THE OCEAN EXPLORATION TRUST
2024 FIELD SEASON

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SUGGESTED CITATION
Wagner, D. (ed.) 2025. The Ocean Exploration Trust 2024 Field Season. Ocean Exploration Trust. 88 pp.
https://doi.org/10.62878/unc751

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INTRODUCTION

Daniel Wagner and Allison Fundis

This annual report marks the 16th anniversary of Ocean Exploration Trust's E/V *Nautilus* exploring poorly known parts of our global ocean in search of new discoveries. Since its first season in 2009, E/V *Nautilus* has conducted a total of 169 multi-disciplinary expeditions throughout the Pacific, Atlantic, Mediterranean, and Black Sea for a total of 2,133 days at sea (~5.8 years). These scientific expeditions included a total of 1,078 successful ROV dives, as well as mapped over 1,204,000 square kilometers of seafloor. The results of these expeditions have been summarized in over 360 peer-reviewed scientific publications covering a wide range of scientific disciplines, including marine geology, biology, archaeology, chemistry, technology development, and the social sciences.

Over the past 16 years, E/V *Nautilus* has not only been a platform for ocean exploration and discovery, but also a training workspace for early career professionals to obtain valuable at-sea experience, thereby helping to develop a more robust workforce. It has also catalyzed numerous technological innovations, multi-disciplinary collaborations, and inspired millions through Ocean Exploration Trust's extensive outreach initiatives. The 2024 field season was no exception, with E/V *Nautilus* undertaking 11 multi-disciplinary expeditions that explored some of the most poorly surveyed areas across both sides of the Pacific, all of which included numerous activities to share expedition stories with audiences of all ages.

As in previous years, E/V *Nautilus* began its 2024 operations with a shakedown expedition to complete a series of engineering tests in preparation for the field season, and then conducted expeditions focused on mapping large stretches of seafloor across the Pacific, supporting maintenance of the Ocean Networks Canada cabled observatory, multi-vehicle explorations in American Samoa, ROV explorations of the Palau National Marine Sanctuary, and deployments of multiple robotic assets to study the physical oceanography around the Palauan Islands. Three of these expeditions included the deployment of multiple vehicles from partners of the NOAA Ocean Exploration Cooperative Institute, a consortium of oceanographic institutions that brings together the extensive expertise of the University of Rhode Island, University of New Hampshire, Woods Hole Oceanographic Institution, University of Southern Mississippi, the Ocean Exploration Trust, and its many partners to advance the core mission of NOAA Ocean Exploration. These technology integration expeditions showcased the value of combining complementary ocean exploration technologies, in addition to inter-institutional collaborations, to increase the depth and breadth of ocean exploration missions.

Stories and discoveries resulting from E/V *Nautilus* expeditions were shared with broad audiences via numerous avenues, collectively reaching millions around the world. Across the 2024 field season, expedition teams hosted 545 live interactions from the broadcast studio onboard E/V *Nautilus*, welcomed aboard 74 students and educators, gathered over 59 million impressions via Ocean Exploration Trust's social media channels, developed 130 new educational resources, and worked to promote the results of our expeditions via 1,722 press stories published by media outlets in 68 different countries.

The accomplishments of the 2024 field season were only possible thanks to the numerous partners that contributed to our work, including both ship-based and shore-based partners that are detailed throughout this report. In 2024, we continued to build on our long-standing collaborations with NOAA Ocean Exploration, NOAA Ocean Exploration Cooperative Institute, NOAA Office of National Marine Sanctuaries, Ocean Networks Canada, Office of Naval Research, National Geographic Society, Museum of Comparative Zoology, Marine Geological Samples Laboratory. Additionally, we initiated many new partnerships with government agencies, academic institutions, and private organizations in the geographies where expeditions took place. These partnerships focused not only on gaining new information about our largely unexplored ocean, but also on how to meaningfully share this knowledge with a wide array of stakeholders. In particular, we leveraged our partnerships with the National Marine Sanctuary of American Samoa and the Palau International Coral Reef Center to ensure that our expeditions in these areas were thoughtfully planned and implemented in a way that incorporated local priorities, participation, and input.

TECHNOLOGY

Samantha Wishnak, Captain Pavel Chubar, Josh Chernov, Derek Sowers, Matt Koskela, 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, Rostock, Germany

IMO Number: 6711883

LENGTH: 68.23 meters (224 feet)

BEAM: 10.5 meters (34.5 feet)

DRAFT: 4.9 meters (14.75 feet)

