAS *Canberra*, and an unidentified small pontoon boat). These acoustical and optical data sets were then combined to produce high-resolution, three-dimensional reconstructions of each shipwreck (Figure 5). In addition to the 979 square kilometers of seafloor mapped by *DriX* during the NA173 mission, the EM 302 multibeam sonar of E/V *Nautilus* was also used to map 5,280 square kilometers of seafloor in and around Iron Bottom Sound (Figure 6).

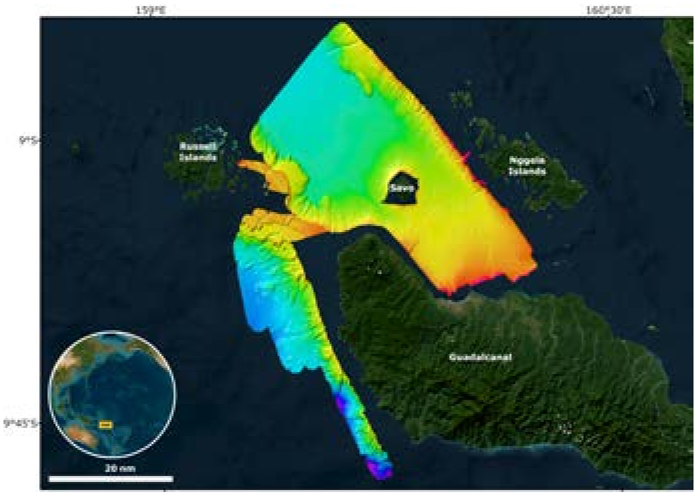


Figure 6. Map showing the locations mapped in and around Iron Bottom Sound using the EM 302 multibeam sonar on E/V *Nautilus*.

In addition to scientific exploration, the NA173 expedition included numerous outreach activities to share the mission's findings with audiences around the world. Over the course of the expedition, live-stream video feeds received 307,153 views, and highlight videos garnered 285,927 views. Expedition content on Ocean Exploration Trust's social media channels attracted over 3.84 million impressions. The team created 18 highlight videos summarizing the many accomplishments of the expedition, in addition to five blogs and three photo albums, all of which were posted on the expedition webpage on Nautilus Live. Additionally, the team hosted 47 live ship-to-shore interactions from the onboard broadcast studio, reaching over 2,150 people across the Solomon Islands, 13 US States, and four other countries. As of March 2026, expedition results have been featured in 582 media stories published in 59 countries and in 29 different languages.

The many accomplishments of this multidisciplinary expedition were made possible thanks to the expertise and collaboration by many partners, including NOAA Ocean Exploration, US Naval History and Heritage Command, Solomon Islands National Museum, University of New Hampshire, University of Rhode Island, and Japanese, Australian, New Zealand, and Solomon Islands colleagues, among many others. Funding for E/V *Nautilus* shiptime and *DriX* operations was provided by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute. The Office of Naval Research provided additional support for the field testing of acoustic and imaging systems, as well as the educational programs.

COOPERATIVE EXPLORATION IN IRON BOTTOM SOUND

Val Schmidt, Larry Mayer, KG Fairbarn, Avery Muñoz, Andy McLeod, Skylar Voglar, Nathan Hall, and Basile Rose

In the summer of 2025, the University of New Hampshire embarked on an expedition to the Solomon Islands to explore Iron Bottom Sound, the storied site of the World War II Battles of Guadalcanal. In close collaboration with E/V *Nautilus*, the US Navy, and Japanese and other naval historians, the NA173 expedition sought to locate and characterize the many shipwrecks that resulted from a series of conflicts between the Japanese and US forces beginning in August 1942 and extending to February 1943, as each side attempted to take control of Guadalcanal Island (see Ballard et al. in this report).

In support of the expedition, the University of New Hampshire team deployed the uncrewed surface vessel *DriX*. Manufactured in La Ciotat, France by Exail (then iXblue). *DriX* is a 7.7-meter-long, 0.8-meter-wide, uncrewed and remotely operated surface vessel purpose-built for seafloor mapping. It is equipped with a Kongsberg EM 712 mid-range multibeam echosounder for seafloor mapping, a PHINS with Septentrio GPS for precise navigation, and Starlink low-earth-orbit satellite radio system for primary communications.

DriX was primarily operated from shore in Honiara, the Solomon Islands' capital city, which enabled the E/V *Nautilus* to deploy its remotely operated vehicles without operational conflict. The University of New Hampshire team established a remote operating center in the conference room of a local hotel (Figure 1), with shore-side Starlink systems to augment the hotel's own internet service. Through their respective Starlink systems, the *DriX* and the remote operating center ashore were connected to a cloud-based server to facilitate the transfer of operational and mapping data during deployments.

Working in this unique setting, shore logistics were complex, but through the creativity of the University of New Hampshire team and the superb help of Debbie Lukisi, a local coordinator, all worked out well. Arrangements were made to moor the *DriX*'s universal deployment system within the partial protection of

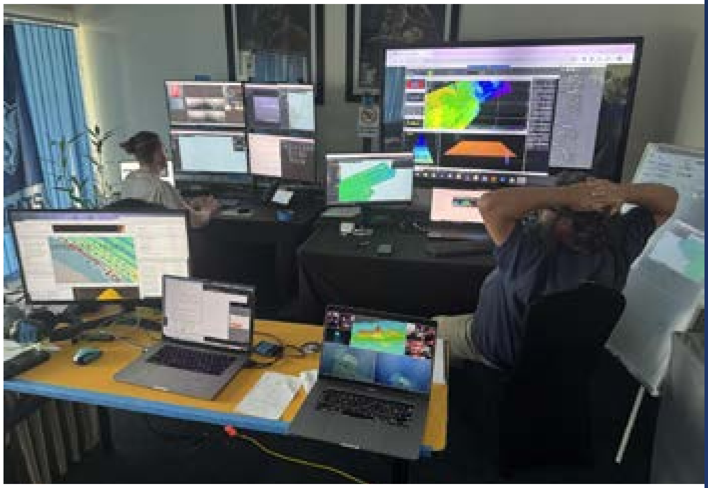


Figure 1. The University of New Hampshire team controlling *DriX* from the remote operations center in Honiara, while E/V *Nautilus* ROVs simultaneously investigate targets identified in mapping data collected by *DriX* the day prior.

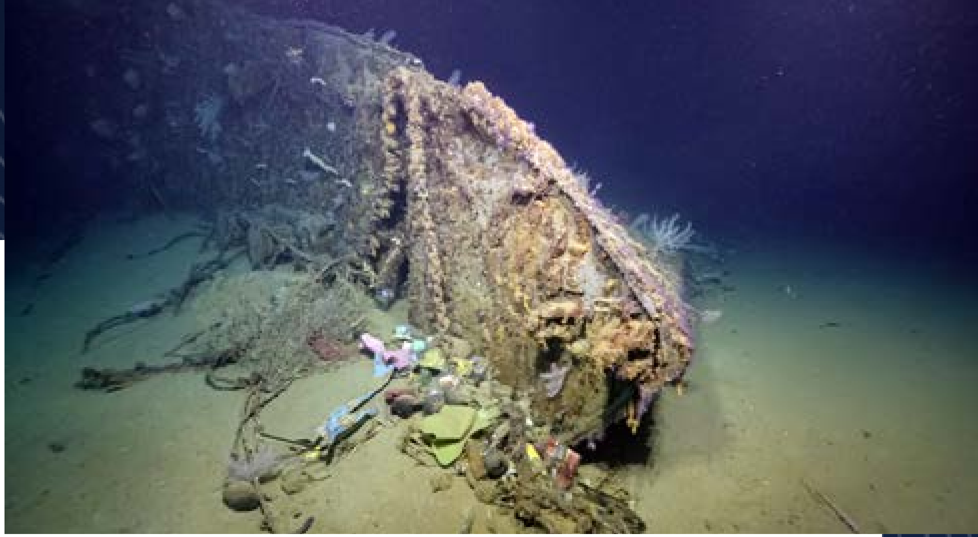


Figure 2. Photograph of the bow section of the USS *New Orleans*, which was located using mapping data collected by *DriX* and then visually surveyed using E/V *Nautilus*' ROVs.

a jetty surrounding a local boat ramp adjacent to the hotel. Shore electrical service was provided by a rented generator, when necessary on the jetty. Refueling was accomplished by fueling both tanks of a rented, diesel Land Rover SUV at local fuel stations and then transferring that fuel by pump to the *DriX* while moored along the shore. Spares and other support gear were stored either in a 20-foot container delivered to the parking lot of the hotel for our use, or simply under a shore-side pop-up tent. A twenty-four-hour watch was employed to provide security to the vehicle and gear, as the site provided no provision for physical security.

In the first few days of deployment, the team used known shipwreck sites to establish a mapping protocol. Most of Iron Bottom Sound ranges from 500–1000 meters in depth. At 500 meter depth, the footprint of the *DriX* nadir beam is 8.5 meters, growing in size for beams steered athwartships. When set in a typical swath mapping configuration with a 130-degree swath and equal-distant soundings, the across-track sounding spacing would range from 5–10 meters in these water depths. It was quickly realized that this configuration would be unsuitable for detection of shipwrecks whose beam was sometimes no more than 20 meters across. Instead, the multibeam swath was narrowed to between 50 and 70 degrees, increasing the density of soundings to approximately one per 2-meter interval. Given the complexity of the seafloor in the region, backscatter was found to provide little to no useful information in locating wrecks.

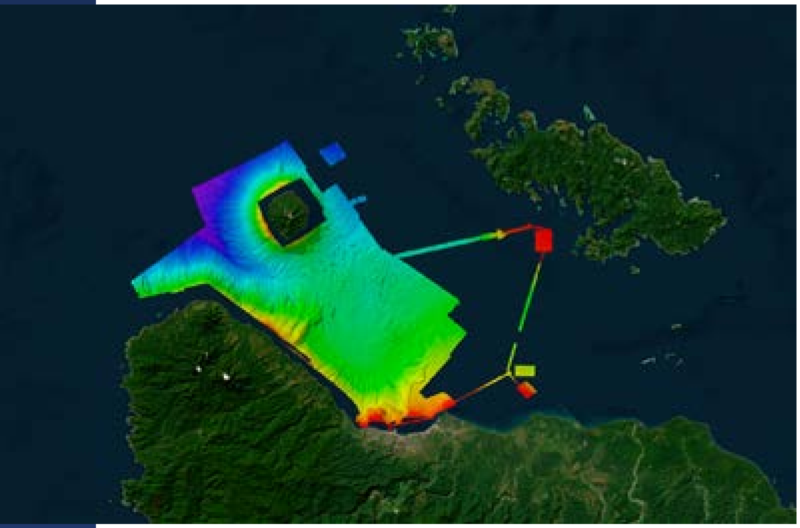
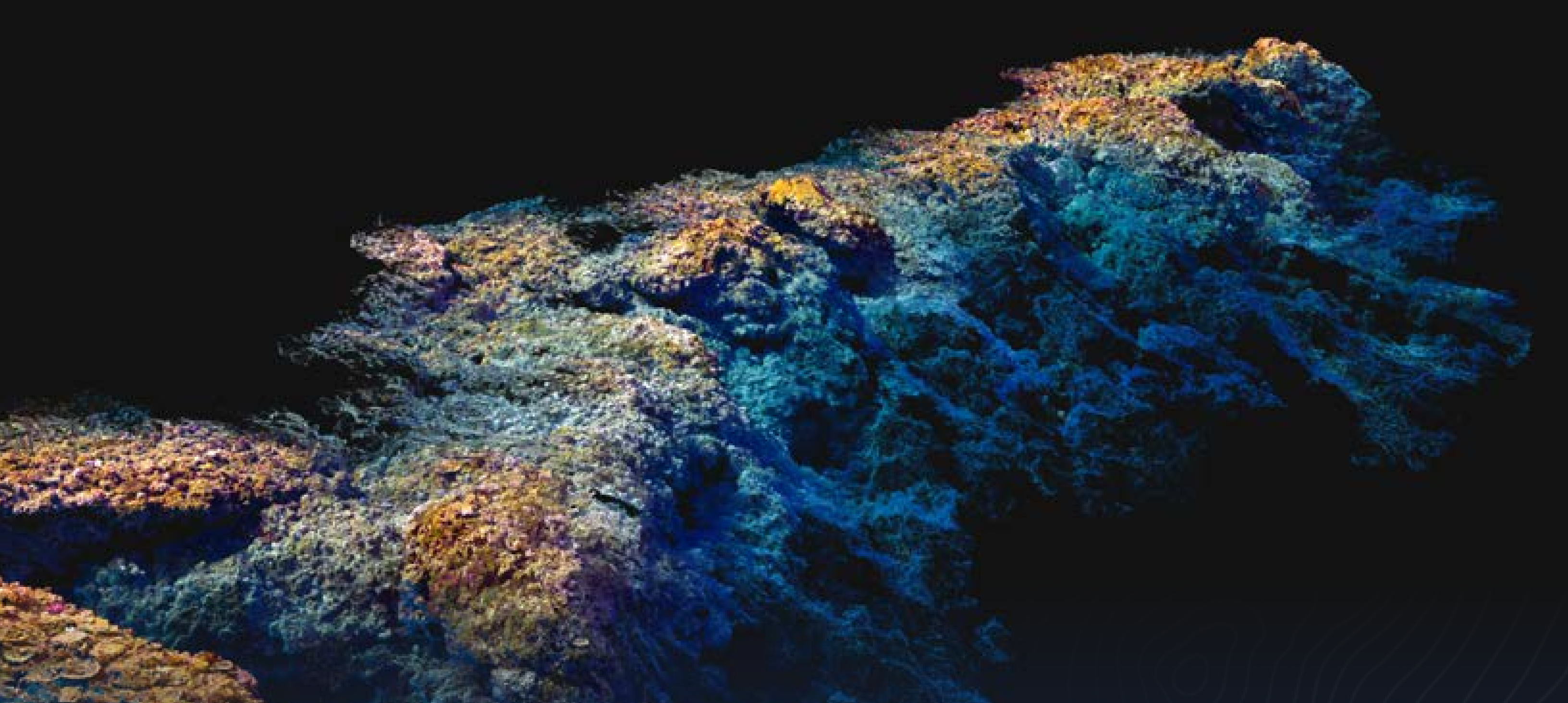


Figure 3. Map showing seafloor areas mapped using the EM712 multibeam sonar on *DriX* during the NA173 expedition to Iron Bottom Sound.

As data was collected, it was transferred via the *DriX* Starlink to a server located at the University of New Hampshire campus in Durham, New Hampshire via an automated process in roughly 10-minute intervals. The server at University of New Hampshire provided an off-site backup of the raw data. A subsequent process then replicated the data automatically to both the remote operating center in Honiara and to a server aboard E/V *Nautilus*. While primary processing occurred at the remote operating center, these data transfers facilitated real-time collaboration between ship and shore teams. Candidate targets for exploration were identified in the *DriX* mapping data and communicated to the shipboard personnel, who then planned a series of proximate sites for exploration to maximize bottom time for each ROV deployment. This operational model allowed the exploration process to be carried out with tremendous efficiency—with *DriX* searching for the next potential target while E/V *Nautilus*' ROVs explored a previously detected one. After completing a visual survey, the ROVs could then proceed immediately to the next potential target, often without being recovered. Highlights from this collaborative work included identifying the bow of the cruiser USS *New Orleans* (Figure 2), which was detected in one of our first deployments (see Ballard et al. in this report). The *DriX* team later identified an enigmatic target from a scant series of data, which visual ROV surveys later identified as the Imperial Japanese Navy destroyer *Teruzuki*. The final resting place of this vessel too had been unknown. *DriX* was deployed for a total of 380 hours over the course of the expedition, during which it mapped 979 square kilometers of seafloor in Iron Bottom Sound (Figure 3).



ULTRA-HIGH RESOLUTION MAPPING AND IMAGING OF SHALLOW-WATER HABITATS IN THE SOLOMON ISLANDS

Kristopher Krasnosky, Jonathan Fiely, and Jason Gulley

INTRODUCTION

During the NA173 expedition to the Solomon Islands, our team conducted a series of shallow-water surveys, complementing deep-water explorations by E/V *Nautilus*, its ROVs (see Ballard et al. in this report), and uncrewed surface vehicle *DriX* (see Schmidt et al. in this report). Using M/V *Berry Ferry*—the dive boat tender of the yacht M/Y *Wildberry*—we explored nearshore environments unreachable by larger vessels. These surveys formed a key component of the Ocean Exploration Trust's broader effort to integrate deep-water surveys, autonomous systems, and nearshore mapping into a unified understanding of the region's maritime heritage. Our work combined high-resolution acoustic mapping, precise geodetic positioning, and optical imaging to produce detailed reconstructions of complex underwater environments. The optical and acoustic imaging systems deployed during this effort were developed and tested with support from the Office of Naval Research. This included an R2Sonic 2020v+ multibeam sonar mounted on a dive boat, three-camera arrays mounted on diver propulsion vehicles, and integrated ROS2-based processing workflows designed to enable real-time data fusion. The Solomon Islands deployment represented a critical field validation of these technologies.

FIELD SITES

Over the course of 21 multibeam surveys and 19 SCUBA dives, the team comprehensively surveyed four sites that were both historically significant and ecologically interesting. The known wreck of a World War II-era PBY Catalina flying boat located off Florida Island served as an important test environment for the project by providing an ideal benchmark for evaluating the performance of the multibeam at different frequencies (Figure 1). The shallow-water waters adjacent to one of the most historically significant airfields of the Pacific Theater, Henderson Field, and its very dense aggregation of submerged artifacts were key to helping refine survey methodologies.

Above. Optical reconstruction of the coral reef shelf off Kovuhiko island, developed using the ultra-high resolution optical and acoustic datasets collected as part of this mission.

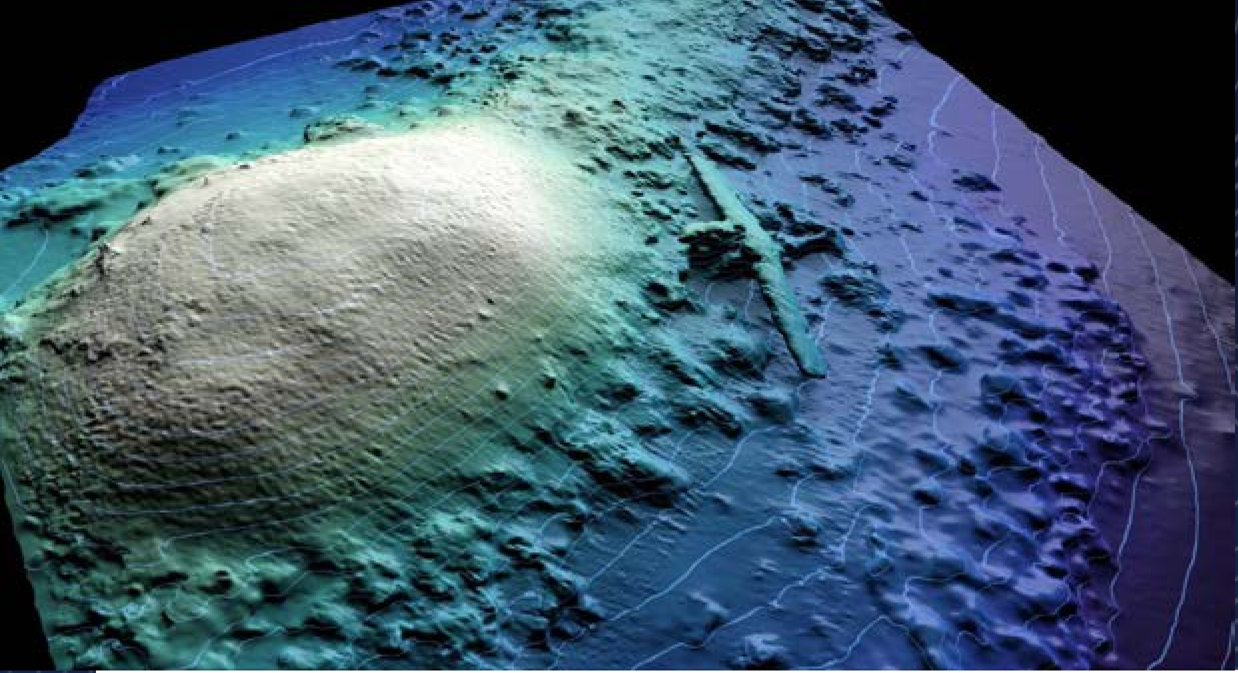


Figure 1. PBY Catalina wreckage in 30 meters of water surveyed at 700 kilohertz (image credit: Kristopher Krasnosky, Seaward Science).

Surveys here identified many structures consistent with pontoon barges, construction debris, and geomorphic features associated with wartime shoreline modification (Figure 2). The dramatic vertical reef formations on a shallow-water seamount in Iron Bottom Sound, a well known dive site known as Twin Tunnels, provided a good contrast to the other sites, as well as yielded one of the expedition's most unexpected discoveries, an unknown shipwreck (Figure 3). Finally, the complex reefs around Kovuhika Island served as the main site to demonstrate all the survey methods in action (Figures 4–5). Over the course of five days of mapping and 13 SCUBA dives, the team comprehensively surveyed this complex terrain.