TONNAGE: 1,249 gross, 374 net

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

ENDURANCE: 40 days at sea

SPEED: 10 knots standard, 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

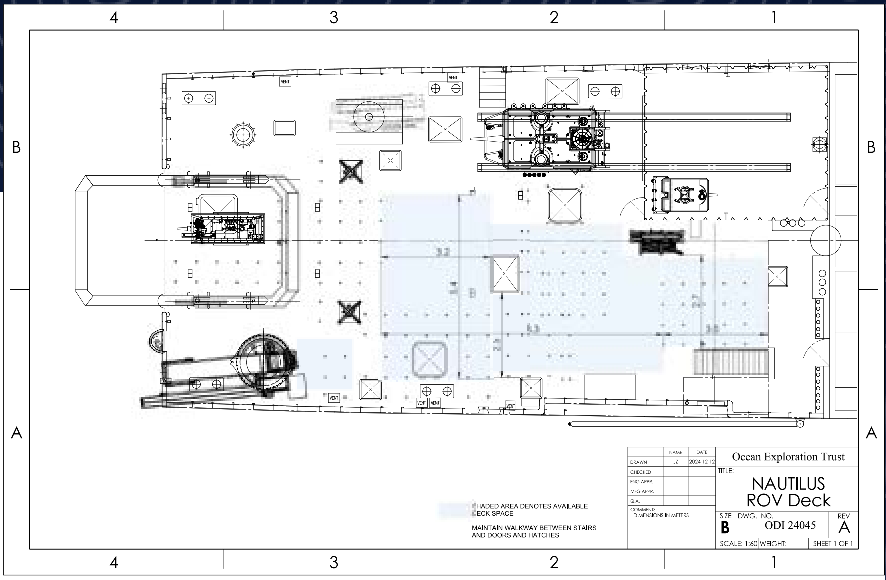
DYNAMIC POSITIONING SYSTEM: Wartsila Nacos Platinum DP0 with 2 independent stations

SHIP SERVICE GENERATORS: Three x Caterpillar C18 585 kilowatt generators

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

COMPLEMENT: 52 (17 crew and 35 science operations)

FLAG: Saint Vincent and the Grenadines



BACK DECK

AREA: 19 meter long (62.3 feet) x 10 meter 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 2000 pound line pull at 50–80 feet per minute and capacity for 1,000 meters of 0.322 wire (science-supplied)
- Bonfiglioli knuckle-boom crane, 2–6 ton capacity, two extensions
- 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 tons safe working load
- Crane and davit, 0.9 metric tons safe working load for deploying two rescue boats

SMALL BOATS

Zodiac Pro 5.5 EPA/ABYC with Yamaha F150LB outboard motor

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

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)

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

CAMERAS: 24 high-definition cameras: aft port, amid and starboard (pan/zoom/tilt), 180° wide aft, transom, bow, command center (8), 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, 2x LTO-6 archive media drives, 2x LTO-8 archive media drives

PRODUCTION STUDIO

AREA: 12 square meters (130 square feet)

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

PRODUCTION: 10-input video production ATEM switcher for live-produced ship-to-shore interactions, full production editing workstation for remote production needs. Mobile belt packs for dynamic connections with 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 engineer

RACK ROOM

AREA: 17.3 square meters (185 square feet)

DATA STORAGE: 50 terabyte onboard storage for non-video data, 150 terabyte disk storage for video data

EMERGENCY COMMUNICATIONS: Iridium phone, KVH 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, approximately 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

ROCK SAW: MK Diamond Products MK-101-24 Tile Saw

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

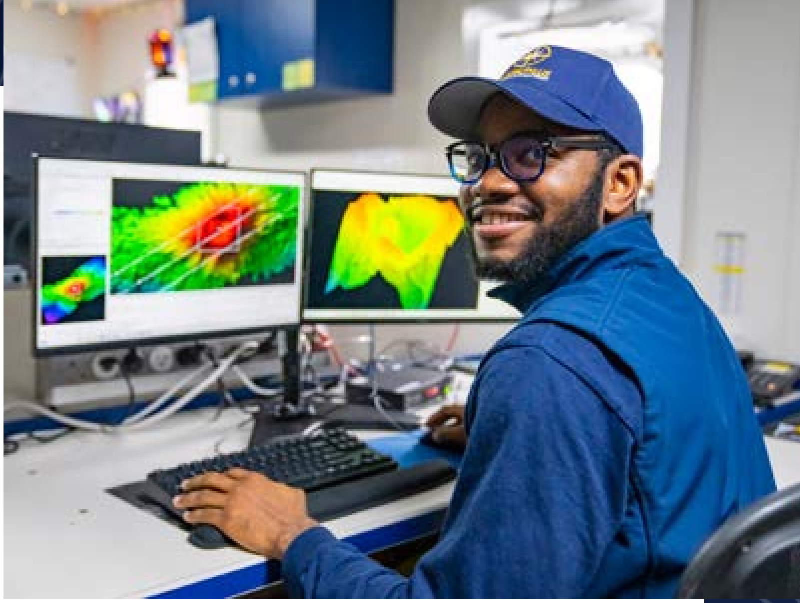
STORAGE: Storage for spares and other equipment

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 about 80 meters below the seabed surface.

OPERATING FREQUENCY: Dual frequency, 3.5 and 15 kilohertz

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

RANGE: 50 meters to full ocean depth

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: About 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)

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 to allow acoustic signals between the ship and each vehicle to determine their 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 also be mounted on the ROV upon request. *Hercules* can carry up to 113 kilogram (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: ~ 2,500 kilograms (5,500 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/second (<0.25 knots) over complex 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 3830

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)

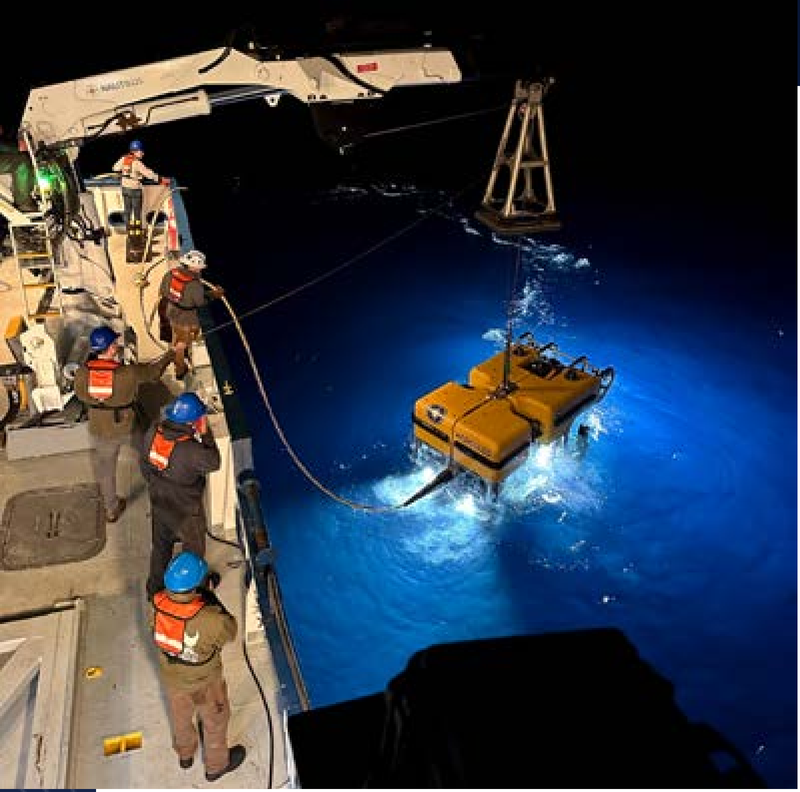
FORWARD-LOOKING SONARS

- 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)
- 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 6 x 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 USER-INSTALLED TECHNOLOGY

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

- *In situ* mass and laser spectrometers
- Fluorometer, pH sensor, eH sensor
- Kongsberg M3 multibeam sonar
- Norbit wideband multibeam sonar - forward or downward facing
- 18 megapixel ethernet connected digital still camera
- Low-light camera
- Modular soft grippers

REMOTELY OPERATED VEHICLE (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)

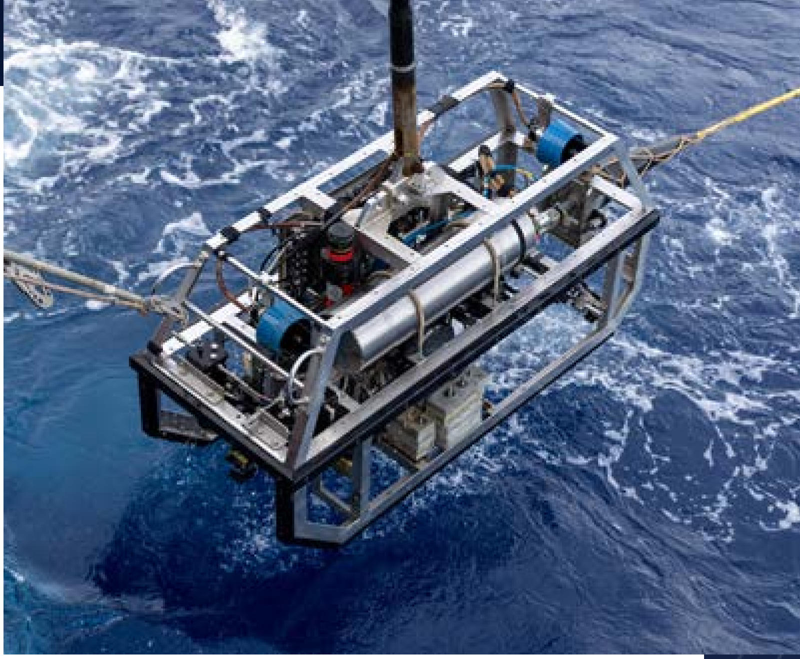
PROPULSION: Two Tecnadyne Model 1020 1 HP thrusters for heading control

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

REMOTELY OPERATED VEHICLE *LITTLE HERCULES*

ROV *Little Hercules* is a smaller sister to *Hercules* with 6,000-meter capability, designed to function similarly 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.