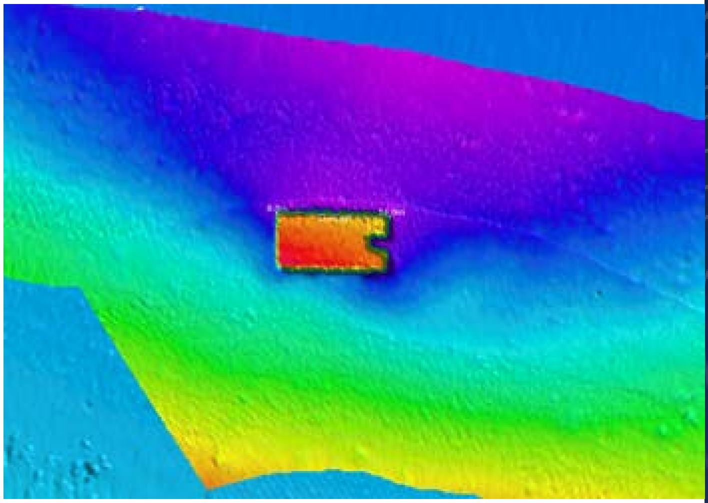


Figure 2. Detail of one of four Seabees pontoon barges discovered during the survey near Henderson Field (image credit: Kristopher Kransosky, Seaward Science).

FIELD SURVEY METHODS

M/V *Berry Ferry* served as the agile shallow-water survey platform. Its shallow draft and ability to safely maneuver through complex terrain allowed the team to access nearshore sites that are unreachable by larger vessels. Despite its compact footprint, M/V *Berry Ferry* carried a full-featured survey suite centered around an R2Sonic 2020v+ multibeam. The system was deployed on a universal sonar mount, allowing rapid installation, safe transport, and repeatable alignment throughout the mission. The sonar operated across its broadband range, using a 400 kilohertz frequency for wide-area search, and 700 kilohertz for ultra-high resolution characterization. Precise navigation and motion compensation were achieved through a dual-antenna PPP GNSS system for robust heading and geodetic accuracy, integrated motion reference unit for vessel-motion stabilization, and Marinestar PPP satellite corrections providing consistent centimeter-level positioning.

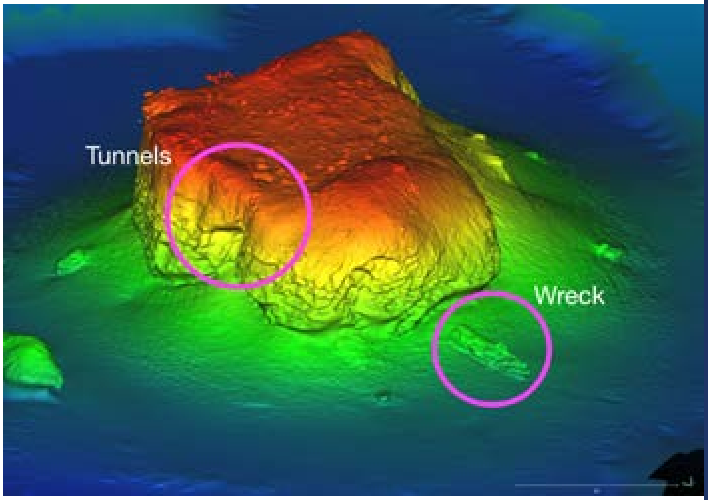
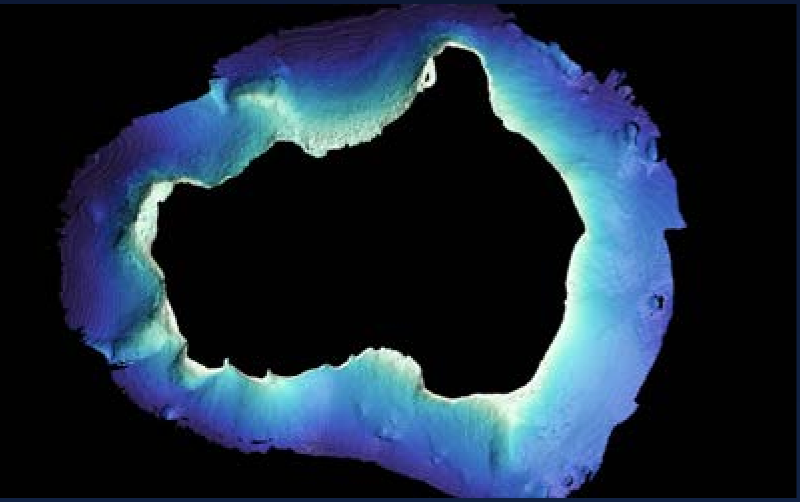


Figure 3. Multibeam survey of the Twin Tunnels site at 40 kilohertz displaying the namesake tunnels and the discovered shipwreck, which was too deep to access via SCUBA divers (image credit: Kristopher Kransosky, Seaward Science).



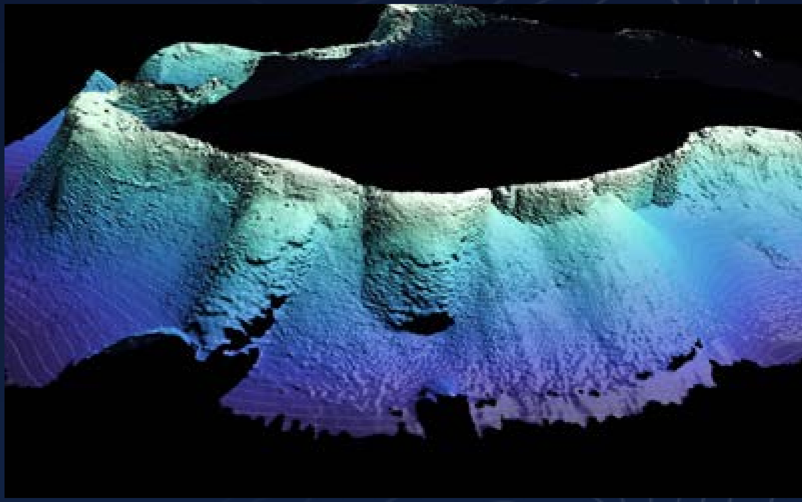


Figure 4. Multibeam survey of Kovuhika island at 400 kilohertz. Perspective view (right) illustrates the ability to capture vertical structure (image credit: Kristopher Kransosky, Seaward Science).

After targets were mapped using the multibeam, SCUBA divers were deployed with SEACRAFT Freedom diver propulsion vehicles equipped with a newly developed three-camera imaging array (Figure 6). The system was designed to be similar to the Widefield Camera Array deployed on ROV *Hercules*, enabling comparable high-resolution optical data collection in shallow-water environments. Each camera system housed two Sony ILX-LR1 61-megapixel cameras, 5-axis inertial measurement units, and synchronization systems. The systems were designed for rapid collection of photogrammetry at landscape scales, with divers working in tandem to collect georeferenced imagery. The SEACRAFT Freedom scooters, equipped with advanced navigation consoles, guided precise underwater survey tracks during data collection, providing up to six hours of endurance when equipped with the camera payload. Real-time diver positioning was enabled by a SubSonus diver tracking system, which allowed the support vessel to record the location of the divers via rechargeable transponders attached to SCUBA tanks. These tracking data were used to georeference photogrammetry models during post-processing, with transponder tags also left underwater to relocate notable features identified during dives.

DATA PROCESSING AND VISUALIZATIONS

The acquisition, monitoring, and reconstruction of multibeam data was performed using Acoustic Explorer, a new software package developed in partnership with Seaward Science and field-deployed for the first time during this project. Built on the underlying capabilities of Seaward Sciences's existing RoShip marine-robotics integration framework, Acoustic Explorer was designed to streamline small-vessel workflows, strengthen quality control and enable high-resolution visualization optimized for high-frequency multibeam data.

Figure 5. Dive sites at Kovuhika island provided a rich variety of benthic features and high biodiversity for our scooter-based camera systems. This image shows a large cavern imaged with the optical array (image credit: Jonathan Fiely, Wild Technologies).

Figure 6. The scooter-based three-camera optical array, designed in partnership with Wild Technologies, was used for rapid imaging across underwater transects (image credit: Jason Gulley).

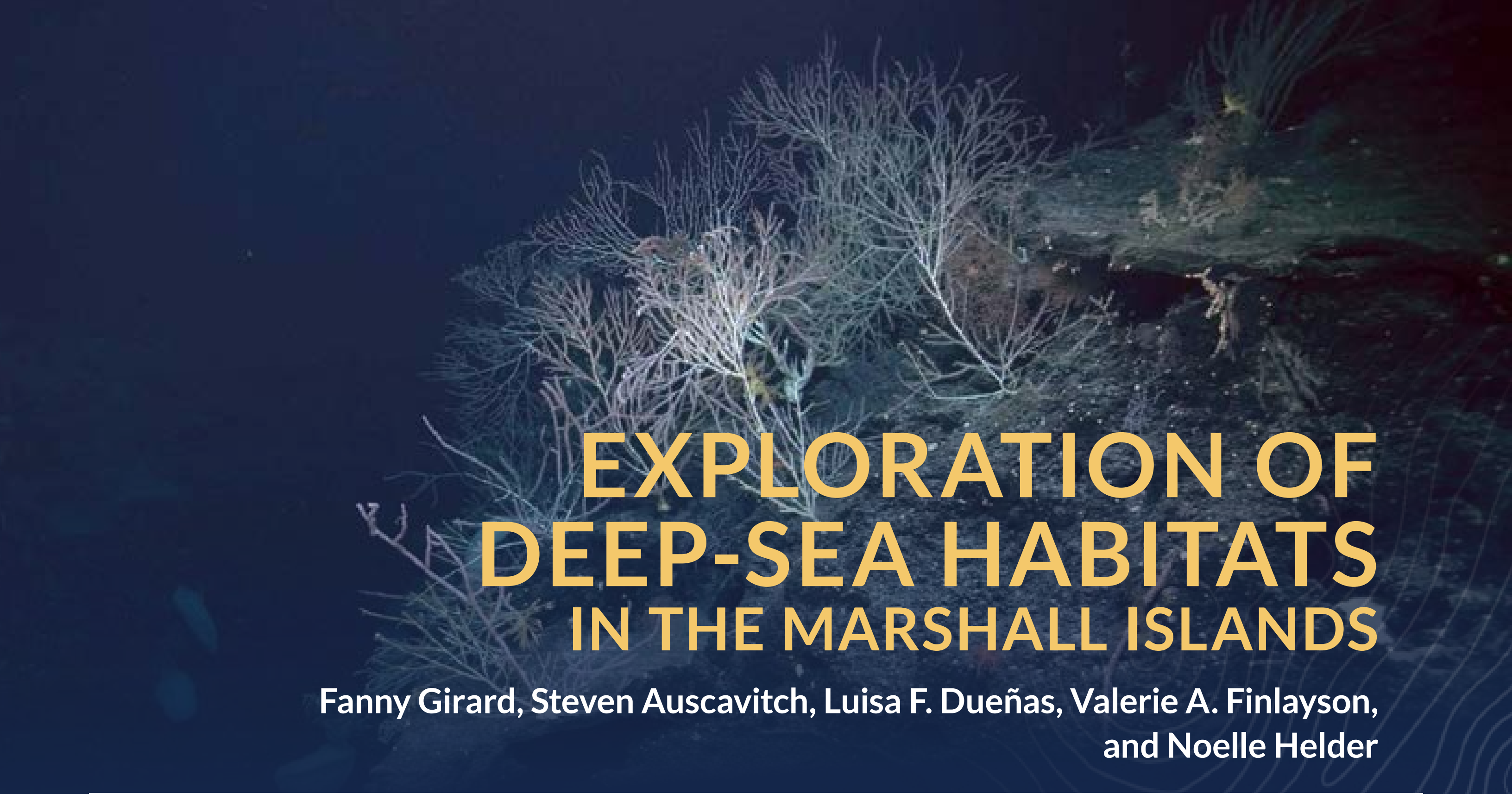
Imagery collected by the underwater cameras was processed in RealityCapture to generate photogrammetric reconstructions. Diver tracking data from the SubSonus system enabled georeferencing of the models during structure-for-motion processing. Models were exported in multiple formats to support different visualizations and analyses. Optical and acoustic datasets were aligned and compared in CloudCompare for quality assessment and geometric verification. This workflow enabled validation of acoustic bathymetry against high-resolution optical reconstructions and provided complementary data layers for comprehensive seafloor characterization. Final rendering of fused datasets was performed in a custom Unreal Engine environment, enabling qualitative comparison of acoustic and optical models and providing an interactive platform for site assessment. Models were also published to Cesium Ion to develop georeferenced visualizations accessible via web browser for collaborative analysis and stakeholder engagement.

CONCLUSION

The mission provided an important field demonstration of how agile platforms, modern multibeam systems, and integrated software workflows can unlock access to historically and ecologically significant nearshore environments, both in terms of allowing their exploration in the field, as well as visualizing these complex terrains to audiences far afield. By combining high-frequency multibeam sonar, diver-deployed optical imaging arrays and advanced photogrammetric reconstruction, the team documented known World War II sites, discovered previously unrecorded features, and established a scalable framework for future exploration. By combining acoustic multibeam reconstructions with close-range imagery, the program established hybrid workflows that leverage both sonar mapping and photogrammetric reconstruction techniques for comprehensive site documentation—extending the deep-water methodologies from ROV *Hercules* to accessible diver-based platforms in shallow-water environments.

This work would not have been possible without the generous support of Bill and Sheri Berry, who provided the M/Y *WildBerry*, M/V *Berry Ferry* (Figure 7), and the equipment necessary for safe SCUBA operations throughout this three-week expedition. Development and testing of the optical and acoustic imaging systems described in this report was supported by the Office of Naval Research.

Figure 7. M/V *Berry Ferry* in survey configuration with the pole and multibeam deployed (image credit: Kristopher Kransosky, Seaward Science).



EXPLORATION OF DEEP-SEA HABITATS IN THE MARSHALL ISLANDS

Fanny Girard, Steven Auscavitch, Luisa F. Dueñas, Valerie A. Finlayson, and Noelle Helder

Located in the heart of the Central Pacific, the Republic of the Marshall Islands is a vast island nation, with the ocean covering 98.9% of its territory. It is home to diverse deep-sea habitats, including more than 300 seamounts, island slopes, and deep-sea ridges, which are largely unexplored and unmapped. Between July 27–August 17, 2025, the Ocean Exploration Trust partnered with the Marshall Islands Marine Resources Authority to fill critical data gaps in the deep waters of the Marshall Islands. Funded by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, this expedition provided a unique opportunity to map, observe and sample deep-sea habitats across the Marshall Islands for the very first time. In particular, this expedition shed new light on the deep-sea ecosystems within the recently designated Bikar and Bokak National Marine Sanctuary, providing invaluable information for the management of one of the most pristine regions on our planet. Over the course of this expedition, over 31,000 square kilometers of seafloor were mapped for the first time, in addition to surveying eight previously unexplored seamounts during ROV dives between depths of 953–3,326 meters.

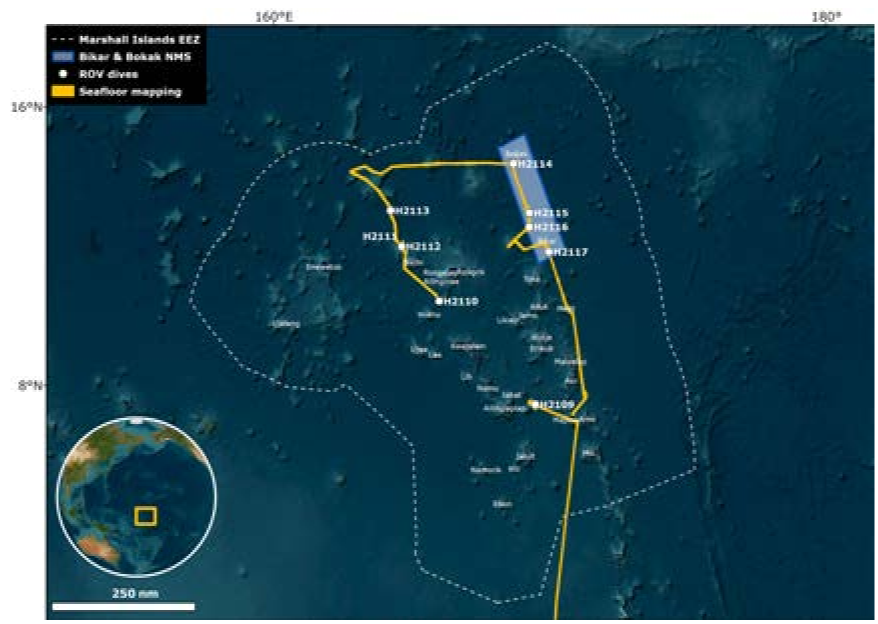


Figure 1. Map showing the locations of ROV dives and seafloor mapping operations conducted in the waters of the Marshall Islands during the NA174 expedition.

GEOLOGY

ROV dives were primarily focused on traversing the flanks of seamounts. The igneous substrate portions of these seamounts were coated in well-developed ferromanganese crusts that appeared to be several centimeters thick at a minimum, and likely much thicker. Ferromanganese nodules were common during several of the earlier dives (H2109–H2112) in the southwestern region of the Marshall Islands.

Figure 2. A fragmented lava suspended in lithified sediment. When exposed to UV light, the sediment phosphoresces, glowing green for several seconds. This brief glow in the dark effect tells us that the sediment is made out of calcite or a phosphate mineral.

A consistent morphological feature observed along with these thick crusts were tapered growth patterns on the sides of lava flows that gave the substrate an almost ledge-like appearance. This mature ferromanganese encrustation made collecting geological samples largely impossible, with the exception of the occasional loose pieces that were not encrusted to the seafloor. By contrast, dives within the Bikar and Bokak National Marine Sanctuary on the far northeastern side of the Marshall Islands surveyed seamounts that showed morphological evidence of modification by regional tectonic stresses that post-dated the main platform-building phases of volcanic activity. Rock samples collected from this region bore evidence of hydrothermal mineralization—minerals formed by hot fluids moving through the lava—that could be linked to this regional tectonic activity, as this alteration style was only observed within the Sanctuary and not in the surrounding areas.

Regardless of dive depth, most of the substrate surveyed during this expedition was volcanic. In the southern and western volcanoes, any carbonate caps are limited to shallower depths, and are likely less than 500 meters thick. This is consistent with previous findings from the region with only ~200 meters of pelagic sediments and fossiliferous carbonates documented along the summit of Wōdejebato Guyot. Our dive on Wodejebato (H2112)—a large guyot complex northwest of Bikini Atoll—surveyed up to a minimum depth of about 1550 meters, and did not observe a basalt-to-carbonate transition, further confirming the limited extent of carbonate formation atop this feature. By contrast, within the Bikar and Bokak National Marine Sanctuary we encountered much thicker carbonate caps: a distinct change from the igneous substrates consistently encountered during earlier dives. This included a dive transect (H2115) that started ~2,000 meters deep that was entirely within the carbonate section of Ļōkōto-Nōrnōr Seamount with no observations of obvious intercalated lava flows.

Taken together, these observations suggest some rough geographic boundaries within the Marshall Islands waters based on where various geological resources (e.g., ferromanganese nodules), carbonate cap changes (e.g., depth of transition from volcanic basement), and secondary regional tectonic (or tectonomagmatic) processes shape the geological diversity. Although refining these regions will require follow-up surveys, this expedition provided unique insights into the geological setting of this greatly undersampled region.

Throughout the expedition, we collected a total of 29 geological samples across all ROV dives. Lithologies recovered include basalts of various types, marine sandstones, ferromanganese nodules, hyaloclastites, and carbonates/phosphates, showcasing the diverse geological setting of this undersampled region. To help refine the identification of sedimentary and chemosedimentary samples (e.g., marine sandstones, phosphates, and carbonates), as well as identify potential secondary alteration processes, we used a simple field UV light to check for phosphorescence, which showed promising results (Figure 2). This technique is non-destructive, relatively inexpensive, and shows potential for further field development. Most of the basalts and some of the marine sandstones were further subsampled for future geochemical and geochronological analysis that will help constrain the timing and provenance of the surveyed volcanoes.

Figure 3. Deep-sea coral habitats encountered in the Marshall Islands include a mixed assemblage of deep-sea corals and glass sponges (left) and a high density community of *Ramuligorgia militaris* gorgonian corals and bamboo corals (right).

BIODIVERSITY

As is common on seamounts across the Pacific, deep-sea octocorals and sponges were the main habitat-forming taxa observed in the Marshall Islands (Figure 3). While densities were variable, with relatively low faunal densities observed during the deepest dives, species diversity was generally high. Observed species varied along depth gradients and, although genetic analysis will be required to confirm species identifications (see Govindarajan and Auscavitch in this report), many coral and sponge taxa observed during this expedition have been documented in other parts of the Central Pacific. Notably, high-density and high-diversity coral communities were observed on multiple seamounts, including a thriving community on Ļōkōto-Nōrnōr Seamount in the Bikar and Bokak National Marine Sanctuary. The analysis of video footage, including standardized video transects and three-dimensional reconstructions of the seafloor using photogrammetry, will shed light on biodiversity patterns found in the Marshall Islands.

POTENTIAL NEW SPECIES DISCOVERIES

Given the vastness of the deep sea and the small proportion that has been explored, the likelihood of discovering new species is high. To document the biodiversity associated with the seamounts of the Marshall Islands, specimens of the representative organisms from these communities were collected. Specifically for octocorals, 33 collections were made at depths between 971–3,055 meters, within which the families Primnoidae, Keratoisididae, Chrysogorgidae, Corallidae, Victorgorgiidae, and Umbellulidae were recorded.

Preliminary observations of the octocoral samples suggest the presence of several new species, including one specimen of the genus *Calyptrophora*, one of the genus *Sibogagorgia*, and two of the genus *Paragorgia*, both of which likely belong to the same species (Figure 4). These corals were identified from their notably unique growth forms and sclerites when observed through light microscopy on board the vessel. Additional analyses using scanning electron microscopy and molecular confirmation methods are currently underway to verify their status as a new species before writing up their official descriptions.