2024 TECHNOLOGY COLLABORATIONS

UNIVERSITY OF NEW HAMPSHIRE
USV *DriX*

WOODS HOLE OCEANOGRAPHIC INSTITUTION
AUV *Mesobot*, AUV *Sentry*, Sensor for Aqueous Gases in the Environment (SAGE), Oceanic-WHOI eDNA multisampler, Aquatic Labs eDNA Multipuffer

UNIVERSITY OF RHODE ISLAND
Deep Autonomous Profiler, Norbit wideband multibeam sonar (on ROV)

SCRIPPS INSTITUTION OF OCEANOGRAPHY
Boeing Liquid Robotics Wave Gliders, Teledyne SLOCUM G3 Buoyancy Gliders, USV *WAM-V 16*, wave buoys

OCEAN NETWORKS CANADA & FISHERIES AND OCEANS CANADA
Deep ARVOR floats, ARVOR-I floats, PROVOR-I floats

NOAA PACIFIC ISLANDS FISHERIES SCIENCE CENTER
High-frequency Acoustic Recording Package (HARP)

2024 REMOTELY OPERATED VEHICLE OPERATIONS OVERVIEW

Josh Chernov, Jonathan Zand, Robert Waters, Dan Cormany, and Jake Bonney

The 2024 E/V *Nautilus* field season marked continued advancements in Ocean Exploration Trust's remotely operated vehicles (ROVs), enhancing both their key functions, and exploration applications. The team focused on upgrading the mechanical and software systems of ROV *Hercules*, as well as integrating new tools to expand its scientific capabilities. These targeted improvements were key to the successful execution of 61 successful ROV dives throughout the 2024 season, during which the vehicles logged an impressive 672.5 hours (28 days) exploring deep-sea environments throughout British Columbia, Hawai'i, American Samoa, and Palau (Figure 1).

ROV MECHANICAL UPGRADES

Following the replacement of the ROV *Hercules* aluminum frame in 2023, the team concentrated on enhancing key ROV components and systems to support Ocean Exploration Trust's primary exploration goals of capturing high-quality video imagery and physical samples during dive missions. The next step in this effort was upgrading the hydraulic manifolds, and replacing the port-side manipulator arm. A critical improvement built into the new hydraulic manifolds was the addition of remote adjustment control proportional valves (Figure 2), enabling finer speed control over individual hydraulic functions. This upgrade significantly enhanced general operations, particularly in terms of enabling more controlled movements of the main video camera, which allows for smoother, slower adjustments that vastly improved video quality.

Figure 1. Throughout the 2024 season, the ROV team integrated a series of improvements to the mechanical, hardware and software systems of ROV *Hercules*, which were key to the successful execution of 61 ROV dives.

Additionally, the team retired the ISE Magnum manipulator arm, and replaced it with the more advanced Schilling Orion 7RE arm. This new arm offers superior functionality, reliability, and ease of maintenance. Paired with a smart hydraulic manifold, the Orion 7RE enabled more customized control. Jake Bonney, with support from Dan Cormany, developed an innovative pilot control interface, which was integrated into the existing pilot graphical user interface. Despite tight timelines, the team successfully created a system for single-function control with adjustable flow settings for each joint. The new arm performed exceptionally well, particularly during the NA161 expedition to British Columbia, which required extensive use of the manipulator arm to support maintenance of Ocean Networks Canada's cabled observatory.

Looking ahead, the team is working to develop a new joybox interface to leverage the smart technology in the hydraulic manifold. This project aims to create a manipulator arm that functions more like a spatially-correspondent arm, as opposed to a rate arm. Significant progress has been made during the 2024 season, and the team is excited to implement this new capability in 2025.

GENERAL ROV CONTROL SYSTEMS

The ROV team has been steadily advancing plans to upgrade the main electronics hardware, software control systems, and pilot interfaces of ROV *Hercules*. This long-term project has involved years of development and testing to refine both the hardware and its associated control systems. During the 2025 season, the team will continue testing new power and relay systems by operating a few isolated subsystems. If these tests are successful, they will lay the groundwork for a broader overhaul of the overall control system of ROV *Hercules*. While this ambitious project presents significant challenges, it promises substantial benefits for both the ROV system, and the Ocean Exploration Trust as an organization.

The accomplishments of the 2024 season were made possible thanks to the continued hard work of the collective Ocean Exploration Trust team and its extensive network of partners. Looking ahead, the ROV team eagerly anticipates the challenges of 2025 and beyond, building on the continued successes of past years.

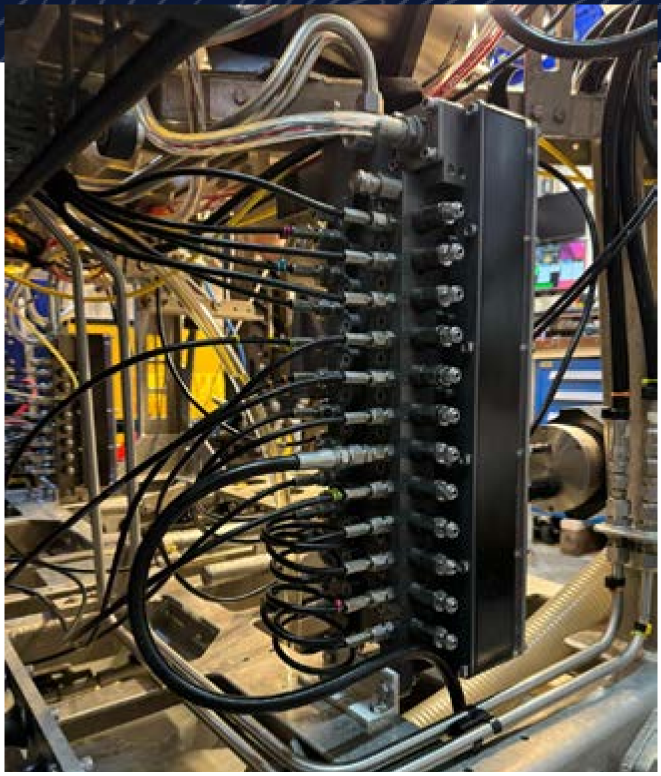


Figure 2. The ROV team added remote adjustment control proportional valves to the hydraulic manifolds of ROV *Hercules*. This upgrade allows for much finer control over individual hydraulic functions, enhancing operations, particularly in terms of improving video quality.

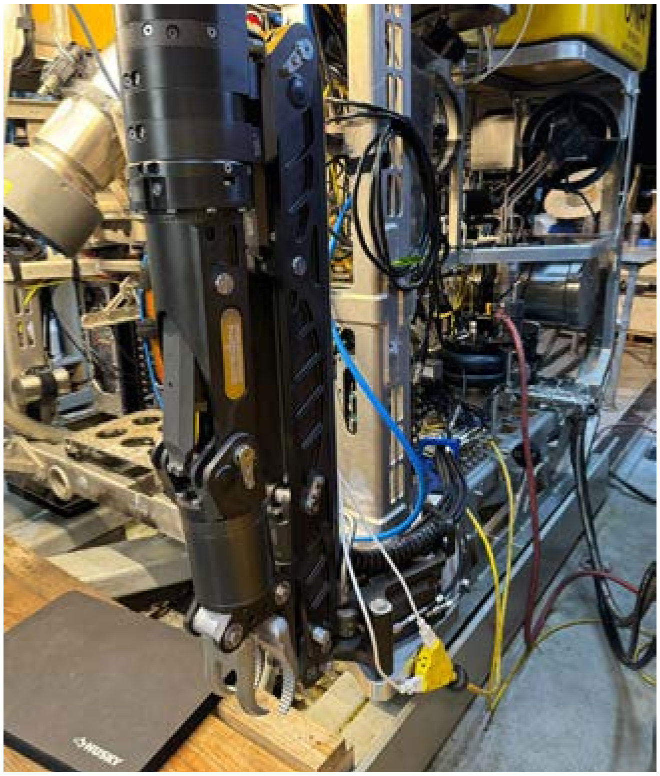
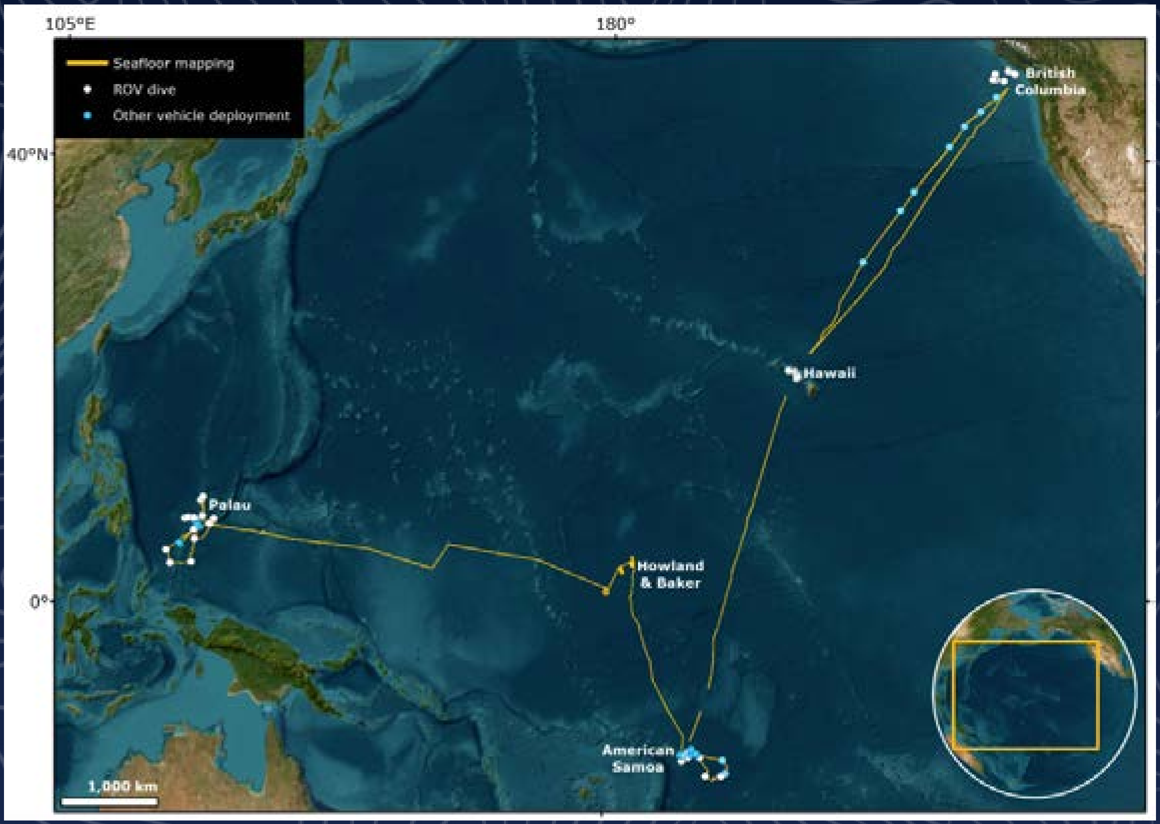