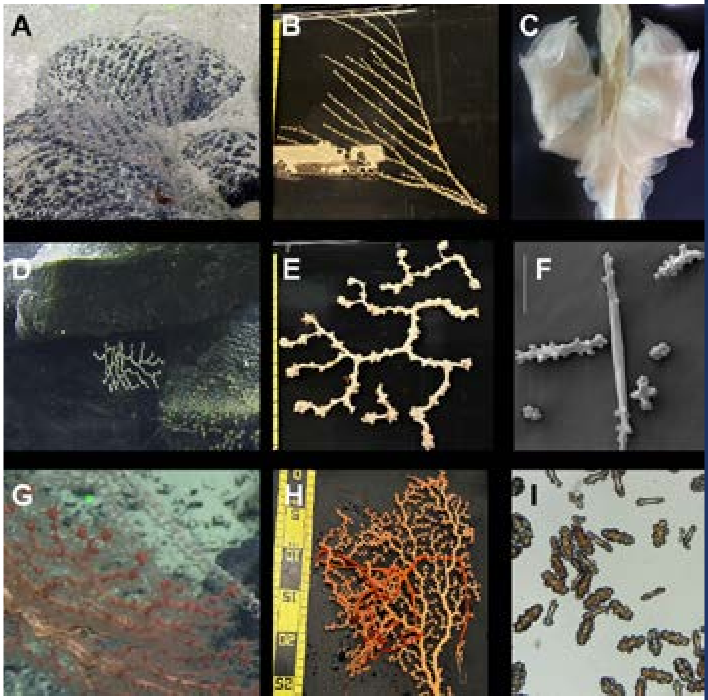


Figure 4. Probable new species and their unique characteristics from the Marshall Islands currently being worked on by Dr. Luisa Dueñas: A–C. *Calyptrophora*, D–F. *Sibogagorgia*, and G–I. *Paragorgia*.

While these three samples showed quickly identifiable features suggesting their uniqueness, the presence of other new species among the collected samples cannot be ruled out. In particular, the family Keratoisidinae requires extensive taxonomic work, as its morphology is highly variable and difficult to resolve fully in the field.

CORAL LIFE HISTORY AND REPRODUCTION

Information on fecundity, reproductive strategy, and timing is essential to understand species distribution patterns, dispersal, connectivity, and ability to recolonize injured habitats following disturbance. However, the reproductive biology of deep-sea species, including deep-sea corals, one of the main ecosystem engineers on seamounts, remains poorly known. This is particularly true in the Central Pacific, where information on reproduction exists for only three deep-sea coral species.

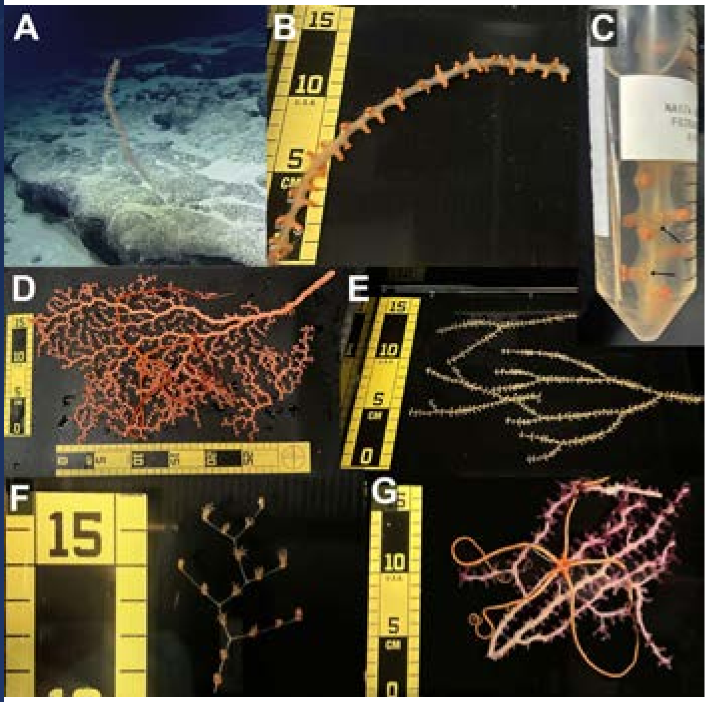
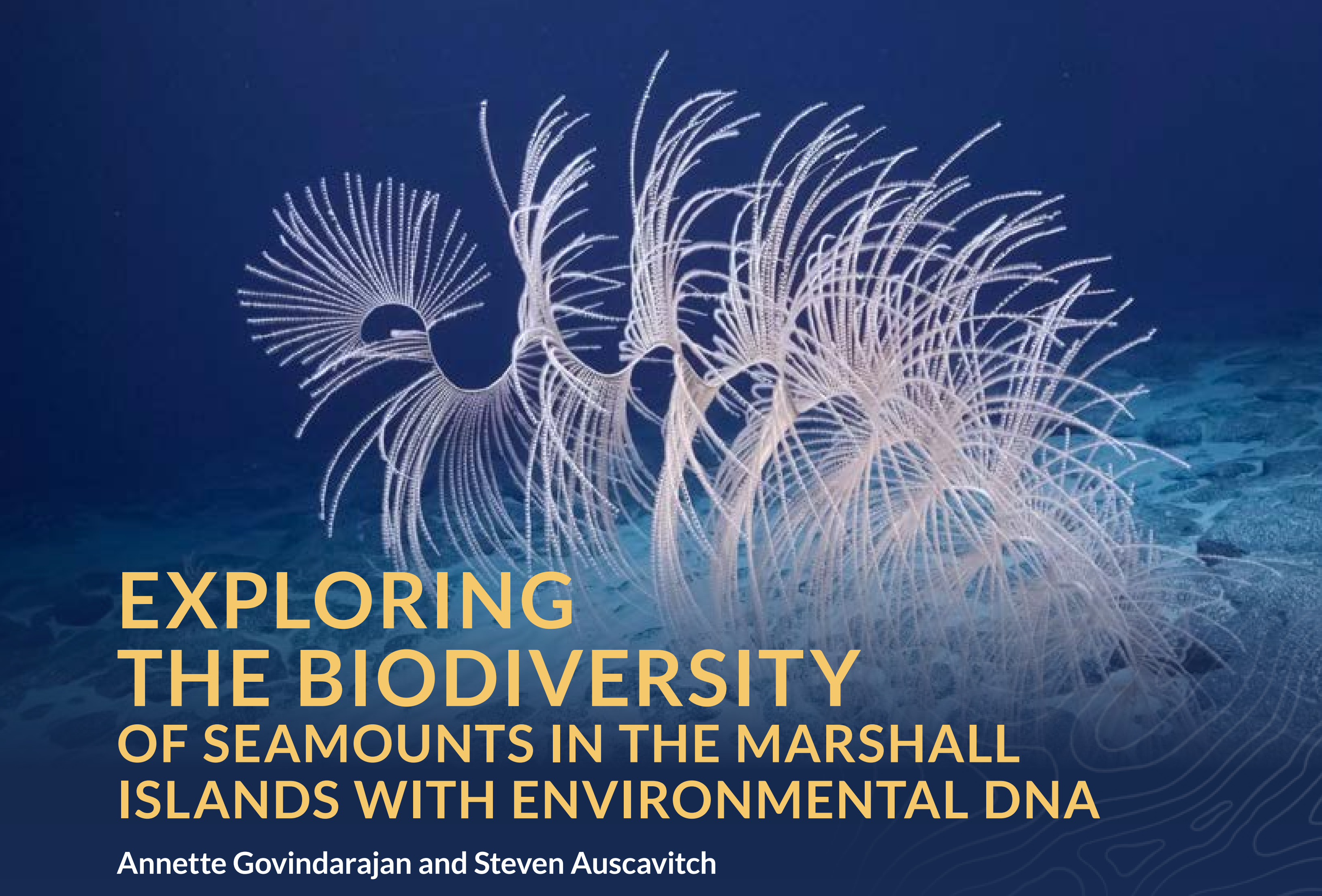


Figure 5. Example of octocorals taxa collected for reproductive studies. A–C. Unbranched bamboo coral collected at 2,400 meters (*in situ* and lab photos). C. Black arrows indicate visible eggs. D–G. Various coral species preserved for histology: D. *Hemicorallium* sp., E. *Candidella* sp., F. *Chrysogorgia* sp., and G. *Victorgorgia* sp.

This expedition provided the opportunity to characterize the reproductive traits of deep-sea coral species in the Marshall Islands for the very first time. Subsamples from each of the 33 octocorals collected were preserved for further histological analysis. Based on preliminary taxonomic identification, these samples represent at least 24 unique species of octocorals, several of which were displaying clearly visible eggs (Figure 5). The analysis of these samples using histological methods is currently underway. These data will significantly increase our understanding of deep-sea octocoral fecundity and reproduction strategies in the Marshall Islands and the broader Central Pacific, filling critical knowledge gaps on the biology of these foundational species.

The E/V *Nautilus* expedition to the Marshall Islands marked an important milestone in expanding deep-sea exploration across the Central Pacific. Through community-led planning and telepresence-enabled operations, the expedition successfully mapped and explored previously unstudied deep-sea habitats, generating valuable geological and biological data. These findings are already improving our understanding of the region's seafloor and ecosystems, while laying the groundwork for future collaborative exploration.



EXPLORING THE BIODIVERSITY OF SEAMOUNTS IN THE MARSHALL ISLANDS WITH ENVIRONMENTAL DNA

Annette Govindarajan and Steven Auscavitch

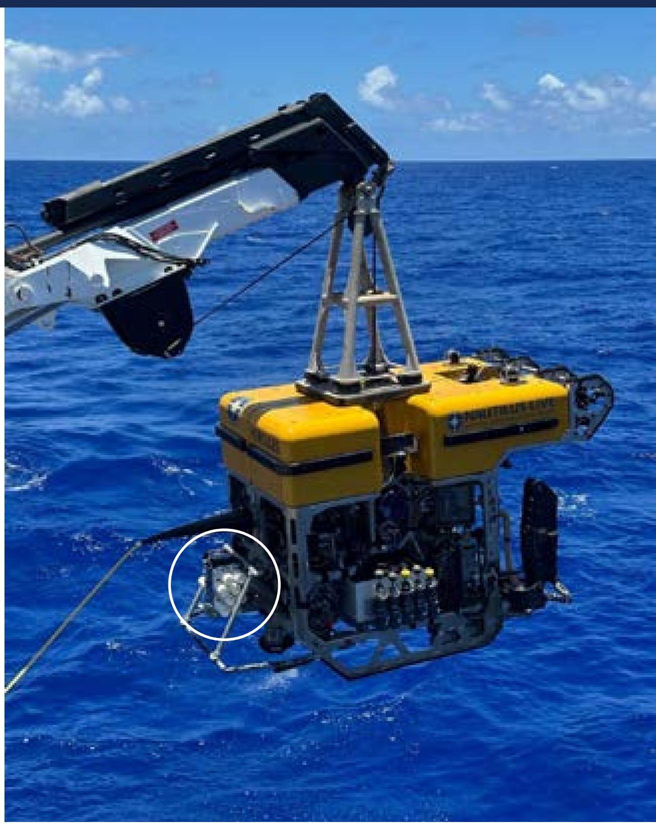


Figure 1. The MultiPuffer sampler mounted on the back of the ROV *Hercules* for a sampling deployment. Sample filters are housed inside the 16 white cylindrical cartridges (image credit: Annette Govindarajan, Woods Hole Oceanographic Institution).

During the NA174 expedition, we explored the geologic history and biodiversity of never-before-surveyed seamounts in the Republic of the Marshall Islands (see Girard et al. in this report), while also pioneering the application of genetic sampling technologies for the deep sea. Our approach entailed the application of environmental DNA (eDNA) analyses—that is the collection and sequencing of genetic traces of fauna that were present in the seawater at locations explored by the ROV. We used a ROV-mounted autonomous eDNA sampler, the Aquatic Labs MultiPuffer, that was designed specifically for large-volume deep-sea applications (Figure 1). In addition to carrying the eDNA sampler, we used ROV *Hercules* to collect biological specimens for the purpose of developing a reference library that could later be used to identify eDNA sequences obtained by the sampler. The eDNA samples, informed by the reference sequences and complemented by video collected by ROV *Hercules*, will allow us to learn more about patterns of biodiversity relative to seamount features, as well as to understand biogeographic connectivity between seamounts in the Marshall Islands and elsewhere.

Above. An *Iridogorgia* sp. octocoral.

Figure 2. Mounting eDNA filter cartridges onto the MultiPuffer eDNA sampler (image credit: Annette Govindarajan, Woods Hole Oceanographic Institution).

Figure 3. Annette Govindarajan processing eDNA filters in the wet lab aboard E/V *Nautilus*.

Seawater is filtered to obtain eDNA. Traditionally, seawater is collected by Niskin bottles and then filtered on board the ship. However, this approach is time consuming, labor intensive, and typically limited to small sample volumes (e.g., 1–5 liters), which miss eDNA signatures found in the deep sea where eDNA abundances are usually relatively low. Large-volume sampling tailored towards deep sea was pioneered with the development and application of the Oceanic-WHOI and MultiPuffer samplers deployed on previous E/V *Nautilus* expeditions using various platforms, including AUV *Mesobot* (NA139, NA155, NA164), the *Deep Autonomous Profiler* (NA155, NA164), and ROV *Hercules* (NA165). On NA174, we refined and optimized the sampling strategy for ROV *Hercules* by setting waypoints during the dive planning to correspond to autonomous sampling intervals.

Duplicate samples were pumped over 0.2 micron capsule filters housed in individual cylindrical adapters (Figure 2) during each waypoint interval, resulting in the sampling of hundreds of liters of seawater. MultiPuffer samples were complemented by seawater collections made using the Niskin bottles mounted on ROV *Hercules*, which were triggered to collect at locations with notable biodiversity. After each ROV dive, filters were removed from their capsule housings (Figure 3), stored at -80° C, and prepared for shipment to the Woods Hole Oceanographic Institution for analysis. A total of 113 MultiPuffer samples, representing 20,720 liters of filtered seawater, and 44 Niskin bottle samples, representing 187 liters of filtered seawater, were obtained during the NA174 expedition.

Below. A flytrap anemone *Actinoscyphia* sp.

Figure 4. The NA174 science team processing coral specimens for DNA barcoding and taxonomic analysis in the wet lab.

Figure 5. A ghost shark or chimaera (above) and a glass sponge (Bolosominae) (below).

Another expedition priority was to obtain biological specimens to generate voucher-based reference DNA sequences, which are needed for taxonomic identification of the eDNA sequences. In parallel with the eDNA sampling, deep-sea corals and associated fauna were collected (Figures 4–5; see Girard et al. in this report). Across all collected specimens, 140 tissue samples were preserved for subsequent DNA analysis.

DNA will be extracted from these tissues and will undergo genome skimming to produce libraries of short-read DNA sequences. From these, mitogenomes from each specimen will be bioinformatically generated, and common DNA barcode markers will be extracted, including the same markers that will be sequenced from the eDNA. These new barcode sequences will be combined with those from existing repositories such as GenBank to produce reference libraries. As our study area was previously unexplored, these new reference libraries will greatly improve species identification in eDNA profiles from our samples and throughout the region.

COMMUNITY-LED DEEP-SEA EXPLORATION
IN THE MARSHALL ISLANDS

Benedict Yamamura and Noelle Helder

Nestled in the heart of the Pacific, the Republic of the Marshall Islands is an atoll nation surrounded by over 2.13 million square kilometers of seafloor. With a total land area of only 181 square kilometers, 98.9% of the Marshall Islands Territory is underwater—the largest proportion of water to land of any sovereign state. The waters surrounding the Marshall Islands hold immense cultural and ecological significance, yet are also some of the least explored on the planet.

In light of this significance, the Ocean Exploration Trust's 2025 expedition to the Marshall Islands (NA174) was co-developed with Marshallese leaders to prioritize local knowledge and management and ground the expedition in local priorities. This partnership paired the knowledge and expertise of numerous local agencies with the deep-sea technologies onboard E/V *Nautilus* to ensure that the expedition would address both local priorities along with global science needs.

To date, less than 10% of the seafloor that lies in the Marshall Islands Exclusive Economic Zone has been mapped with modern technologies. Like in many other Pacific island countries, the vast majority of marine scientific research in the region has focused on shallow-water reefs. Numerous shallow-water surveys have documented the region's rich marine biodiversity, which includes over 2,000 species. However, because few deep-water habitats have been explored, it's true marine biodiversity is likely much higher.

Through this partnership, E/V *Nautilus* expedition NA174 was able to help fill in some of these critical knowledge gaps, mapping over 20,000 square kilometers of previously unmapped seafloor and spending more than 100 hours exploring deep-sea habitats with ROVs (see Girard et al. in this report).

Above. Three young Marshallese explorers joined the E/V *Nautilus* expedition NA174. From left to right: Hovell Warane Dako, Meriana Poznanski, and Keoni Kattil.

Figure 1. Marshallese community members were welcomed aboard E/V *Nautilus* at the close of the NA174 expedition to learn about onboard exploration technologies and hear preliminary findings directly from expedition participants.

E/V *NAUTILUS* TECHNOLOGIES MEET LOCAL PRIORITIES

From the origins of the expedition, the Ocean Exploration Trust supported by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute partnered with leaders from the Marshall Islands Marine Resources Authority as well as other government agencies, conservation groups, cultural leaders, and educators to co-create mission priorities. Several planning calls and opportunities for community input were created to ensure that stakeholders with a wide range of expertise could participate and share perspectives to inform the expedition plan. Numerous virtual meetings were held over a year in advance of the expedition with local partners, creating an opportunity to establish relationships and build trust.

To bring these different leaders together, the Ocean Exploration Trust and the Marshall Islands Marine Resources Authority co-hosted a workshop in Majuro that brought together over 25 stakeholders from government agencies, conservation groups, and academic institutions (Figure 2). Central to the workshop was a commitment to open dialogue and active listening sessions where community members were invited to share their own perspectives about the deep sea in their own backyard, cultural connections to ocean, and thoughts on how to best deploy E/V *Nautilus* capabilities to address local management, science and education needs. Input received during the workshop directly informed decisions about which areas to prioritize for exploration with the variety of technologies available aboard E/V *Nautilus*.

Figure 2. Ahead of the NA174 expedition, the Ocean Exploration Trust and the Marshall Islands Marine Resources Authority co-hosted an expedition planning workshop in Majuro. The workshop brought together 25 participants from government agencies, community organizations, and academic institutions to discuss how the science, education, and telepresence capabilities of E/V *Nautilus* could be best deployed to address local priorities.

Conversations from this workshop reflected local Marshallese priorities of understanding marine biodiversity and filling in mapping data gaps in addition to a rich cultural connection to the ocean. While acknowledging that deep-sea exploration using modern technologies has been limited throughout most Pacific Islands, the people from these places come from a long line of traditional ocean knowledge through traditional fishing, navigation and wayfinding. In addition to the workshop, the expedition team met with numerous agencies and groups

Figure 3. Local participants Keoni Kattil and Hovell Warane Dako shared their experience onboard E/V *Nautilus* with Marshall Islands Marine Resources Authority Director Glen Joseph and other staff members at a port event after the expedition.

connected with the ocean in the Marshall Islands, including the Council of Iroij, Ministry of Education, Ministry of Natural Resources and Commerce, Cultural and Historic Preservation Office, College of the Marshall Islands, and Marshall Islands Marine Resources Authority.

INSPIRING THE NEXT GENERATION OF MARSHALLESE OCEAN EXPLORERS

Co-developed expeditions aboard E/V *Nautilus* are not just about the great science that happens onboard, but equally about opportunities for sharing ocean stories with the world. While in Majuro for the workshop, staff from the Ocean Exploration Trust were invited to share expedition stories with students from the Marshall Islands High School and College of the Marshall Islands, spreading the excitement of ocean exploration in their own waters.

Additionally, three early-career Marshallese scientists from partner institutions joined the NA174 expedition team at sea (Figure 4). These participants were vital members of the expedition team, contributing key scientific observations and sharing deep place-based knowledge. As local ambassadors, these participants also joined numerous live ship-to-shore interactions that connected the broadcast studio aboard E/V *Nautilus* with an Ocean Symposium held in Majuro. Furthermore, community members were welcomed aboard E/V *Nautilus* at the conclusion of the expedition to meet the mission team, interact with the technologies, and get a glimpse at preliminary findings from the expedition (Figures 1, 3).

A MODEL FOR CONTINUED EXPLORATION

The success of the NA174 expedition demonstrates the power of science rooted in relationships. Collaborative, co-developed exploration is essential to not only fill in critical information gaps, but also to connect this information to the people, communities and institutions that are ultimately the stewards of these places. By centering local leadership, shared decision-making, and mutual learning, this expedition moved toward a model of exploration grounded in trust and respect. The NA174 expedition offers a replicable framework in which scientific discovery advances hand in hand with stewardship and community.

Figure 4. Local participant Meriana Poznanski sits watch as a supporting scientist in the control van during ROV operations.

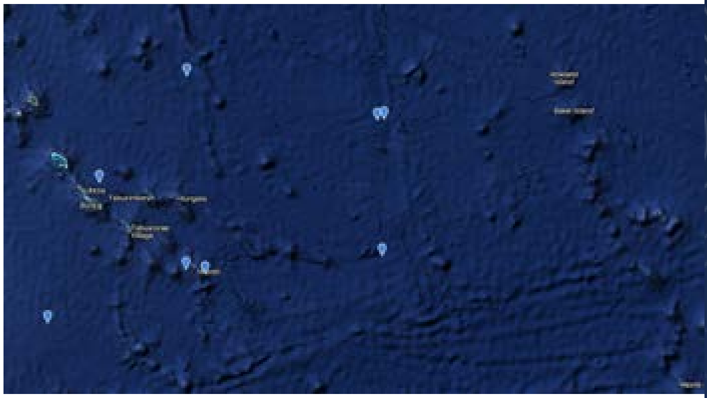
TOPSIDE SEABIRD AND WILDLIFE OBSERVATIONS
ON NA175

Adrian Burke

As E/V *Nautilus* embarked on the NA175 expedition to map the seafloor around the islands Howland and Baker in the remote tropical Pacific, topside seabird and marine wildlife observations were carried out daily to collect baseline data about species diversity in this undersurveyed part of the ocean. This represented a unique opportunity to collect an additional dataset alongside the expedition's primary mapping mission, allowing E/V *Nautilus* to maximize the scope of knowledge gained while out at sea in these rarely visited regions. Data were collected using two online citizen science platforms. eBird was used to record survey effort as well as exhaustive bird diversity and abundance data, whereas iNaturalist was used to document the location and time of individual sightings of organisms. In total, over 8,000 individual birds of at least 30 species were observed during the NA175 expedition, as well as four species of cetaceans totalling over 65 individuals. Flying fish were observed on most days, though species could not be determined.

The Sooty Tern (above) made up the bulk of individual bird sightings, with observers documenting more than 5,000 individuals. This species was especially common in the US Exclusive Economic Zone around the islands of Howland and Baker (Figure 1), where it breeds in impressive numbers alongside modest numbers of the Gray-backed Tern, of which nine were recorded during the expedition. A large proportion of birds observed were related tern-like birds including hundreds of Blue-billed White-Terns, Brown Noddies, and Black Noddies.

Above. Sooty Tern *Onychoprion fuscatus* (image credit: Adrian Burke).



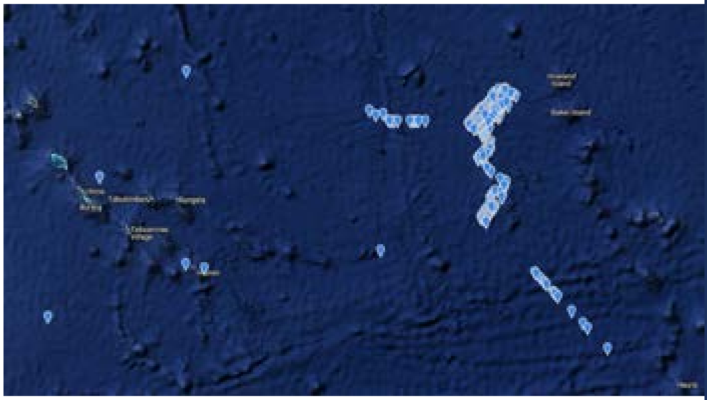


Figure 1. Map of eBird records of Sooty Tern before (above) and after (below) expedition NA175, illustrating the general paucity of data in this region (image credit: Adrian Burke, eBird).

Also well-represented among the birds observed were the boobies, which were widespread and conspicuous, often feeding in mixed flocks with terns, noddies, and frigatebirds. Some rode the vessel, sallying out to hunt for flying fish. Most were Red-footed Boobies, but Brown and Masked Boobies were spotted as well.

Figure 2. Nazca Booby *Sula granti* around Howland and Baker (image credit: Adrian Burke).

Figure 3. Red-tailed Tropicbird *Phaethon rubricauda* (image credit: Adrian Burke).

A noteworthy observation near Howland and Baker was an adult Nazca Booby, well out of the species' normal range in the Eastern Pacific (Figure 2). Lesser Frigatebirds and a handful of Great Frigatebirds were consistently seen following mixed feeding flocks to steal food. Modest numbers of Red-tailed (Figure 3) and White-tailed Tropicbirds were detected, with White-tailed Tropicbirds being more prevalent around the higher islands of Samoa. Interestingly, Red-tailed Tropicbirds were observed making courtship display flights far offshore of Howland and Baker Islands, a behavior typically observed only at breeding colonies.

Perhaps the most quintessential group of seabirds, the tubenoses, were overall scarce in number during expedition NA175 despite being represented by at least 11 distinct species that were observed. These remarkable birds generally spend their entire lives at sea, coming ashore only to breed. They are long-lived and slow to reproduce, and they nest on the ground, making them vulnerable to population declines as a result of introduced predators where they breed. Many species are threatened with extinction, and many local breeding populations have been lost, including those on Howland and Baker. Tubenose species observed on the NA175 expedition included regional breeding species like Wedge-tailed Shearwater, Tropical Shearwater (Figure 4), Christmas Shearwater, Phoenix Petrel, and Tahiti Petrel, as well as migrants and wanderers from far-flung breeding sites such as Leach's Storm-Petrel, Black-winged Petrel, Buller's Shearwater, and Short-tailed Shearwater.

In addition to seabirds, two species of migratory shorebirds—Pacific Golden-Plover and Ruddy Turnstone—were repeatedly seen far out at sea, typically flying a loop around the vessel before continuing on their way south from their Arctic breeding grounds to their island wintering locations. Cetacean sightings were fairly sparse and often not identifiable, but two sightings of short-finned pilot whale pods (Figure 5) and at least one observation of a sperm whale were made near Howland and Baker. Other sightings included a Cuvier's beaked whale near Kiribati and a humpback whale near Tutuila, American Samoa.

The NA175 E/V *Nautilus* expedition represented a rare opportunity to survey the fauna of some of the most remote and understudied regions of the Earth's ocean. Observation data were logged and made public via eBird and iNaturalist upon expedition completion, providing important baseline data in one of the most remote parts of the Pacific.

Figure 4. Tropical Shearwaters *Puffinus bailloni* (image credit: Adrian Burke).

Figure 5. Short-finned Pilot Whales *Globicephala macrorhynchus* (image credit: Adrian Burke).

NA176: EXPLORATION OF ABYSSAL HABITATS OF THE COOK ISLANDS

Adam Soule, Aurora C. Elmore, John Parianos, and Amanda Demopoulos

Deep seafloor environments around the Cook Islands are largely unexplored. Vast areas of the Cook Islands Exclusive Economic Zone are unmapped, and only a handful of direct observations of the seafloor environment have been conducted using deep submergence vehicles, with most of those efforts focused on the Manahiki Plateau to depths of 4,800 meters in the northern portion of the exclusive economic zone. Despite limited data, local agencies, including the Cook Islands Seabed Mineral Authority, have worked diligently to classify the deep-sea habitats within the region based on a variety of factors, including seafloor geomorphology and primary productivity. This analysis formed the basis for selecting ROV dive locations conducted during the 2025 E/V *Nautilus* expedition to the Cook Islands (NA176), with an intent to refine these habitat zones.

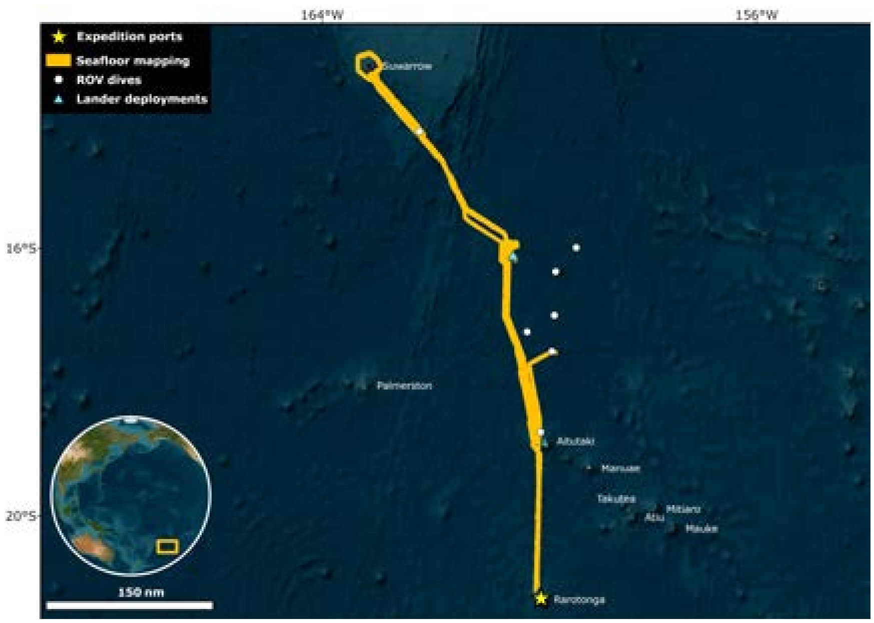


Figure 1. Map showing the locations of seafloor mapping, ROV dives, and lander deployments conducted during the NA176 expedition.

During the NA176 expedition, exploration was conducted through a combination of ship-based seafloor mapping and ROV exploration via the 6,000-meter rated *Little Hercules* and towsled *Atalanta* (Figure 1). Additionally, the mission included the deployment of two autonomous benthic mini-landers at depths of 4,830 and 4,968 meters for retrieval by another vessel in February 2026. Most of the ROV explorations conducted during NA176 targeted depths greater than 5,000 meters, since these abyssal plains are of particular interest to the Cook Islands Government as it controls the management of the contained seafloor resources. Seafloor mapping was carried out with E/V *Nautilus*' EM 302 multibeam echosounder. A total of 14,145 square kilometers of seafloor were mapped at a resolution of approximately 50 square meters. Mapping was optimized to fill gaps in previously mapped areas and to match transit tracks from prior expeditions. Highlights from the mapping work included the collection of new bathymetry data between the islands of Rarotonga and Aitutaki

Above. Big-fin squid (genus *Magnapinna*) observed at a depth of 5,215 meters during dive L1011 on the NA176 expedition.

that revealed a linear structure or ridges connecting the two islands. This previously unknown feature may [explain enigmatic co-eval volcanism on these two islands during the Holocene] that is inconsistent with our current understanding of the location of the mantle plume feeding the magmatic system of the islands.

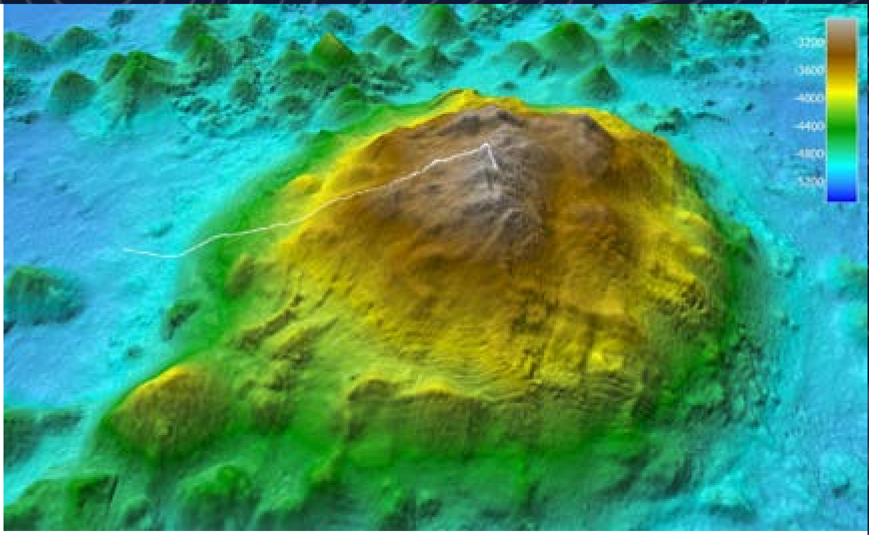
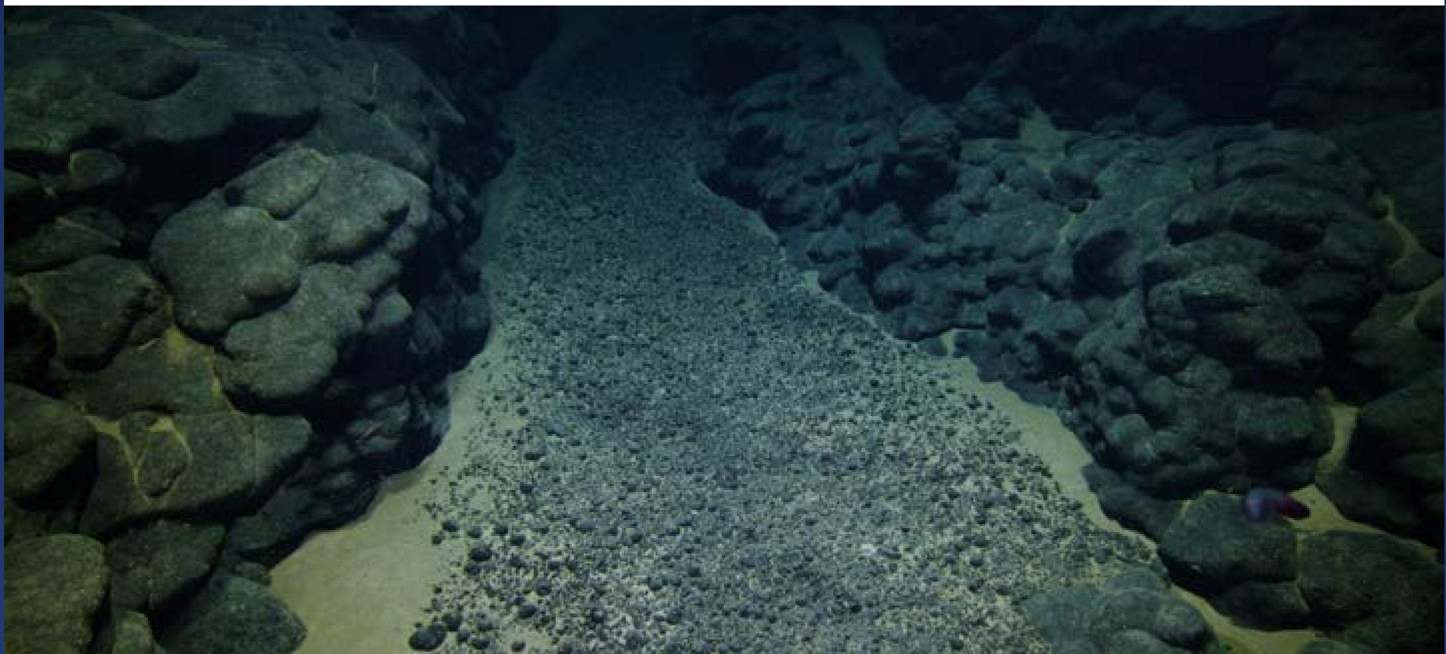


Figure 2. Three-dimensional map of the ROV dive track (shown in white) from dive L1009, showing the vehicle's ascent along the flank of a seamount from a depth of approximately 4,750 meters to above 3,000-meter depth. The color ramp represents depth in meters.

Long dives with ROV *Little Hercules* at five locations were intended to survey distinct abyssal morphologies, including flat, abyssal plains and high-standing volcanic structures. In addition, one dive was conducted up the eastern flank of Aitutaki Island. No sampling was conducted during the dives, but ultra high-resolution video imagery was collected via the DeepSea MxD SeaCam imaging system, which was attached to ROV *Little Hercules* throughout this mission (see Steiner and Rossoshanskiy in this report).

Seamount dives (L1007, L1009): Two dives focused on ascending volcanic structural features that dot the abyssal plains north of Aitutaki. Dive L1007 traversed the southeastern edge of a complex of volcanic knolls, beginning on the abyssal seafloor at a depth of about 4,500 meters and rising more than 750 meters up one of the knolls over a period of 22 hours. Within the volcanic constructions, the ROVs encountered a series of benches and swales. From the beginning of the dive, the sedimented seafloor was largely blanketed by small polymetallic nodules that were less than 10 centimeters in diameter. At the base of the knoll complex, the nodules were highly regular in shape and size, with diameters of up to 10 centimeters. As we progressed up the volcanic feature, large ferromanganese-coated outcrops were interspersed with sediment and nodules. The outcrops appeared to have the form of basaltic pillows and blocky talus slopes, but were too heavily crusted for certainty, and were not sampled. Between outcrops, sedimented regions were again blanketed by small polymetallic nodules of varying size and shape. A variety of fish, sponges, corals, and crustaceans were present on the transect. Although the abundance of organisms was greater on the slopes of the volcanic construct, overall densities remained low.

Figure 3. Polymetallic nodules accumulating within a sedimented chute on the face of a seamount from dive L1009, between formations of likely polymetallic-coated pillow basalts.



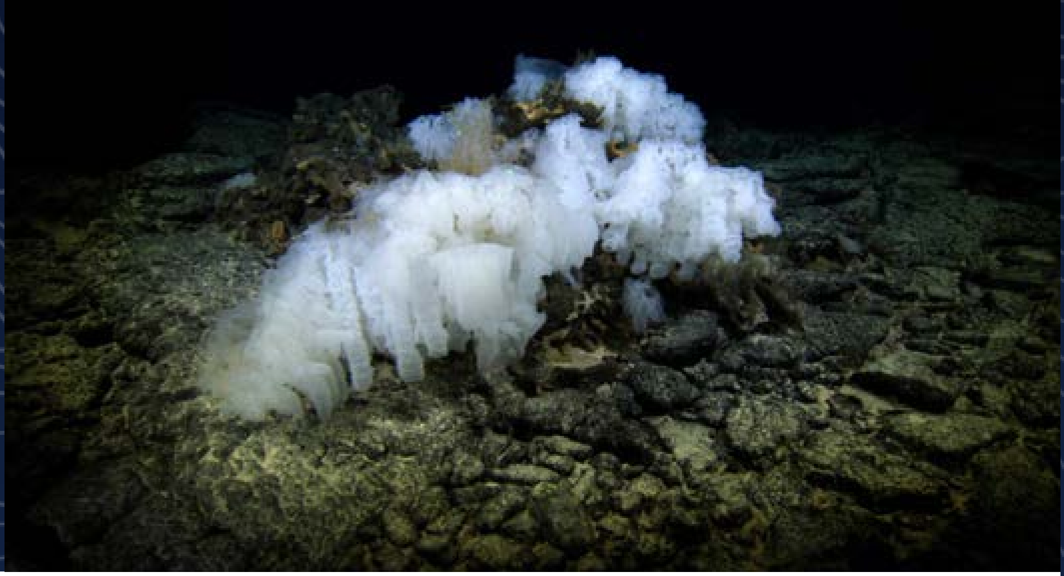


Figure 4. Large white sponges observed at 2,810 meters near the summit of the seamount surveyed during dive L1009.

Dive L1009 ascended the west face of a 15-kilometer wide, 2.5-kilometer high seamount (Figure 2). Beginning at a depth of approximately 4,750 meters, the dive descended to a flat abyssal seafloor that was blanketed with polymetallic nodules that ranged in diameters between 3–10 centimeters. Nodule coverage remained high, but graded into more diverse shapes and sizes closer to the seamount. Sparse sponges, jellies, and fish were on the flat seafloor. The seamount flanks were heavily covered in polymetallic crusts of ferromanganese oxyhydroxide, and included volcanic forms such as pillows and lobate flows. Flat benches encountered on the ascent included flat-lying ferromanganese crusts with attached nodules, as well as loose nodules of varying size and shape. The seamount flank had sparse occurrences of corals, sponges, and anemones. Between heavily encrusted outcrops, sedimented chutes were covered with abundant nodules (Figure 3), with rare patches of bare sediment. An increase in sediment and decrease in nodule abundance was observed on the upper reaches of the seamount, at depths less than 3,500 meters where slopes were steeper. At the seamount summit, above 3,000 meters, abundant corals and sponges were observed (Figure 4), along with the detritus of dead sponges.

Abyssal plain dives (L1008, L1010, L1011): These dives each traversed about 10 kilometers of flat, abyssal plain north of Aitutaki at depths below 5,000 meters (Figure 5). The dives crossed a variety of benthic substrates although most were completely blanketed by small, spherical, polymetallic nodules that were 3–10 centimeters in diameter (Figure 6). While dives L1008 and L1010 were dominated by polymetallic nodules, some regions contained irregular and sometimes angular nodules. Some areas were dominated by sediment with few nodules, while others were composed of thick, flat-lying ferromanganese crusts (Figure 7). Polymetallic crustal environments were more prevalent on dive L1011. Interestingly, no discernible change in environment or morphology accompanied these distinct areas, but many of the more sedimented areas showed greater evidence of bioturbation (Figure 8). Many of the surveyed regions included regularly spaced mounds of sediment, fecal casts, and feeding trails, as well as holothurians and worms that are likely responsible for creating these features. In addition, various species of fish, urchins, corals, sponges, crustaceans, stars, hydroids, jellies, octopuses, and other organisms were observed. A particular highlight was the observation of a big-fin squid (genus *Magnapinna*), one of the deepest known squids, and one that has rarely been observed.

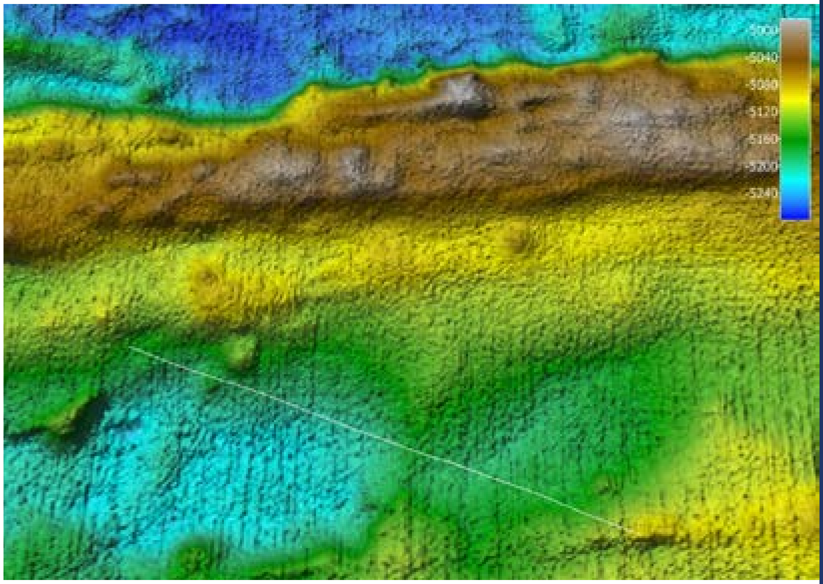


Figure 5. Three-dimensional map of the ROV dive track (shown in white) from dive L1010, showing the vehicle's traverse along abyssal plain habitats at depths of about 5,100–5,200 meters.