Figure 3. The ROV team installed a new Schilling Orion 7RE manipulator arm on ROV *Hercules*, which offers superior functionality, reliability, and ease of maintenance in comparison to the previous ISE Magnum manipulator arm.



2024 FIELD SEASON OVERVIEW

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

In 2024, E/V *Nautilus* completed an eight-month field season consisting of 11 multi-disciplinary expeditions that explored the Pacific for a total of 163 days at sea. The 2024 season began with a shakedown expedition in Hawai'i to prepare for the fieldwork ahead, followed by others centered on seafloor mapping across the Pacific, supporting maintenance of the Ocean Networks Canada cabled observatory, multi-vehicle explorations in American Samoa, ROV explorations of the Palau National Marine Sanctuary, and deployments of multiple robotic assets to study the physical oceanography around the Palauan Islands. Collectively, the 2024 expeditions mapped over 150,000 square kilometers of seafloor, completed 61 successful ROV dives, and 61 deployments of other vehicles, and engaged many millions of viewers around the world.

SHAKEDOWN (NA159)

Between May 15–22, E/V *Nautilus* conducted a shakedown expedition to prepare the ship's mapping, ROV, and telepresence systems for the 2024 season. During this seven-day expedition in the Main Hawaiian Islands, the team successfully completed annual quality assurance tests of E/V *Nautilus*' mapping and navigation systems, including a multibeam patch test, speed noise testing, and accuracy surveys over a variety of different seafloor depths. Shakedown operations also included five test dives using the ROV system in different configurations (Figure 1).

Figure 1. In preparation for the 2024 field season, the shakedown expedition included five dives to test various components of the ROV system.

HAWAIʻI-BRITISH COLUMBIA MAPPING (NA160 & NA162)

Between May 25–June 4 and June 28–July 7, E/V *Nautilus* conducted two expeditions that mapped the seafloor during transits between British Columbia and Hawaiʻi (Figure 2), focusing on areas that had not previously been mapped. Funded by Ocean Networks Canada, these two expeditions mapped 42,653 square kilometers of seafloor, which included passage over unmapped portions of the Mendocino, Pioneer and Murray fracture zones, as well as several unmapped seamounts. In addition to transit mapping, one of the expeditions (NA162) included the deployment of seven Argo floats from Ocean Networks Canada to support large-scale ocean monitoring efforts. Argo floats were deployed in international waters along the transit route, thereby adding important coverage to the over 3,800 floats that are currently operational globally.