Figure 6. Field of small polymetallic nodules of uniform size covered the seafloor on dive L1010 with a large jellyfish and small urchin in view.

Aitutaki margin dive (L1012): The ROVs surveyed benthic habitats and megafaunal communities along a 11-kilometer transect on the Northwest Aitutaki Slope. The dive began on sedimented seafloor interspersed with scattered volcanic gravel and manganese-crusted fragments, where shrimp, sponges, anemones, and occasional fishes were observed. As the transect progressed upslope and across a knoll, the seafloor transitioned repeatedly between sediment plains, ferromanganese crusts, volcaniclastic deposits, and extensive volcanic structures including lobate flows, breccia, and stacked pillow lavas with radial fracturing. Several distinct boundaries were documented, including transitions between sediment and micro-nodule fields and steep lava walls. Hard substrates supported diverse sessile fauna, including bamboo corals, octocorals, black corals, large stalked sponges, and crinoids, often with associated communities. Sedimented areas contained holothurians, xenophyophores, feeding traces, and ripple fields, with occasional fishes including tripod fish and cusk eels. Organism densities were generally higher on exposed volcanic substrates and manganese-crusted ledges than on sedimented plains.

Overall, ROV dives from the NA176 expedition gathered 199 hours of visual information about the deep-sea habitats of the Cook Islands. All data gathered during NA176 mission has been delivered to the Cook Islands Government and is publicly available from various online repositories for E/V *Nautilus* data, including Nautilus Live, Rolling Deck to Repository, Marine Geoscience Data System, NOAA's National Centers for Environmental Information, and YouTube. ROV dive videos revealed at least 400 individual macrofaunal species, and scientific documentation of these species is currently underway. While much of the Cook Islands Exclusive Economic Zone remains unexplored, the NA176 expedition provided substantial new information about the geologic structures, features, and environmental context of several key regions of the eastern-central abyssal plain.

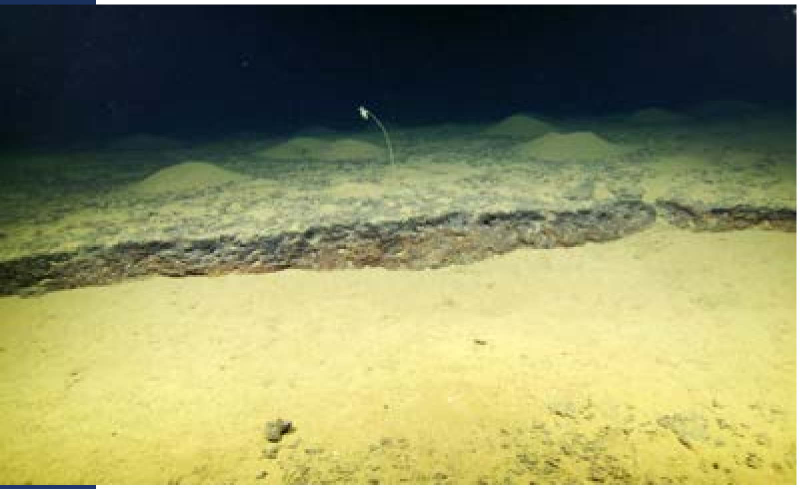


Figure 7. Polymetallic crust that is approximately 20–30 centimeters thick overlying sedimented seafloor on dive L1011. Parallel lasers are 10 centimeters apart.

Figure 8. Uniformly-distributed sediment mounds observed at depths of 5,032 meters suggest evidence of bioturbation in a highly sedimented area on dive L1011. Parallel lasers are 10 centimeters apart.

FIELD TRIALS OF THE MXD SEACAM ON EXPEDITION NA176 TO THE COOK ISLANDS

Aaron Steiner and Mikhail Rossoshanskiy

In September–October 2025, DeepSea, a manufacturer of subsea imaging and lighting systems, partnered with the Ocean Exploration Trust to conduct field trials of a first of its kind, 7,000-meter rated ultra high definition imaging system: the MxD SeaCam. The trials took place during E/V *Nautilus* expedition NA176, which focused on exploring some of the deepest seafloor surrounding the Cook Islands (Figure 1; see Soule et al. in this report).

For the Ocean Exploration Trust, the deployment provided an opportunity to document the region's largely unexplored deep-sea habitats with unprecedented image fidelity. High-quality, real-time imagery of macrofauna and mesofauna along seamounts and abyssal plains supported detailed observation and enhanced situational awareness during deep-water transects. For DeepSea, NA176 marked the first operational deployment of the commercial version of the MxD SeaCam. Placing the system in the hands of professional video engineers and expedition operators provided direct insight into real-world performance under demanding at-sea conditions.

SYSTEM INTEGRATION AND SHIPBOARD INFRASTRUCTURE

Integrating the MxD SeaCam with ROV *Little Hercules* and the shipboard video infrastructure aboard E/V *Nautilus* presented both technical and operational challenges. Successful integration required close coordination between DeepSea personnel and the ROV and video teams aboard E/V *Nautilus*, and offered hands-on experiences that could not be replicated in shore-side facilities. Working alongside operators with decades of expedition experience provided valuable feedback on both the strengths of the system's design and areas for improvement.

Figure 1. The MxD SeaCam installed on ROV *Little Hercules* going over the side of E/V *Nautilus* while at anchorage off the coast of Rarotonga for a test dive (image credit: Mikhail Rossoshanskiy, DeepSea).

The deployment also allowed the expedition video team to stress-test onboard infrastructure used to receive, capture, display, and broadcast live video from the ship. In doing so, the team gained practical experience relevant to future transitions toward ultra high definition workflows at sustained data rates of 12 gigabits per second.

Above. A large Corallimorpharian imaged at 4,229 meters using the MxD SeaCam.

BACKGROUND AND SYSTEM LINEAGE

The MxD SeaCam traces its origins to a collaboration initiated in 2019 between DeepSea and the Monterey Bay Aquarium Research Institute (MBARI). The objective was to introduce ultra high definition imaging capability to MBARI's 4,000-meter-rated ROVs *Doc Ricketts* and *Ventana*, integrating broadcast-grade camera and lens systems while maintaining reliable operation at extreme depths.

DeepSea led the development of the pressure housing and corrector optics required to adapt a Sony camera and Canon zoom lens for subsea operation behind a glass dome. MBARI developed the camera chassis, control electronics, and topside operator interface. The system name—MxD—reflects the contributions of both organizations. Through 2024, MBARI operated the only two MxD SeaCam systems in existence. In parallel, DeepSea developed a deeper-rated configuration and adapted the MBARI design into a commercial system suitable for broader operational use.

FIELD INTEGRATION CHALLENGES

Integration of the MxD SeaCam with ROV *Little Hercules* proved more complex than initially anticipated, underscoring the importance of field trials. Following its arrival in the Cook Islands, the system passed functional checkout after several weeks in transit, and initial bench testing confirmed full functionality.

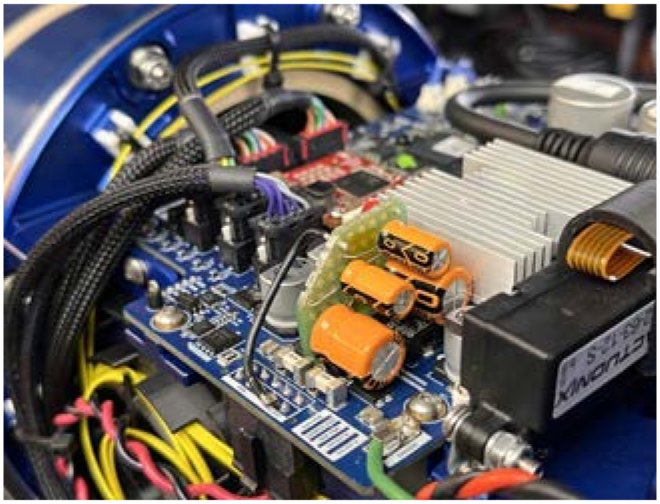


Figure 2. The hardware patch used to stabilize the MxD SeaCam power supply during the inrush surge of the Sony camera. The fix was possible thanks to the experience and foresight of the ROV team, who had the required capacitors and breadboard on hand in their onboard ROV shop (image credit: Aaron Steiner, DeepSea).

However, once mounted on ROV *Little Hercules* and powered by the vehicle, the camera failed to initialize or produce video. After a rapid series of diagnostic tests, the team identified a power surge during startup of the Sony camera as the most likely cause. The transient current draw briefly pulled ROV *Little Hercules*' supply voltage below the camera's operating threshold. Fortunately, the necessary components were available in the onboard ROV shop (Figure 2), enabling the team to design and implement a hardware modification to stabilize the power rail during startup (Figure 3).

Figure 3. DeepSea Technology Specialist Mikhail Rossoshanskiy inspecting the corrector lens cell in the onboard ROV shop before reassembling the MxD SeaCam (image credit: Aaron Steiner, DeepSea).

EXPEDITION OPERATIONS AND ADAPTATION

DeepSea personnel were embedded with the ROV team for the duration of the NA176 expedition, aligning with the 12-hour operational watch schedule. This allowed direct participation in vehicle preparation, launch and recovery operations, and ongoing maintenance while adapting to shipboard work—an unfamiliar environment for both DeepSea team members that sailed on NA176.

Initial integration challenges were followed by a series of expedition-level setbacks. Persistent poor weather conditions limited diving during the early phase of NA176. On the first successful dive, a flooded thruster control bottle forced a dead-vehicle recovery shortly after ROV *Little Hercules* reached the seafloor. The ROV team swiftly rebuilt the affected systems and returned the vehicle to service.

Figure 4. An ultra high definition image collected using the MxD SeaCam integrated on ROV *Little Hercules* during the NA176 expedition to the Cook Islands. A community of crustaceans, bivalves, brittle stars, and urchins imaged on a wood fall at a depth of 5,038 meters in the abyssal plains north of Aitutaki.

On a subsequent dive, the tether connecting ROV *Little Hercules* to *Atalanta* became looped around *Atalanta*. Movement of the ship from surface swell transferred force through the tether, causing a sudden jerk to ROV *Little Hercules*. Video and telemetry were lost, prompting a second dead-vehicle recovery. Once back on board, the ROV team rapidly isolated the damage and fabricated a replacement tether, restoring dive capability within hours. These events tested both equipment and personnel, reinforcing the importance of adaptability, redundancy, and close collaboration in deep-sea operations.

OPERATIONAL REFINEMENT AND OUTCOMES

In addition to these technical incidents, several smaller challenges emerged over the course of the expedition. These included adjustments to operator control behavior, slow offload rates for high-bandwidth, ultra high definition video data, and intermittent electrical failures in the tilt unit supporting the camera. None of these issues ultimately impeded the pace of operations during the latter half of the expedition. Each was addressed through coordinated troubleshooting, drawing on the team's combined experience and preparedness to ensure that scientific and operational objectives were met.

EXPEDITION VALUE AND SIGNIFICANCE

The integration and operation of the MxD SeaCam during NA176 highlighted the value of close, in-field collaboration between equipment developers and expedition operators. Operating under real expedition conditions alongside ROV pilots, video engineers, and scientists provided insights that laboratory testing alone cannot deliver and is directly informing ongoing refinement of the system.

At the same time, imagery collected during the Cook Islands expedition demonstrated the scientific value of high-fidelity, studio-grade video at depth, supporting more detailed observation of biological communities and seafloor features (Figures 4–5). Expeditions such as NA176 illustrate how partnerships between organizations like DeepSea and the Ocean Exploration Trust can advance deep-sea exploration through shared technical development and operational experience.

Figure 5. A large holothurian, likely in the genus *Psychropotes*, documented at a depth of 4,817 meters at the base of an abyssal seamount north of Aitutaki.

KIA ORANA! THE COOK ISLANDS WELCOME E/V *NAUTILUS*

IN ITS QUEST FOR DEEP-SEA KNOWLEDGE

John Parianos, Aurora C. Elmore, Adam Soule, Amanda Demopoulos, Daniel Wagner, and Allison Fundis

The waters of the Cook Islands are integral to the country's way of life, supporting daily needs, economic activity, and long-term sustainability. When E/V *Nautilus* arrived in the Cook Islands for the NA176 expedition in October 2025, it was for more than to execute a scientific mission. It was a joining of hands—a shared voyage on the same *vaka* (traditional sailing canoe) to understand the deep-ocean world that has remained largely hidden. Strong and enduring relationships are often forged in times of trial, and the team behind NA176 was tested by both the elements and unexpected hurdles.

FITTING FORM AND FUNCTION

We are not sure what the record is for the most quickly planned expedition in the 17-year history of E/V *Nautilus*, but NA176 has to be in the running at a little under two months. NA176 partners Ocean Exploration Trust, NOAA Ocean Exploration and the Cook Islands Seabed Minerals Authority were a great match and were able to make it happen quickly by working together and building upon the strengths of each partner.

Above. View of Rarotonga from the deck of the E/V *Nautilus*. Who could get too stressed living here? (image credit: Mikhail Rossoshanskiy, DeepSea).

The first technical team meeting in August 2025 involved scratching of heads as we considered elemental questions such as: What are the ship's capabilities? How deep can it collect data? How long does it take to process a research permit? All of these questions had to be answered, and answer them we did. We worked out that the E/V *Nautilus*' exceptional capability in deep-sea ROV observations could address two of the biggest outstanding questions on the Cook Islands Government's mind—What types of megafauna call our nodule fields home? And how does that vary for different types of deep-sea landforms such as seamounts versus abyssal plains?

GETTING WORKED: TIMES 1, 2, 3...

We compiled a great team of people to sail on the NA176 expedition, adjusted the vessel schedule, and completed some minor ship repairs in Pago Pago before E/V *Nautilus* headed to the Cook Islands. The expedition plan was developed, local participants were signed up, the research permission was secured, and over 20 scientists and engineers flew in from the other side of the planet to participate. So we were set to go and the weather was looking great.

Figure 1. Cook Islands participant Tanga "TJ" Morris working as Data Logger in the control van during ROV dive operations, capturing images of the seafloor and recording scientific observations.

However, a few challenges cropped up that we had to address, from rough weather to technical issues, a US Government shutdown, and a medical emergency. Despite this, the team pulled together and persevered. It never ceases to amaze how a bit of endurance, a good dose of persistence, and no shortage of competence can sort things out. We ran smaller teams, collected a bit more transit seabed mapping than originally planned, and adjusted secondary expedition objectives. A special callout to the ship-to-shore interactions folks who, throughout all the other challenges, kept getting up at 2 or 3 AM to engage with people from around the world.

WELCOME TO THE TEAM

In the Cook Islands, it is important that no one is left behind. As islanders say, there is space for everyone on the *vaka*; and from the outset, partners from NOAA and Ocean Exploration Trust welcomed a strong Cook Islands contingent on the expedition. Local scientists from the Cook Islands Seabed Minerals Authority, the National Environment Service, the Ministry of Marine Resources, and one of our local NGOs joined the expedition. The local islanders brought enthusiasm aboard, knuckling down with the crew during their shifts (Figure 1). It was truly a great experience for them. Kia Orana!

CALLING HOME

A key part of the E/V *Nautilus* mission is communication and outreach and a synergistic key objective of the Cook Islands Seabed Minerals Authority is sharing knowledge. Thus, a highlight of the expedition was the ship-to-shore interactions with people around the world, especially during real-time operations. Our seabed operations were constantly being followed by curious Cook Islanders online. The Cook Islands Seabed Minerals Authority streamed the survey live

Figure 2. Cook Islands expedition members Antony Vavia, John Parianos, and Tanga "TJ" Morris hosting a ship-to-shore interaction with learners in the Cook Islands from the E/V *Nautilus* broadcast studio.

into the office and there were many interactions with local schools. Further illustrating the importance Cook Islands put on new knowledge being gained during the mission, one live interaction occurred with the Cook Islands Prime Minister (Figure 2).

COOK ISLANDS WELCOME

The NA176 expedition began and finished on the main island of Rarotonga, with an official ceremony to recognize and celebrate this pioneering collaboration. But perhaps the best example of being welcomed came from the more northerly island of Aitutaki. Towards the end of the mission, a last-minute opportunity arose to do one ROV dive up the flanks of the atoll. However, to conduct this dive survey we needed the endorsement of the local council. With only an hour or two to spare, the direct cold call phone to the council went something like this:

"Hi, we would like to do a marine survey up the side of the atoll. We have a national permit in place but wanted to ask for your endorsement as well."

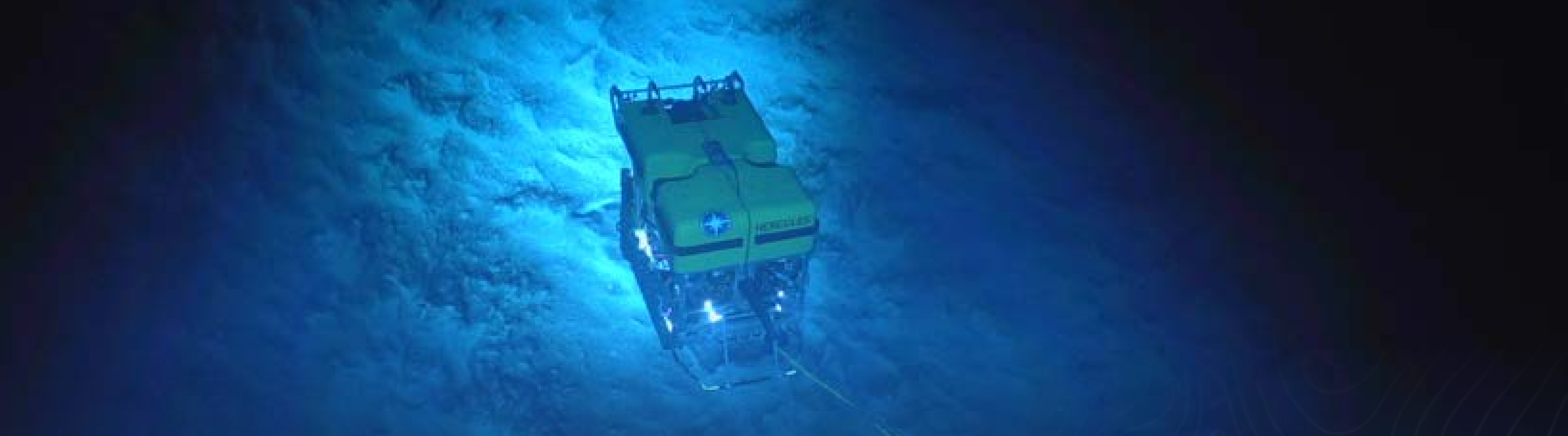
"Go for it! By the way we have been following you online, and we will live stream this dive on one of the channels of our local TV network."

This simple exchange showed that the research was not being done for the community, but with them.

KIA ORANA!

So, what is Kia Orana? Kia Orana is more than just a greeting; it is the heart and soul of the Cook Islands. This simple phrase encapsulates the Cook Islanders' spirit, way of life, and hopes for the future. Literally translated as "may you live long," Kia Orana is a heartfelt wish for a long and fulfilling life. It is a blessing, an expression of goodwill, and an invitation to connect on a deeper level. It is the local islanders' desire to share this spirit with visitors, inviting them to experience the Cook Islands way of life. By embracing Kia Orana, Cook Islanders hope to create a community where everyone thrives and their island home flourishes (Figure 3).

Figure 3. Cook Island officials gathered in front of E/V *Nautilus*, showcasing pride in collaboration.



OVERVIEW OF 2025 OCEAN ACTIVITIES
SUPPORTED BY THE NOAA OCEAN EXPLORATION COOPERATIVE INSTITUTE

Nina M. Pruzinsky, Aurora C. Elmore, William Mowitt, and Adam Soule

The NOAA Ocean Exploration Cooperative Institute (OECI) brings together five world-class research organizations to support NOAA Ocean Exploration's mission. Together, University of Rhode Island, Woods Hole Oceanographic Institution, University of New Hampshire, University of Southern Mississippi, and Ocean Exploration Trust work in partnership with NOAA to accelerate the pace of ocean exploration, advance ocean exploration technologies, increase the utility of deep-sea data, and train the next generation of ocean explorers. NOAA Ocean Exploration is deeply appreciative of the level of collaboration, technical expertise, dedication, and overall impact of the OECI during the sixth year of their activities.

Figure 1. During the 2025 field season, scientists aboard E/V *Nautilus* collected 353 new deep-sea samples, including rocks, biological specimens, and environmental DNA samples as part of ongoing efforts to further advance deep-sea science.

During the highly-successful 2025 field season, OECI completed seven expeditions aboard Ocean Exploration Trust's E/V *Nautilus*, totaling 114 days at sea. These expeditions supported OECI projects across the Pacific, including around the Mariana Islands (NA171 and NA172), Solomon Islands (NA173), Marshall Islands (NA174), Howland and Baker Islands (NA175), and Cook Islands (NA176). Collectively, OECI expeditions aboard E/V *Nautilus* mapped over 106,591 square kilometers of seafloor, completed 36 remotely operated vehicle dives, deployed 20 other vehicles and technologies, and collected 353 eDNA, biological, and geological samples (Figure 1). These expeditions support federally sponsored ocean exploration activities within the Central and Western Pacific, align those activities with the needs of local communities, and catalyze capacity development in this vast and mostly unexplored part of the deep ocean.

Figure 2. The NA171 expedition to the Mariana Islands used Orpheus Ocean's autonomous underwater vehicle to image abyssal plain habitats for the first time in the region.

The E/V *Nautilus* expedition in the Mariana Islands (NA171) made significant contributions to mapping efforts in the region and to exploring priority areas identified by the local management and scientific communities (see Chadwick et al. in this report). The team investigated sites of recent volcanism, abyssal plain habitats, bottomfish habitats, and mesophotic coral ecosystems in this region by using ROV *Hercules* and Orpheus Ocean's autonomous underwater vehicle (NA171), the latter of which completed engineering dives to test various components of the vehicle, followed by successful operational dives (Figure 2). This demonstration for Orpheus Ocean's autonomous underwater vehicle was not only critical in the development and testing of the vehicle (see Machado et al. in this report), but it was also valuable to the seafloor exploration activities in this region.