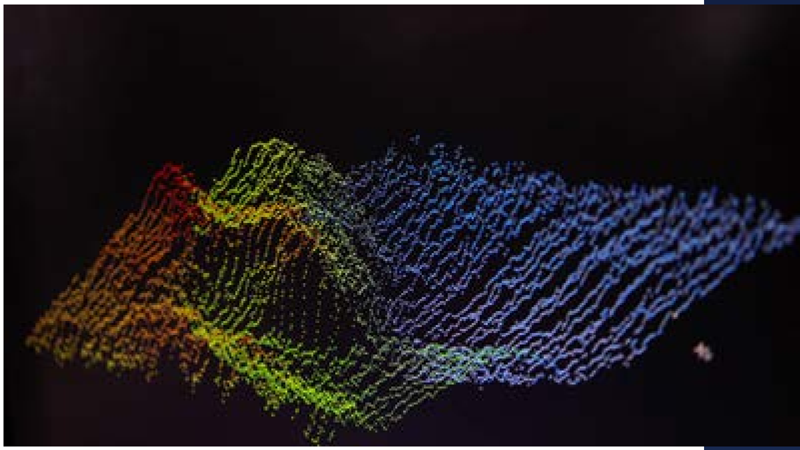
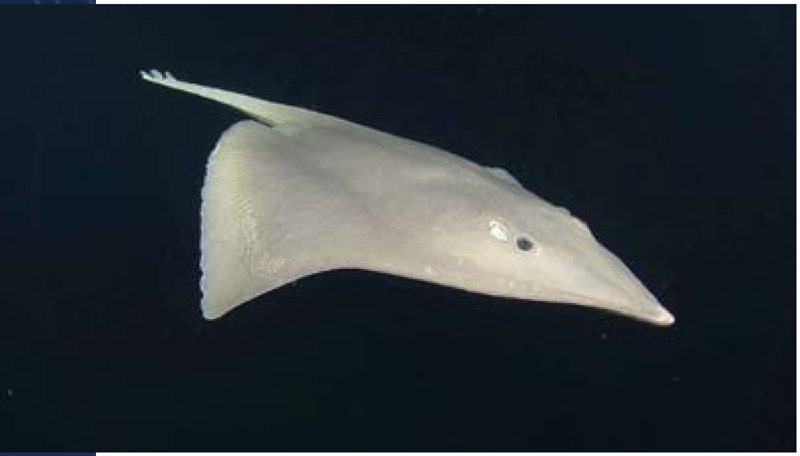


Figure 2. In May-July, E/V *Nautilus* conducted two transit mapping expeditions that mapped seafloor between Hawaiʻi and British Columbia.



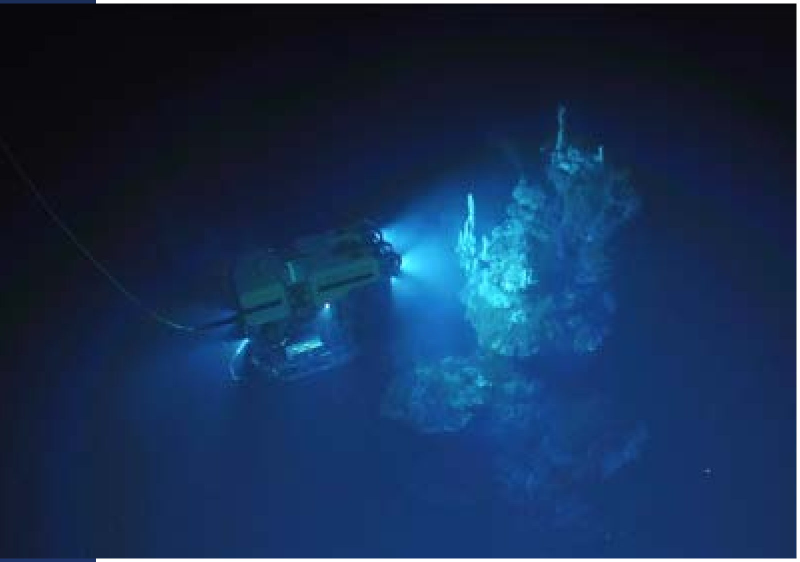


Figure 3. Marking the eighth year of a successful partnership between Ocean Networks Canada and the Ocean Exploration Trust, E/V *Nautilus* supported a 21-day expedition that included ROV surveys of six different NEPTUNE observatory sites, including the Endeavour hydrothermal vent field.

OCEAN NETWORKS CANADA OBSERVATORY MAINTENANCE (NA161)

Between June 6–27, E/V *Nautilus* conducted an expedition to support maintenance of the NEPTUNE Cabled Observatory located off the coast of British Columbia. Funded by Ocean Networks Canada, the expedition included ROV and seafloor mapping operations, as well as the deployment of various instruments. The mission completed 19 successful ROV dives focused on deploying and recovering sensors, in addition to conducting visual surveys at six different observatory sites, including the Endeavour hydrothermal vents field (Figure 3). The mission also included 61 hours of deck operations not associated with ROV dives, including the deployment of three CTD rosette casts, two moorings, six sediment traps, and five ocean bottom seismometers. Furthermore, the expedition included a coordinated dual-ship operation with Global Marine's cable ship *Cable Innovator*, during which the team was successful in laying a secondary replacement cable at Cascadia Basin.

HAWAIʻI-AMERICAN SAMOA MAPPING (NA163)

Between July 22–August 6, E/V *Nautilus* mapped seafloor in the Central Pacific. While the original goal was to conduct ROV operations around Jarvis, the expedition start date had to be delayed due to unforeseen ship repairs. As a result, the expedition shifted its focus to transit mapping operations between Hawaiʻi and American Samoa. Funded by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, the expedition mapped 18,680 square kilometers of seafloor, including 6,555 square kilometers in the US Exclusive Economic Zone around Hawaiʻi, Palmyra, and American Samoa. The expedition also completed one ROV dive to survey the Makapuʻu precious coral bed located east of Oʻahu, which provided important new information to delineate the boundaries of the bed and inform essential fish habitat designations. Furthermore, the expedition deployed an acoustic mooring in American Samoa to support cetacean monitoring efforts (Figure 4).