Figure 3. Faceless cusk eel (*Typhlonus nasus*) documented using DeepSea MxD SeaCam attached to ROV *Little Hercules* during the Cook Islands expedition (NA176).

By using multiple, complementary exploration technologies, E/V *Nautilus* documented historically significant maritime heritage sites from the Battles of Guadalcanal in the Solomon Islands' Iron Bottom Sound (NA173). The expedition efficiently used the University of New Hampshire's uncrewed surface vehicle *DriX* for initial site location (see Schmidt et al. in this report), followed by comprehensive archaeological surveys conducted with Ocean Exploration Trust's ROV *Hercules* (See Ballard et al. in this report). This coordinated technology approach demonstrates new efficiencies in maritime archaeology. We commend both the *DriX* team for advancing their vehicle's capabilities and also the mission team for working closely with stakeholders from all nations involved in the Battles of Guadalcanal to ensure expedition activities honored lives lost.

Unlike the other expeditions this season, OECI used the 6,000-meter-rated ROV *Little Hercules* in combination with towsled *Atalanta* to reach depths greater than 5,000 meters, where abundant mineral resources were expected in the abyssal plain habitats of the Cook Islands (NA176). Through a partnership with DeepSea (see Steiner and Rossoshanskiy in this report), ROV *Little Hercules* was equipped with a new MxD SeaCam, which allowed for the collection of highly detailed imagery of the seafloor, including observations of the geological substrates and biodiversity (Figure 3). Two industry-owned autonomous benthic landers were also deployed during the expedition for onward oceanographic monitoring purposes. In order to support future shallower-water monitoring research in the area, the OECI also gifted the Cook Islands a Blue Robotics BlueROV2 at the conclusion of the expedition. By leveraging new technological advancements, this expedition effectively explored abyssal plain habitats in this region.

Figure 4. During operations in the Marshall Islands, the Aquatic Labs MultiPuffer autonomous eDNA sampler was integrated onto ROV *Hercules* enabling the collection of environmental DNA samples alongside seafloor mapping and ROV surveys.

In addition to these technology-driven expeditions, researchers mapped areas in the Marshall Islands (NA174), Howland and Baker (NA175), and along the transit route between the Marshall Islands and American Samoa, filling seafloor mapping data gaps (see Sowers et al. in this report). In the Marshall Islands, OECI explored seamounts and other high-biodiversity areas through mapping and conducting ROV dives with an autonomous eDNA sampler integrated onto ROV *Hercules*, advancing our knowledge on these unique environments (Figure 4; see Govindarajan and Auscavitch in this report).

Beyond its scientific accomplishments, the Ocean Exploration Trust shared its discoveries with the world. The impressive outreach initiatives captivated and inspired a global audience through their engaging highlight videos, livestream events, ship-to-shore interactions, and workshops with local communities (see Zaccaria et al. in this report). Ocean Exploration's Trust's efforts to collaborate with local communities has helped improve the science and outreach needs in these poorly known parts of our ocean (Figure 5). We are grateful for Ocean Exploration Trust's remarkable ability to advance ocean science and public engagement during these expeditions.

This year, OECI, in collaboration with NOAA Ocean Exploration, also undertook a new major effort to provide operational support for NOAA Ship *Okeanos Explorer*. In November, OECI successfully demobilized ROV *Deep Discoverer*. To ensure seamless operations for the next field season, the University of Rhode Island's Inner Space Center is managing and improving the ship's science network, telepresence, and data pipeline, while Ocean Exploration Trust is managing and operating ROVs *Deep Discoverer* and *Seirios*. Other OECI partners are contributing to the overall success of work on NOAA Ship *Okeanos Explorer* through their collective expertise and resources. OECI is also diligently working to ensure that the ship's systems used for multibeam mapping, ROV exploration, and telepresence are fully operational for the 2026 field season.

Throughout 2025, the successes of OECI have continued to expand partnerships across NOAA, to the broader Federal Government enterprise, and to the commercial sector. This year, OECI's partnerships included the Bureau of Ocean Energy Management, the United States Geological Survey, and the Cook Islands Seabed Minerals Authority, in addition to several industry and commercial partners, including Orpheus Ocean, Blue Robotics, DeepSea, Odyssey Marine Exploration, and Moana Minerals. We look forward to continuing to expand these exciting scientific endeavors and partnerships for many years to come.

Figure 5. Ocean Exploration Trust, in collaboration with the Marshall Islands Marine Resources Authority, hosted a workshop to discuss the community's deep-sea science and ocean outreach needs, demonstrating Ocean Exploration Trust's commitment to engaging local partners in order to advance knowledge in these poorly known parts of our ocean.

BRINGING THE DEEP SEA HOME: E/V *NAUTILUS* EDUCATION AND OUTREACH

Jamie Zaccaria, Kelly Guarino, Jacob Ottaviani, and Megan Cook

Sharing ocean exploration with the world has always been a central tenet of the Ocean Exploration Trust, and in 2025, we advanced our mission working closely with local communities in expedition locations across the Pacific. Through telepresence, live ship-to-shore interactions (Figure 1), press connections, and social media, we explored alongside audiences around the world, sharing the wonders of our global deep sea.

Figure 1. Corps of Exploration members Shelterihna Alokoa and Emily Jones hosting a ship-to-shore interaction with learners around the world from the E/V *Nautilus* broadcast studio.

HOSTING STUDENTS AND EDUCATORS ON E/V *NAUTILUS*

As we explore the unknown, the Ocean Exploration Trust continues to position E/V *Nautilus* as a platform for teaching and learning, providing professional training experiences for the next generation of explorers and educators who bring ocean exploration and other career opportunities to their learners.

The Science Communication Fellowship program invites formal and informal educators to sail aboard E/V *Nautilus* as expedition storytellers, building their professional skills and working together to bring ocean exploration to their communities. In the year-long program, we hosted 11 fellows in 2025, from eight US states and territories.

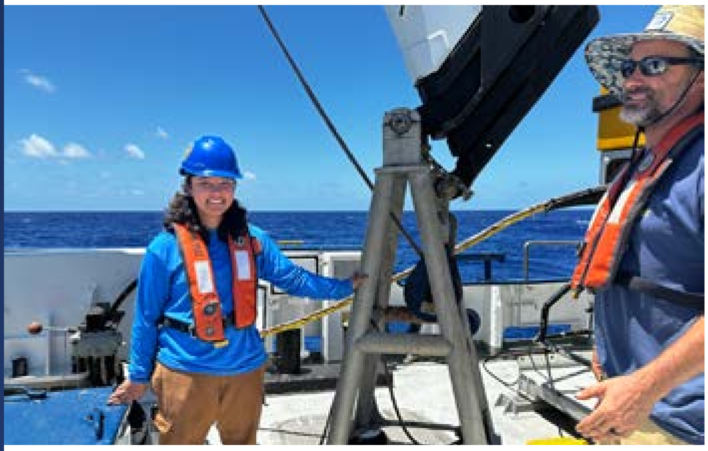


Figure 2. ROV Engineering Intern Mackenzie Hilburn joins in launching ROV *Hercules*, learning hands-on operations from Deck Chief Mike Burns.

Through the robust Science and Engineering Internship Program, 14 students and recent graduates sailed aboard E/V *Nautilus* as ocean science, video systems engineering, ROV engineering, and seafloor mapping and hydrography interns (Figure 2). Working alongside Ocean Exploration Trust mentors, these early-career professionals expanded their professional networks, built workforce-ready skills, and developed their pathways to professional work.

"My internship aboard E/V Nautilus has strengthened my interest in ocean science and exploration, confirming my goal to pursue a career in marine research and conservation. For example, the hands-on experience with data logging and sample processing showed me how I can apply my skills to real-world challenges, while the mentorship I received encouraged me to seek future roles that combine science, technology, and community engagement."

– 2025 Ocean Science Intern

Above. This bioluminescent medusoid jellyfish was spotted at depths of over 5,000 meters during the NA176 expedition to the Cook Islands.

Figure 3. Map showing the countries from which viewers followed 2025 E/V *Nautilus* operations on the Nautilus Live website (teal) or connected to the ship live via ship-to-shore interactions (blue).

As our 2025 expeditions focused on the Pacific, the Ocean Exploration Trust remains committed to elevating participation of local community members. To this end, our expedition team proudly included four educators, four professionals, and three students from the Mariana Islands while exploring the waters of the archipelago. During our expedition to the Republic of the Marshall Islands, our onboard team included three local scientists and interns. While exploring in the Cook Islands, the team included seven local participants. Empowering these local role models as long-term ambassadors for the deep ocean helps ensure expedition data and learning meet local needs.

EXPERIENCING THE OCEAN THROUGH THE SCREEN

The Nautilus Live website gives audiences a front-row seat to our live-streaming ROV dives, as well as a plethora of engaging blogs, videos, and activities to draw audiences into ocean exploration. With over 830,000 views over the course of the 2025 season, three live streams produced from our expeditions attracted almost 11 million minutes of viewership globally (Figure 3). Thousands of viewers submitted questions (23,381, to be exact—a 47% increase over 2024 expeditions) in real-time to the onboard team in the control van. Our interactive programs encouraged participation in exploration from anywhere in the world, drawing in explorers as varied as classroom students and descendants of the World War II servicemembers whose vessels we explored.

Ocean Exploration Trust's digital footprint in 2025 successfully splashed the deep sea onto screens of all sizes, with digital reach surpassing 69.9 million across our seven social media platforms (i.e., Facebook, LinkedIn, Instagram, X, YouTube, Bluesky, and TikTok). This year, we proudly passed the two-million-follower mark, with over 500,000 ocean-loving followers on TikTok, YouTube, and Instagram each (Figure 4). The team also highlighted our work through new online content, including 27 new blogs, 11 new photo albums, four new educational resources, and more.

In 2025, the team produced 63 new highlight videos that showcased expedition highlights, introduced new technology, and explained ocean exploration and science. Some of these amazing sightings went on to achieve exceptionally high viewership and pick up across press outlets, including a rare bigfin squid (genus *Magnapinna*) and faceless cusk eels spotted in the Cook Islands, as well as our highlight videos of maritime heritage sites near Guadalcanal. Beyond expedition highlights, the team created long-form videos to showcase technology such as the deep-diving ROV *Little Hercules*, spotlight science that analyzes expedition data, and elevate role models, including a feature on a ship-to-orbit conversation with an astronaut at the International Space Station.

CONNECTING IN REAL TIME WITH YOUNG EXPLORERS

Within a six-month season at sea, we succeeded in connecting to kindergarten through college classrooms and communities around the world with our live ship-to-shore interactions. These free programs brought together at-sea role models for personal conversations with onshore audiences, showcasing a range of ocean exploration careers, opportunities, and backgrounds. Through 418 interactions, we reached over 16,500 learners in the United States and eighteen other countries.

"We cannot thank you enough. Your enthusiasm was amazing, and our children have talked about it ever since. The staff members we interacted with were so inspirational and spoke to the children in a way they could understand everything that was being said. Thank you so much!"

– 2025 Ship-to-Shore Interaction Participant

Figure 4. The growth of OET's TikTok account to over 750,000 followers opens a door to share all aspects of ocean exploration with global audiences (and especially younger, curious minds).

Leveraging partnerships and venues where audiences are learning about our work, interactions linked with learner programs like Supercharged Science, scout troops, and Exploring by the Seat of Your Pants, training programs like the Office of Naval Research internship programs, the GEOHAB Conference, the Ocean Discovery League Accessing the Deep Workshop, and institutions and public groups such as the Veterans Breakfast Club, the National World War II Museum, the Museum of Science in Boston, and more. During the 2025 season, we prioritized connecting with learners and communities local to our exploration, resulting in 54 interactions in the Cook Islands, Mariana Islands, Solomon Islands, and Marshall Islands.

CULTIVATING PARTNERSHIPS AND COMMUNITY CONNECTIONS

Through the press and media, we briefed audiences worldwide on the latest discoveries in ocean exploration (Figure 5). In 2025, 1,171 press articles with a combined media reach of over nine billion covered our expeditions and Corps of Exploration team members within 80 countries and in 42 languages. In particular, the expedition exploring World War II shipwrecks near Guadalcanal drew significant media interest around the globe, with over 580 pieces about the expedition and our groundbreaking discoveries, including the bow of USS *New Orleans* and the Imperial Japanese Navy destroyer *Teruzuki* (see Ballard et al. in this report).

Beyond media, the Ocean Exploration Trust team continued to engage personally with local, national, and international associations to bring deep-ocean science and education to new audiences. Our staff helped elevate pathways to engaging in ocean exploration at the International SeaPerch robotics competition, the National Marine Educators Association conference, the Island Sustainability Forum at the University of Guam, and the Marshall Islands National Ocean Forum. Ocean Exploration Trust's leadership in co-developing expedition science and outreach priorities with local communities led to the development of a series of community events: Puengen Tasi Siha—Ocean Nights at the Guam Museum, public ship tour events in the Cook Islands and the Republic of the Marshall Islands, classroom visits from explorers, and the community naming of the Mattingan expedition in the Mariana Islands.

The Ocean Exploration Trust is proudly committed to exploring our global ocean and sharing the excitement of discovery with people of all ages, inspiring the next generation of ocean explorers. In 2025, Ocean Exploration Trust's education programs were made possible through generous support from the Office of Naval Research, Phillip Stephenson Foundation, and NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute.

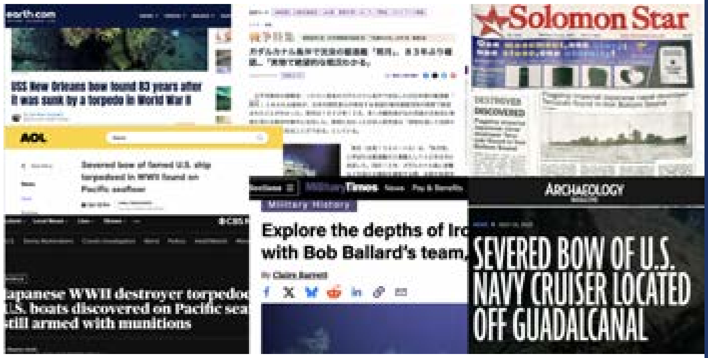


Figure 5. Expedition discoveries drew the attention of global media, with 1,070 articles published in 80 countries, most focused on human-centered ocean stories, such as the Solomon Islands expedition, which revealed World War II history.

THE SCIENTIST ASHORE COMMUNITY

Noelle Helder and Lindsey Jones

Throughout the 2025 expedition season, Ocean Exploration Trust's Scientists Ashore Program continued to expand scientific collaboration beyond the deck of the E/V *Nautilus* through telepresence-enabled operations. The program remains a core organizational mechanism for building a distributed, global deep-sea research community that is not constrained by the number of available berths on any given expedition. This season marked another step toward a more connected model of ocean exploration, in which scientific insight is shared in real time to enable discovery across disciplines.

Figure 2. In 2025, the Scientists Ashore Program attracted a global community of deep-sea experts who shared their expertise with E/V *Nautilus* expeditions from 221 institutions in 30 countries across the globe.

Expeditions aboard E/V *Nautilus* are guided by input from the global community of partners, researchers, resource managers, and knowledge holders in each region of operation. Scientists ashore contribute to every phase of an expedition's lifecycle, from early planning through post-expedition analysis. Feedback is first solicited through an annual call for science input, which invites the broader community to contribute to each expedition's design by identifying scientific objectives, mapping priorities, ROV dive targets, and sampling interests. This information is supplemented through consultations with regional experts, resource management agencies, and other stakeholders with knowledge of the planned areas of operations. Draft expedition plans are then shared with registered scientists ashore for additional refinement, helping ensure that expedition activities align with community-identified priorities.

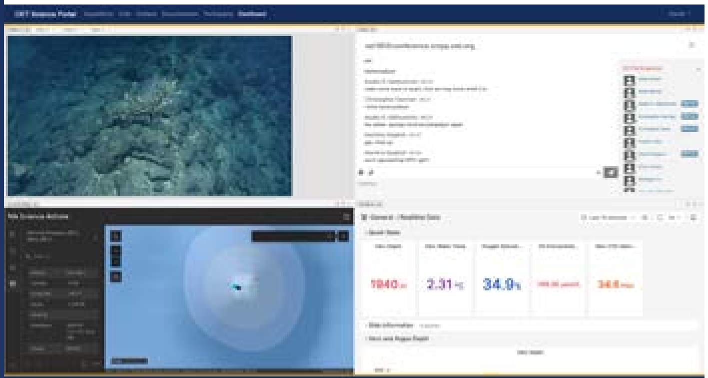


Figure 1. Registered scientists ashore obtain access to the OET Science Portal, which provides real-time access to video feeds, data streams, as well as a text-based chat for communications with the shipboard team and other scientists ashore.

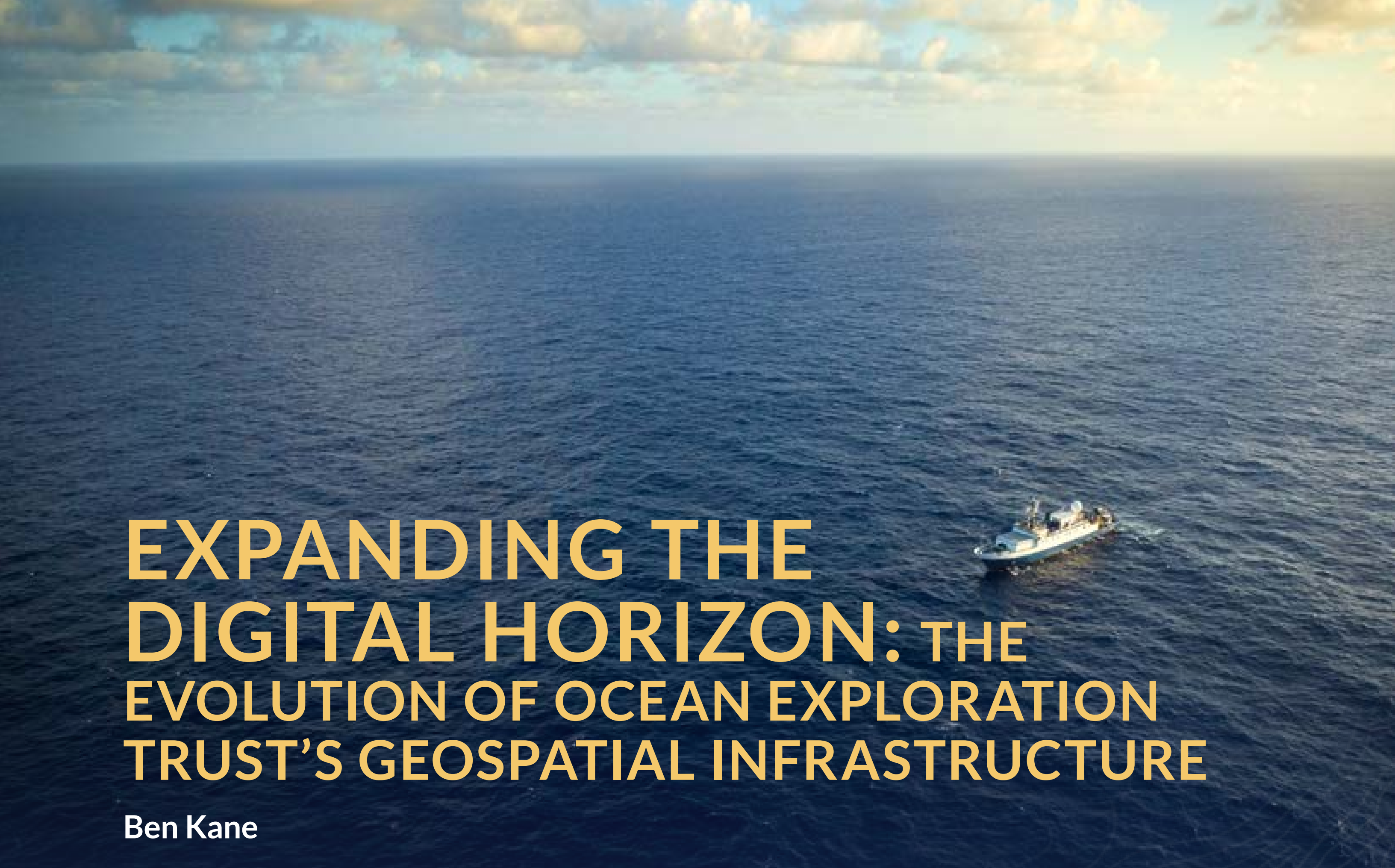
During each expedition, registered scientists ashore gain access to the OET Science Portal (Figure 1), which allows them to access mission data in real time, communicate directly with shipboard science teams and contribute taxonomic identifications, scientific interpretations, and contextual expertise that can inform operational decisions. These low-latency video streams, real-time data, and two-way communication tools simulate being present in the control van and enable meaningful scientific contributions from shore.

Figure 3. The NA173 expedition team in the control van was in constant communication with registered scientists ashore while exploring maritime heritage sites in the Solomon Islands.

Challenging the conventional notion of an at-sea-only expedition team, the program supports an ongoing network of researchers, resource managers, students, and partners who engage throughout the planning, execution, and interpretation of each expedition from their own home institutions. During the 2025 season, shipboard teams were supplemented by 221 scientists ashore representing 155 institutions and a wide range of career stages, from graduate students to senior researchers (Figure 2). This expert community contributed to several highlights of the 2025 season. In the Solomon Islands, the OET Science Portal chat room became a consistently active workspace where archaeologists and historians from the United States, Japan, Australia, New Zealand, Solomon Islands and other countries collaborated to document maritime heritage sites, comparing real-time observations with historical records (Figure 3). Working alongside onboard teams, these experts provided historical and cultural context that enriched site interpretation and contributed to the rapid identification of the IJN *Teruzuki*, which had not previously been located (see Ballard et al. in this report). Other season highlights included the rapid identification of a bigfin squid observed during NA176 operations in the Cook Islands—an organism that has only been seen by humans a few dozen times previously (see Soule et al. in this report). Collectively, these contributions demonstrate how the Scientists Ashore Program expands access to deep-sea exploration, strengthens interdisciplinary collaboration, and enables a more responsive and inclusive approach to ocean science.

In 2025, updates to the OET Science Portal and associated communication systems improved the efficiency and accessibility of shore-based engagement, enabling faster information exchange and broader participation across time zones and disciplines. Several enhancements were implemented this year to improve usability and reliability. Instead of requiring manual uploads of relevant expedition documents to the OET Science Portal (i.e, expedition plan, ROV dive plans, and daily situation reports), documents are now automatically linked from Google Drive when they are created. This allows scientists ashore to view live, most up-to-date versions of documents as soon as they become available. As for the chat function within the portal, participants can now view the full chat history of an expedition, and all chat logs are automatically downloaded and included in the standard data package of a given expedition. We also fixed small bugs and user interface issues. Finally, we set up a development server and automated testing to enable us to make larger changes with less risk of impeding the function of the website. Looking ahead, we will continue refining the OET Science Portal to better meet the needs of the scientific community, including making it easier to view multiple data streams in one place and incorporating feedback from users.

As we look toward the 2026 expedition season, the Ocean Exploration Trust remains committed to catalyzing community-driven ocean exploration through the Scientists Ashore Program. We encourage students, early-career researchers, established scientists, and resource managers, particularly those from regions where E/V *Nautilus* expeditions will take place, to register and participate. Broad engagement from local and regional communities helps ensure that expedition activities address locally relevant science and management priorities. Researchers from all sectors who are interested in contributing to expedition planning, execution, and interpretation are encouraged to register for the 2026 E/V *Nautilus* season and become part of this growing, globally connected scientific community.



EXPANDING THE DIGITAL HORIZON: THE EVOLUTION OF OCEAN EXPLORATION TRUST'S GEOSPATIAL INFRASTRUCTURE

Ben Kane

As E/V *Nautilus* continues to survey remote regions of the Pacific, the Ocean Exploration Trust has expanded and refined how expedition data is processed, organized, and shared. Each mission produces a wide range of navigational records, environmental measurements, sampling events, imagery collections, and seafloor-mapping products. Turning this diverse set of inputs into accessible spatial information has been a multi-year effort, one that now supports both scientific analysis and public understanding of where and how exploration unfolds.

Recent efforts have centered on establishing standardized data schemas, automating conversion routines, and assembling a multi-year spatial archive that reflects the full scope of E/V *Nautilus* operations in the Pacific (Figure 1). This year continued that trajectory with refinements to the geospatial data pipeline, enhancements to the central geospatial repository, and new integrations that bring authoritative spatial layers directly into expedition summaries on Ocean Exploration Trust's Nautilus Live website (Figure 2). These developments strengthen the connection between information collected at sea, the analytical systems that depend on it, and the online platforms that share expedition progress with the public.

At the end of every expedition, the Ocean Exploration Trust compiles an expedition geodatabase containing the ship's trackline, ROV routes for each dive, mapping coverage, and associated scientific activity. An automated workflow ingests raw navigation files, ROV position data, observation logs, sampling metadata, imagery references, and mapping outputs. It then produces the corresponding geospatial datasets, with observation, sampling, and imagery datasets linked to the positions where that data was collected.

Beyond assembling spatial layers, the system generates summary metrics that characterize each mission—dive extents and centroids, total bottom time, depth ranges, observation counts, distances traveled by E/V *Nautilus* and its ROVs, and mapped-area calculations. Updates this season refined spatial processing workflows, streamlined handling of mapping inputs, and clarified differentiation among feature types, enhancing the flexibility and precision of the workflow and preparing it to incorporate additional data types and sensor products as they become available. The resulting expedition-level datasets feed into Ocean Exploration Trust's central geospatial repository, a multi-season archive containing data from all E/V *Nautilus* expeditions in the Pacific, missions dating back

Figure 1. Geospatial data pipeline (image credit: Ben Kane).

to 2015. The repository consolidates navigation tracks, dive footprints, observations, sampling records, and mapping layers into a long-term, stable system that supports scientific research, operational planning, and public-facing tools. Researchers can examine survey coverage, analyze multibeam mapping data, revisit dive sites, and explore spatial patterns across expeditions. This year's work also strengthened the repository's internal organization and its integration with ArcGIS services, improving consistency, enabling more efficient queries, and positioning the system to accommodate new datasets as the workflow evolves.

A major advancement is the expanded use of Ocean Exploration Trust's geospatial web services on Nautilus Live. Although these services have supported internal and public tools for multiple seasons, improvements to the repository now allow the services to align more directly with authoritative source layers. This season, interactive web maps powered by these services were embedded into expedition summary pages, visualizing the ship track, ROV dive paths, and mapping footprints—key layers that help illustrate the geographic scope and sequence of mission activities (Figure 2). These maps provide a clearer spatial context for expedition narratives while demonstrating a scalable, service-oriented architecture adaptable to future needs.

The E/V *Nautilus* ship position map also received refinements, integrating more directly with the underlying systems on Nautilus Live. These updates streamline data flow and simplify long-term maintenance and expansion, while preserving the map's familiar functionality for site visitors.

As Ocean Exploration Trust's geospatial systems continue to evolve, we are increasingly well equipped to support a long-term, authoritative record of deep-sea exploration. Future development will extend both the expedition geodatabase workflow and the central geospatial repository to incorporate additional spatial layers and new forms of seafloor and environmental data, supporting a broader suite of geospatial services as well as analytical and communication products derived from the comprehensive archive of expedition data. This ongoing work will ensure that every trackline, observation, sample, and mapping product contributes to a continually advancing understanding of the deep ocean and the missions that explore it.

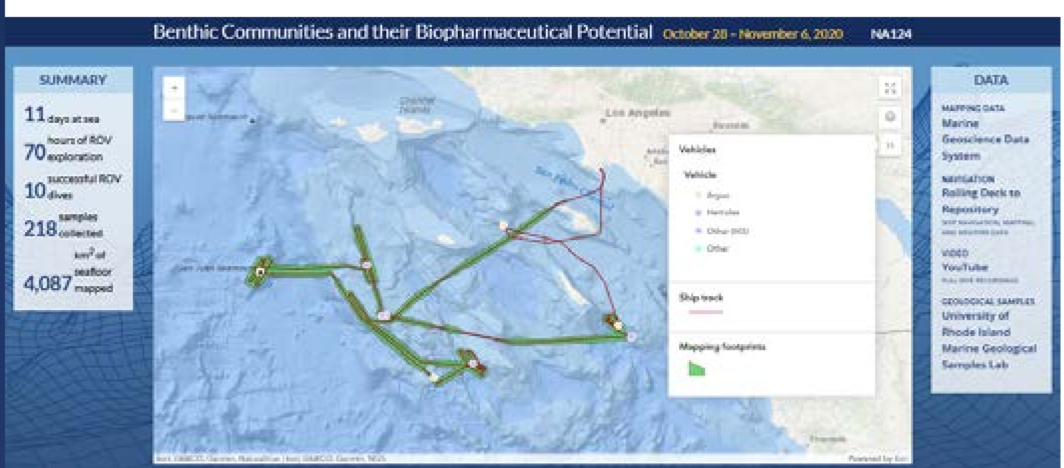


Figure 2. Expedition summary page with new, interactive map (image credit: Ben Kane).

CONTINUAL NETWORK AND INFRASTRUCTURE IMPROVEMENTS ON E/V *NAUTILUS*

Michael D. Labriola

The Ocean Exploration Trust is continuing its mission to share deep-sea ocean exploration with the world, inspiring the next generation of explorers. To do so, we rely on a complex network of technologies and data systems both onboard E/V *Nautilus*, as well as back on shore. During the 2025 season, our team of seagoing data engineers worked tirelessly to handle new challenges that arose within our existing data systems, made creative repairs when things went wrong, and developed plans for future upgrades to continue to grow our onboard data capabilities.

INTERNET CONNECTIVITY TESTING WITH STARLINK AND VSAT

Building upon the 2024 season's experimentation with Low Earth Orbit (LEO) satellite internet providers, this season we increasingly relied on the ship's Starlink system. Historically we have relied on the ship's Very Small Aperture Terminal (VSAT) antenna for all streaming; however, as this workhorse antenna begins to show its age, the Starlink system provides us an opportunity for continued experimentation to ensure reliability while at sea.

Since we had successfully addressed video streaming issues that arose using Starlink during the 2024 field season, our planned operational configuration for 2025 was to have one channel of live video streaming over Starlink with the other two channels streaming over the traditional VSAT. As seen during testing in 2024, the Starlink system—just like the traditional VSAT antenna—continued to be susceptible to connectivity loss during rain or heavy seas. With our shipboard router configured to switch traffic over to the Starlink automatically from the very small aperture terminal if packet loss got too high, we aimed to improve our uptime. Over the course of the 2025 season, we were very pleased with the ship's ability to switch between the two systems, allowing the video streams back to shore to continue seamlessly when one of the interfaces became unusable. On several occasions, two or even all three of the video streams were flowing over the Starlink with good results. Our engineers will continue to define the appropriate thresholds for switching between the two antenna systems, but overall it is proving to be a reliable feature for at-sea operations going forward.

Figure 1. The E/V *Nautilus'* long-serving Very Small Aperture Terminal (VSAT) antenna—the large white ball on top of the ship—has enabled live telepresence and deep-sea exploration broadcasts for many years. During the 2025 field season, Ocean Exploration Trust engineers tested various satellite systems to improve connectivity resilience and ensure seamless data and video streaming during expeditions at sea. If you look closely, you may note several small Starlink antennas mounted on the control van.

While the Starlink system seems to hold up very well to the additional load in general, we did experience a multiple day outage in July 2025. SpaceX described the problem as a 2.5 hour global outage, but due to the complexity of our telepresence system, it took a few days for all the affected components to return to normal operations. During this outage, the ship relied entirely on the traditional VSAT system, which held up nicely despite the increased bandwidth load and loss of any further load balancing.

Our aging VSAT system is now creeping towards the end of its life, with upkeep cost increasing and replacement parts becoming more difficult to source. As such, we are more motivated than ever to find an additional mobile internet system to add to E/V *Nautilus* to ensure reliable internet connectivity during future expeditions. Over the course of the 2026 season we hope to expand our testing to include other competing LEO satellite internet providers, such as OneWeb.

PREPARING TO MIGRATE FROM HIGH DEFINITION TO ULTRA HIGH DEFINITION VIDEO

The ship's video distribution system was initially designed around high definition (HD) video streams, but ultra high definition (UHD) video is starting to become fairly mainstream. While our remotely operated vehicles (ROVs) still have high definition cameras, we took the opportunity during the NA176 expedition to experiment with a UHD camera—the MxD SeaCam from DeepSea—to create a definitive list of pinch points in the video distribution system (see Steiner and Rossoshanskiy in this report). This proactivity enables us to plan for the future integration, paving the way for the eventual upgrade to UHD cameras on our ROVs.

Getting our current video recorders working with the UHD camera required some reconfiguration and a new build of software, but was successfully integrated thanks to the tremendous efforts by our seagoing engineers. Recording UHD video greatly increased our required storage capacity, as well as required write speeds. By the end of the NA176 expedition, we had collected nearly 230 terabytes of data—comparable to a full E/V *Nautilus* season recorded using our existing high definition cameras.

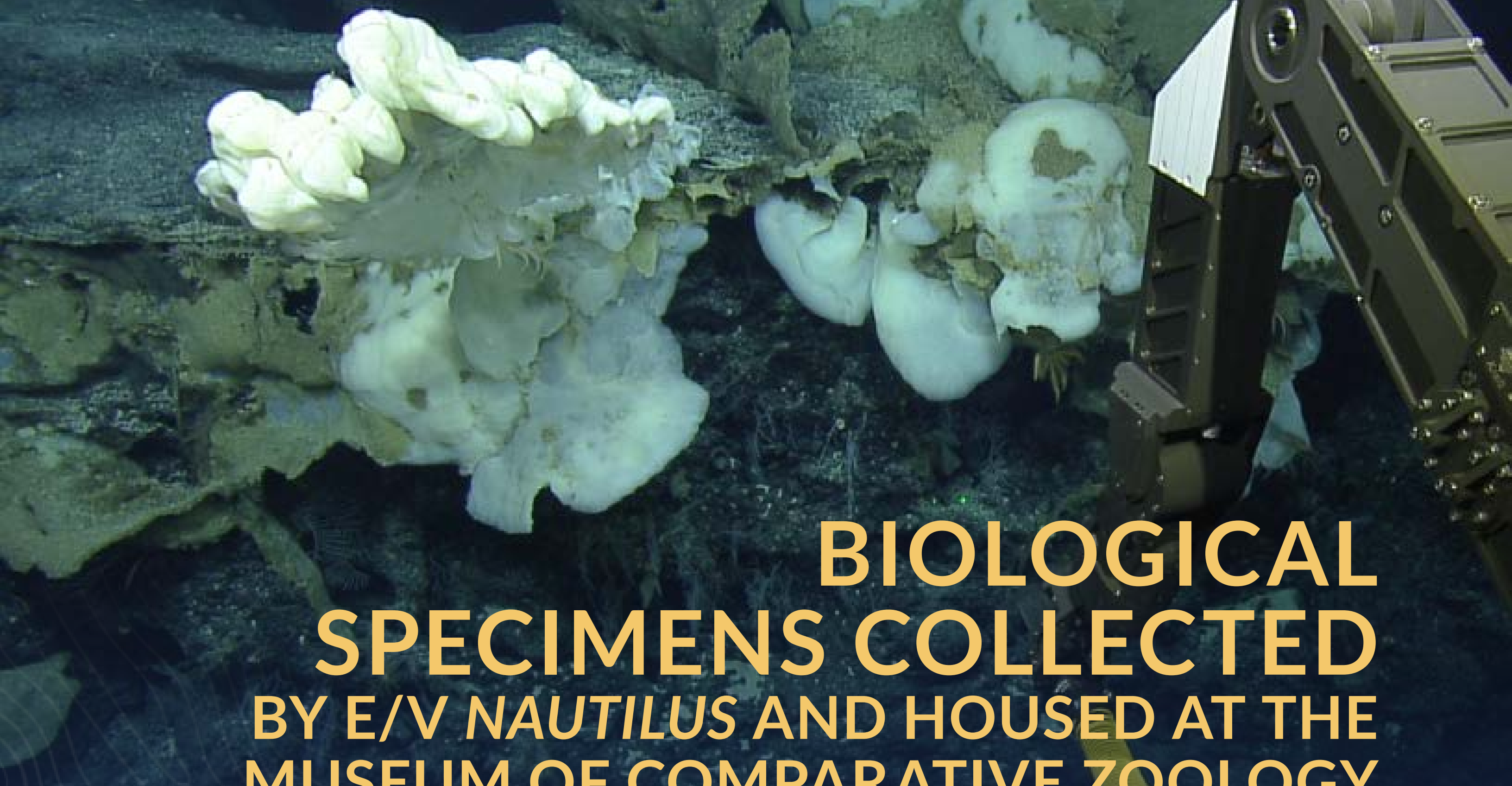
Figure 2. Inside the E/V *Nautilus* control van, integrated data systems power telepresence exploration by routing live video and scientific data from ship to shore. Ongoing infrastructure improvements and adaptive satellite switching help ensure reliable, real-time connections throughout expeditions.

Figure 3. A sea cucumber imaged with the MxD SeaCam highlights the potential of ultra high definition imaging at sea. Capturing this level of detail depended on seamless integration across the ship's data systems.

Our tests showed us that our network speeds were appropriate, but care needs to be taken to ensure full 10 gigabit connections between the recorders, network switches, and the storage array. Playback over the network can be similarly hindered by slow 1 gigabit connections. We even had problems with some computers with multiple network interface cards, one 10 gigabit and one 1 gigabit, doing unhelpful load balancing between the two, resulting in half the network traffic running at 10 gigabit and the other half running at only 1 gigabit.

Normally, our video data, both low and high resolution, is written to a series of physical data storage devices called Linear Tape-Open (LTO) cartridges, which are transported to the Inner Space Center at the University of Rhode Island at the end of each expedition. While our current set of LTO-8 tape drives will write to both LTO-8 and LTO-7 tapes, we have typically used the older LTO-7 tapes. While writing UHD video to the LTO-8 tapes we had on hand for testing, we were able to keep up with the amount of video being recorded. Once we used all our LTO-8 tapes, we switched to LTO-7 for the rest. LTO-7 could not keep up, resulting in a slowly increasing backlog of video to be written to tape as we kept recording UHD video from the ROVs. Luckily, we had just enough time transiting back to shore to finish flushing UHD video to LTO-7 before disembarking. Using LTO-7 tape cartridges also resulted in an unwieldy bag of tapes to bring back home. A normal ROV video recording in high definition to LTO-7 tapes usually results in five to seven tapes being carried home. After our NA176 expedition, we had to carry 22 tape cartridges home (4 LTO-8 and 18 LTO-7).

The opportunity to test out the integration of a UHD camera into our existing data systems proved extremely useful for future planning, enabling the data team to clearly understand the challenges and opportunities ahead. In particular, when our cameras on the ROVs are upgraded to UHD, we will look to increase both the capacity and write performance of our storage array, in addition to upgrading our tape cartridges in order to keep pace with the current state-of-the-art technology.



BIOLOGICAL SPECIMENS COLLECTED BY E/V *NAUTILUS* AND HOUSED AT THE MUSEUM OF COMPARATIVE ZOOLOGY

Adam Baldinger and Jennifer Winifred Trimble

Biological specimens collected by the Ocean Exploration Trust on E/V *Nautilus* expeditions are permanently archived in the Museum of Comparative Zoology at Harvard University. Since 2013, nearly 5,000 biological specimens from 54 different E/V *Nautilus* expeditions have been accessioned at the museum. In 2025, biological specimens collected on E/V *Nautilus* expeditions NA171 and NA174 (Figures 1, 4, and 5) have been deposited in the Invertebrate Zoology and Malacology collections at the Museum of Comparative Zoology. Nearly all these specimens represent deep-sea-specific taxa, including interesting crustaceans and polychaete worms. After specimens are accessioned at the museum, their metadata—such as images, associated location and environmental information—become publicly available online through our museum-wide database, MCZbase. Additionally, this metadata is shared with other data aggregators like GenBank, iDigBio, and GBIF, thereby making these rich biodiversity datasets available to researchers from around the world.

Many of the biological specimens collected by E/V *Nautilus* are either the first occurance for the museum collections or represent a new locality from which a given species is found. Scientists from the Museum of Comparative Zoology and elsewhere use these specimens for research, and several new species have been described from E/V *Nautilus* specimens housed at the museum.

Figure 1. Once ROV *Hercules* returns to the surface, biological samples are carefully identified, imaged, and preserved by onboard scientists before being transferred to the Museum of Comparative Zoology for long-term curation.

Figure 2. The new limpet species *Pectinodonta nautilus*, which was recently described from specimens collected by ROV *Hercules* on dive H1999 during the NA153 E/V *Nautilus* expedition to Johnston Atoll.

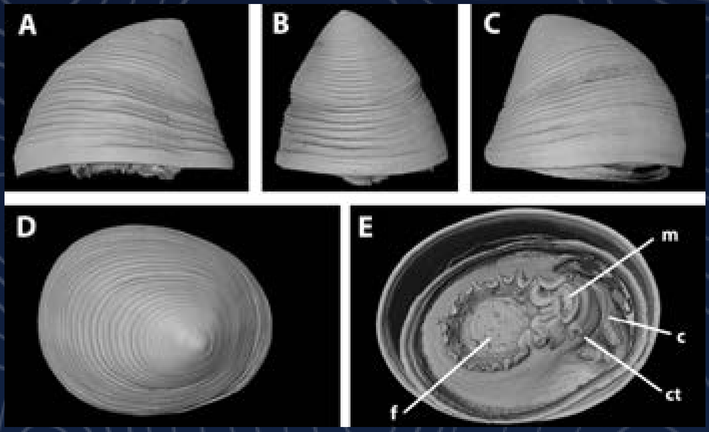


Figure 3. The *Pectinodonta nautilus* holotype housed at the Museum of Comparative Zoology (MCZ:Mala:413272). A: right view, B: frontal view, C: left view, D: apical view, and E: ventral view of body. Abbreviations: c=ctenidium, ct=cephalic tentacle, f=foot, and m=mouth.

Most recently, a new limpet species was described by museum staff members Gonzalo Giribet and Jennifer Winifred Trimble, as well as past postdoctoral fellow Paula Rodríguez-Flores and museum graduate student Arianna Lord. The specimens used to describe the new limpet species were collected during E/V *Nautilus* expedition NA153 from a wood fall at a depth of 2,379 meters near Johnston Atoll (Figure 2). The new species *Pectinodonta nautilus* (Figures 2–3) was named to honor E/V *Nautilus* and published in the journal Molluscan Research (Giribet, Trimble, Rodríguez-Flores, and Lord, 2025). Other invertebrates collected on or associated with this wood fall include squat lobsters, amphipods, polychaete worms, and brittle stars, all of which are housed at the museum.

The museum maintains its commitment to support both new and ongoing research initiatives. Researchers are invited to request high-resolution images or micro-CT scans of the specimens. Additionally, researchers are encouraged to visit the museum for further examination of the specimens. In most cases, archived specimens can also be sent out on loan to qualified researchers around the world.

For further information about E/V *Nautilus* specimens housed at the Museum of Comparative Zoology, image or loan requests, please contact Adam Baldinger (Curatorial Associate, Invertebrate Zoology) or Jennifer Winifred Trimble (Curatorial Associate, Malacology).

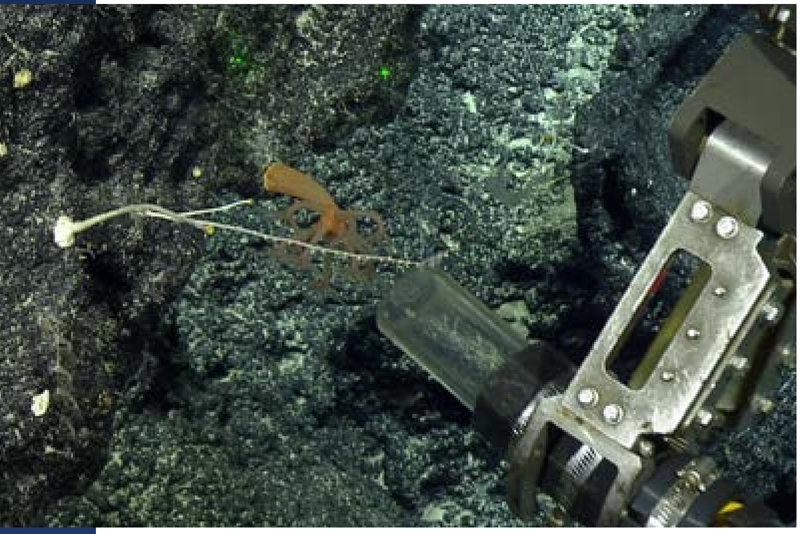


Figure 4. ROV *Hercules* is equipped with a suite of advanced sampling tools that allow scientists to precisely and selectively collect biological specimens, ensuring high-quality samples for further identification and long-term study.

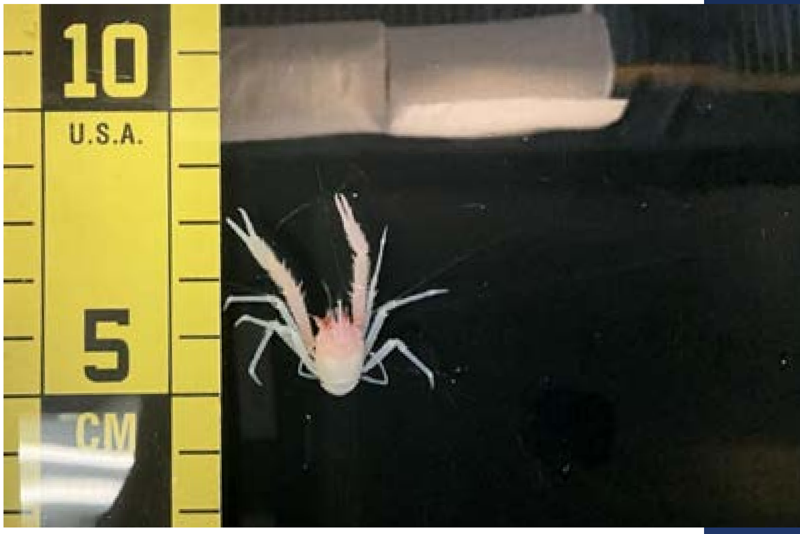


Figure 5. All samples collected during the 2025 expedition season—including this *Munidopsis* squat lobster from the Marshall Islands—are housed at the Museum of Comparative Zoology and are available to researchers for future study and analysis.

E/V *NAUTILUS* GEOLOGICAL SAMPLES ARCHIVES AT THE UNIVERSITY OF RHODE ISLAND'S MARINE GEOLOGICAL SAMPLES LABORATORY

Katherine A. Kelley

In 2024–2025, E/V *Nautilus* explored the Central and Western Pacific, retrieving 138 physical samples of deep-sea rocks and sediments that are now available for scientific research and education through the Marine Geological Samples Laboratory at the University of Rhode Island. We recently completed accessions of these samples, which include specimens collected from American Samoa (NA165), Palau (NA167–169), the Mariana Islands (NA171), and the Marshall Islands (NA174) (Figure 1).

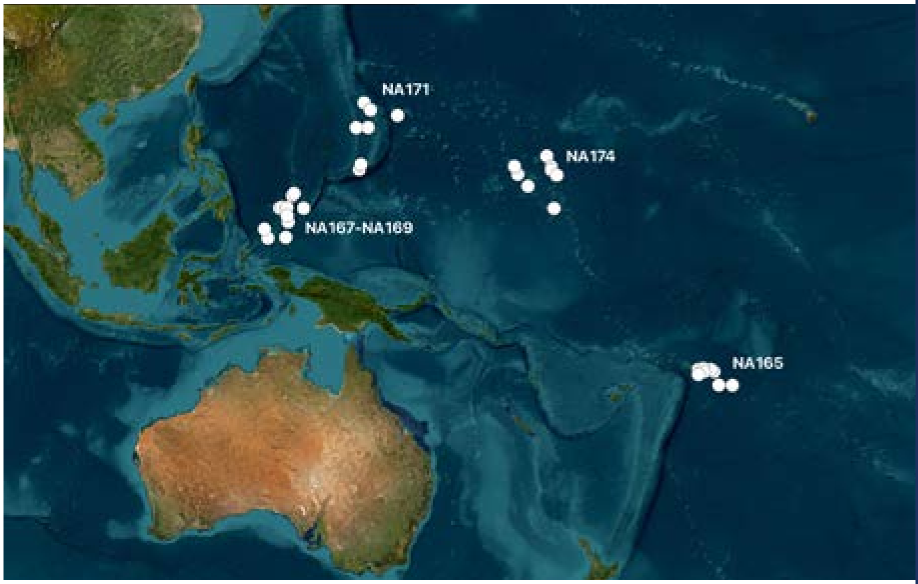


Figure 1. Map showing the locations of geological samples collected during E/V *Nautilus* expeditions in 2024–2025 that were archived at the Marine Geological Samples Laboratory at the University of Rhode Island this year.

Samples from active volcanic regions in the Marianas and American Samoa include young, submarine lava flows, and mineral deposits from active hydrothermal vents (Figure 2), which form through chemical interactions between seawater and hot rocks near submarine volcanoes. Samples from Palau and the Marshall Islands have well-developed ferromanganese crusts (Figure 3) surrounding a variety of igneous and sedimentary rocks. These crusts are slow-growing secondary minerals that precipitate in layers atop hard surfaces exposed on the ocean floor, and can become enriched in metals like cobalt.

Above. A rock sample collected by ROV *Hercules* on a hydrothermal vent deposit on the caldera of Toto Seamount in the Mariana Archipelago.

Figure 2. A rock sample collected by ROV *Hercules* on a hydrothermal vent deposit during dive H2091 on the caldera of Toto Seamount in the Mariana Archipelago.

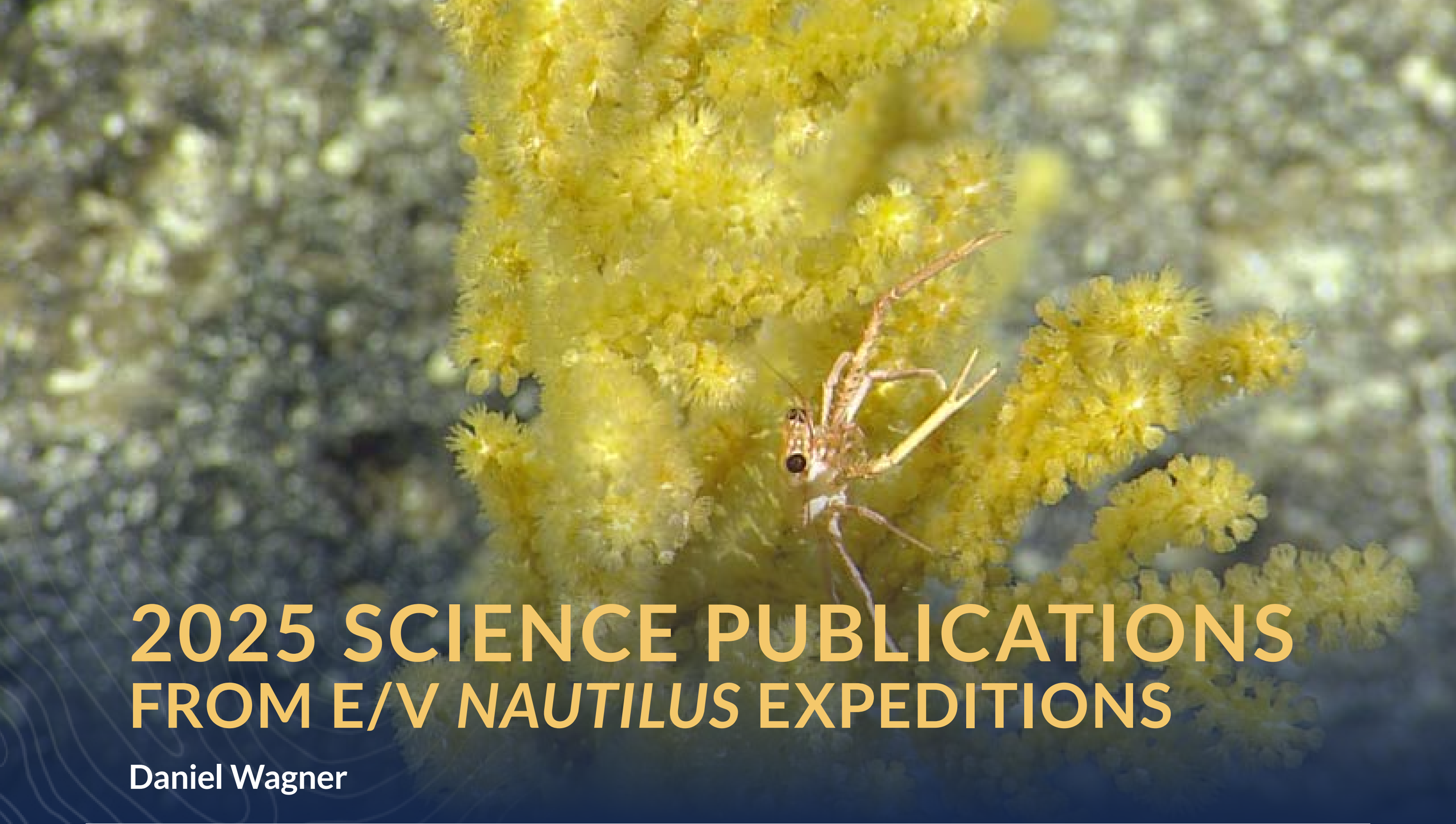
Figure 3. Veined and fractured basalt lava (interior gray rock), coated in a thick ferromanganese crust (black outer layer), collected during the NA174 expedition to the Mariana Islands (image credit: Danielle Cares, University of Rhode Island).

Upon arrival at the Marine Geological Samples Laboratory, samples are cut with a rock saw and described by our staff geologists, assigned permanent International Generic Sample Identifiers, photographed, and stored in accessible racks. Over the past year, the Marine Geological Samples Laboratory has been renovating and expanding its sample storage facilities to accommodate the increasing size of our collections from E/V *Nautilus*, which now contains 2,075 marine geological specimens dating back to 2012. The facility has migrated the E/V *Nautilus* collections to new storage space with improved accessibility and dedicated capacity for future growth (Figure 4).

The descriptive data for each sample is linked to its unique International Generic Sample Identifier and is searchable at the System for Earth Sample Registration. The Marine Geological Samples Laboratory has also developed new online resources to enable easier access and greater discoverability of our sample collections and associated data. Although the NOAA Index of Marine and Lacustrine Geological Samples has ended its active services for listings of marine geological collections at global sample repositories, a static version of their catalog, current to May 2025, is newly re-hosted through the System for Earth Sample Registration. For newer samples, the Marine Geological Samples Laboratory has also launched a new web sample browser platform for viewing our holdings by sample type and expedition, where most E/V *Nautilus* samples are listed under the ROV/HOV grab collection. We are also developing a new web-accessible, searchable database that will come online in 2026.

The Marine Geological Samples Laboratory welcomes inquiries from scientists, educators, and others who aim to learn more about our samples, plan to request samples for research or educational activities, or wish to visit our facility for access to our physical collections or for a facility tour. To learn more visit our website, follow us on Instagram (@URI-MGSL), or reach out to us by email (mgsl@etal.uri.edu).

Figure 4. New storage space and racks for E/V *Nautilus* samples at the URI MGSL (image credit: Danielle Cares, University of Rhode Island).



2025 SCIENCE PUBLICATIONS
FROM E/V *NAUTILUS* EXPEDITIONS

Daniel Wagner

A major goal of the Ocean Exploration Trust is to provide a rich foundation of publicly-accessible information to catalyze follow-on exploration, research, and management activities. In addition to this report summarizing accomplishments from the 2025 E/V *Nautilus* field season, a total of 64 science publications were published in 2025 that used data collected by E/V *Nautilus* expeditions in previous years. These publications cover a wide range of topics and scientific disciplines, highlighting the highly interdisciplinary nature of our work.

Bell KLC, Johannes KN, Kennedy BRC, Poulton SE (2025). How little we've seen: a visual coverage estimate of the deep seafloor. Science Advances 11(19): eadp8602. https://doi.org/10.1126/sciadv.adp8602

Borrero R (2025). El galeón San José: contextualización histórica, riesgos y alternativas a la extracción del hallazgo arqueológico más significativo en aguas colombianas. Maguaré 39(1): 47-87. https://doi.org/10.15446/mag.v39n1.118066

Bourland W, Pomahač O, Méndez-Sánchez D, Beinart RA, Bernhard JM, Čepička I, Rotterová J (2025). The end of a winding path: the anaerobic ciliate *Spirorhynchus* is a member of the class Muranotrichea. Protist 179: 126129. https://doi.org/10.1016/j.protis.2025.126129

Burkhardt I, Bone HK, Grayson NE, Leucke HA, Gutleben J, Jensen PR, Quattrini AM, Chase AB, Moore BS (2025). Diversification of diterpene biosynthesis occurred early in octocoral evolution. Proceedings of the National Academy of Sciences 122(48): e2520279122. https://doi.org/10.1073/pnas.2520279122

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WHAT IS NEXT

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As the pages of this report make clear, the 2025 E/V *Nautilus* field season was defined by discovery, partnership, and the kind of research that only happens when the right people, tools, and questions come together. And yet, for all that was accomplished, it also offers a reminder of how much remains to be explored and better understood. The majority of the global ocean remains unmapped and unexplored, and the Pacific, where E/V *Nautilus* will be focused for the foreseeable future, is no exception. At our current pace, and with the technology available, we do not yet have data at the scale and resolution needed to fully understand these environments—what they contain, what lives there, and what decisions they should inform. That commitment to understanding and to sharing what is found openly and transparently remains as central to the work ahead as it has been to everything you have read in this report. In the years ahead, E/V *Nautilus* will continue to work through seafloor mapping, ROV exploration, and the integration of technologies that expand what is possible. In 2026, expeditions will take the ship to both familiar and new geographies—the Hawaiian Islands, the Mariana Islands, and Wake Atoll—each one an opportunity to ask new questions in parts of the ocean that have rarely been studied.

A consistent principle runs through decades of ocean science and exploration: exploration enables discovery, and discovery provides a foundation for informed decision-making. The ocean is too important, and too little understood, for the decisions made about it to outpace the science behind them. Sustained ocean exploration is how we close that gap, building the trusted body of knowledge that responsible ocean management, at every level, depends on. The 2026 field season will bring significant new tools to E/V *Nautilus*, expanding the scope of what is possible. A new Kongsberg EM 304 MKII multibeam sonar will replace the EM 302 that has served the ship for 13 years, dramatically expanding our ability to map the seafloor at full ocean depth and more than doubling our swath coverage at depths below 5,000 meters. Anticipated upgrades to ROV *Little Hercules* will expand our abilities to collect samples at depths below ROV *Hercules*'s current 4,000-meter depth range, allowing us to more systematically investigate ecosystems and geological features that remain largely underexplored. Each new capability helps us move the needle from discovery to characterization, and as new technologies emerge, the Ocean Exploration Trust will continue integrating cutting-edge tools that expand what is possible and deepen the scientific value of our expeditions.

The multi-vehicle approach that has proved so valuable to our expeditions for years will continue to evolve. Woods Hole Oceanographic Institution's autonomous underwater vehicle *Sentry* will once again work alongside E/V *Nautilus*' ROV and mapping systems. Together with a low-light camera lander, DeepSea's ultra-high definition camera, Biogeochemical-Argo floats, and high-frequency acoustic recording packages, these complementary systems will collectively push the boundaries of what a single expedition can accomplish.

Upcoming expeditions will also advance important interagency priorities. Dedicated surveys around Guam and the Commonwealth of the Northern Mariana Islands will support the US National Strategy for Ocean Mapping, Exploration, and Characterization, building on strong interagency foundations established through E/V *Nautilus* surveys in 2023–2025. The Ocean Exploration Trust will also return to Guadalcanal in 2026 to support shallow-water mapping surveys for the Defense POW/MIA Accounting Agency, work that reflects the many ways ocean exploration can help us honor the past. Beyond the expeditions themselves, we are expanding the Ocean Exploration Trust's educational reach through a new partnership with the National Center on Education and the Economy, and will continue to grow the recently launched traveling exhibit program, bringing the stories of deep-sea exploration to new audiences across the US.

Through it all, partnerships will remain at the heart of this work. The relationships and collaborations you have read about in this report—with NOAA Ocean Exploration, the NOAA Ocean Exploration Cooperative Institute, the Office of Naval Research, and many others—together with Ocean Exploration Trust's dedicated staff, Board of Directors, and contractors, are the foundation upon which every expedition and program is built, and the reason the work ahead is so full of promise. Looking ahead, the Ocean Exploration Trust will continue to cultivate new partnerships that strengthen our ability to explore, understand, and share the deep ocean. Ensuring the long-term sustainability of ocean exploration remains central to our mission, and we will continue working with partners across sectors to support the science and stewardship that informed decision-making requires. Central to that long-term vision is the concept of the Ballard Ocean Exploration Center—a proposed Connecticut-based institution that would serve as an enduring home for the legacy of ocean exploration and a destination for the next generation of explorers and scientists.

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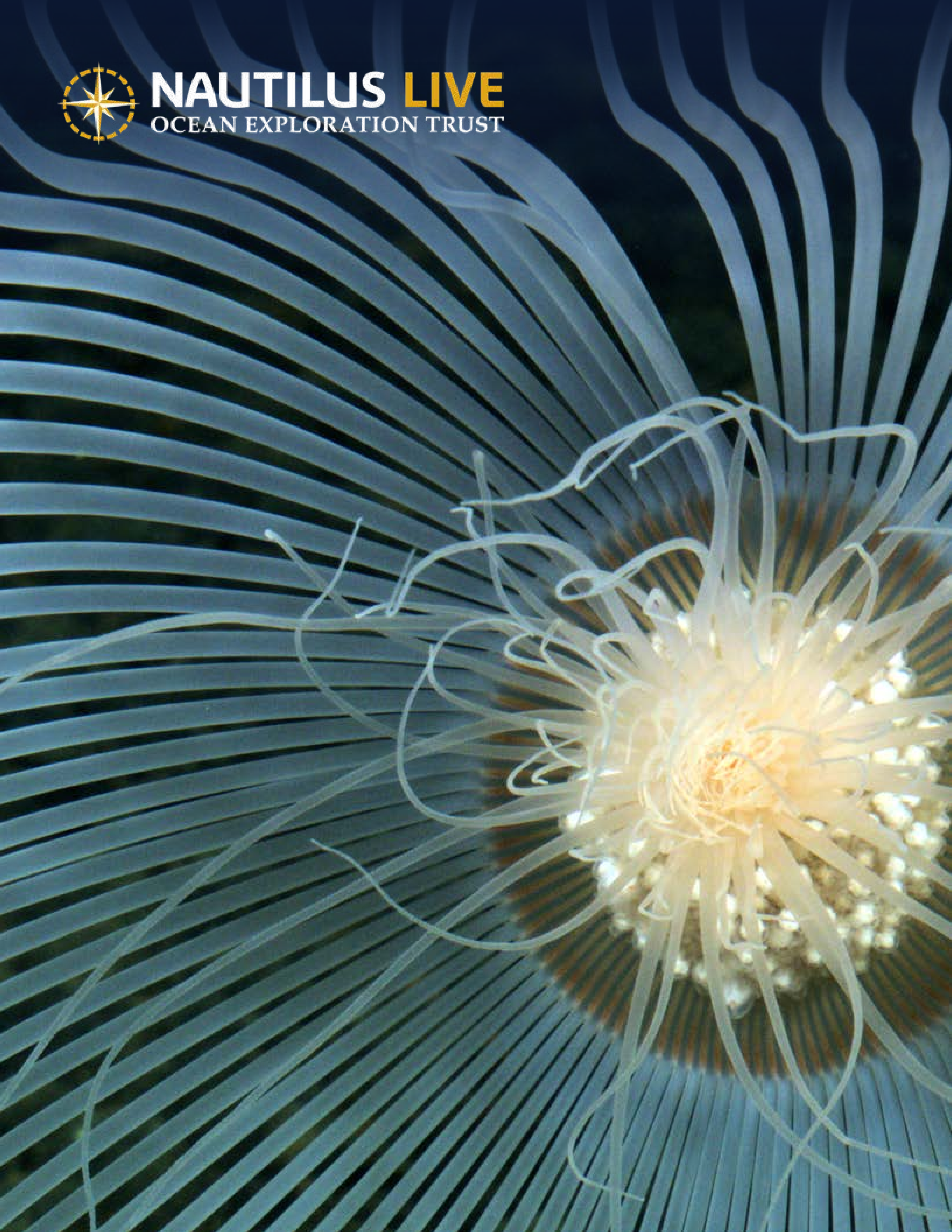
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