Figure 4. On the last day of the NA163 expedition, the team successfully deployed an acoustic mooring east of Tutuila Island to support cetacean monitoring efforts by the NOAA Cetacean Research Program.

E MAMANA OU GATAIFALE I AMERICAN SAMOA MULTI-VEHICLE EXPLORATION (NA164)

On August 10–28, E/V *Nautilus* conducted an expedition focused on integrating exploration technologies from NOAA Ocean Exploration Cooperative Institute partners. Funded by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, the expedition used uncrewed surface vehicle *DriX* launched from a shore-based station in Pago Pago, in combination with autonomous underwater vehicle *Mesobot* and the *Deep Autonomous Profiler* launched from E/V *Nautilus*, to explore seafloor and water column habitats of American Samoa (Figure 5). During 16 days at sea, these advanced exploration technologies were used to map, survey, and sample ocean habitats around Tutuila, Taʻū, and Vailuluʻu Seamount. The expedition successfully completed eight *Deep Autonomous Profiler* and 16 *Mesobot* deployments, most of which were closely coordinated with shore-controlled *DriX* operations. The expedition mapped 651 square kilometers of seafloor, including the entirety of Vailuluʻu Seamount, an active underwater volcano. The mission also collected 357 eDNA samples to support studies on the marine biodiversity of American Samoa.

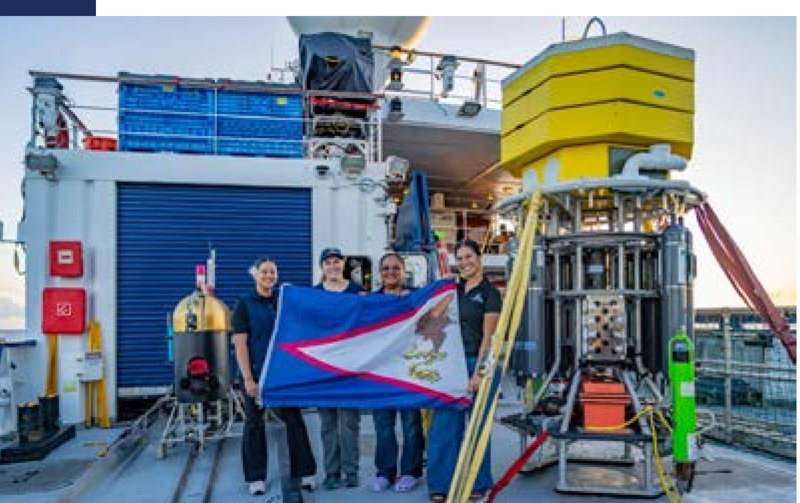


Figure 5. The *E Mamana Ou Gataifale I* expedition deployed various complementary technologies from partners of the NOAA Ocean Exploration Cooperative Institute to explore midwater and seafloor habitats in American Samoa.

E MAMANA OU GATAIFALE II AMERICAN SAMOA DEEP-SEA EXPLORATION (NA165)

From September 1–24, E/V *Nautilus* completed a second expedition to American Samoa, which used the ROV and mapping systems of E/V *Nautilus* in combination with AUV *Sentry* to explore various deep-sea areas prioritized by the science and resource management community. Funded by NOAA Ocean Exploration, the Bureau of Ocean Energy Management, and NOAA Uncrewed Systems Operation Center via the Ocean Exploration Cooperative Institute, the expedition mapped 8,458 square kilometers of seafloor, including seven different seamounts. The expedition also completed 17 successful ROV dives to depths of 300–3,000 meters. Major ROV achievements included the discovery of new vents at Vailulu'u Seamount, and the successful integration of two recently developed instruments. This included the Sensor for Aqueous Gases in the Environment that was used to gather *in situ* methane and carbon dioxide data, and an autonomous eDNA multisampler that was used to filter over 16,000 liters of seawater at depth and collect eDNA samples. The expedition also completed 10 successful dives using AUV *Sentry* (Figure 6), focused on continuing the search for the *Samoan Clipper* underwater maritime heritage site, characterizing abyssal plain habitats, and detecting hydrothermal vent signals above Vailulu'u Seamount. While the *Samoan Clipper* wreck was not located, AUV *Sentry* mapping surveys revealed detailed geologic features at less than 20-centimeter resolution. Other AUV *Sentry* highlights included the deepest surveys in American Samoa to date, the most detailed view to date of the geology associated with the 2006–2019 eruption of Vailulu'u Seamount, and the transmission of data to shore-based scientists in near real time, a unique feat for an untethered autonomous system.

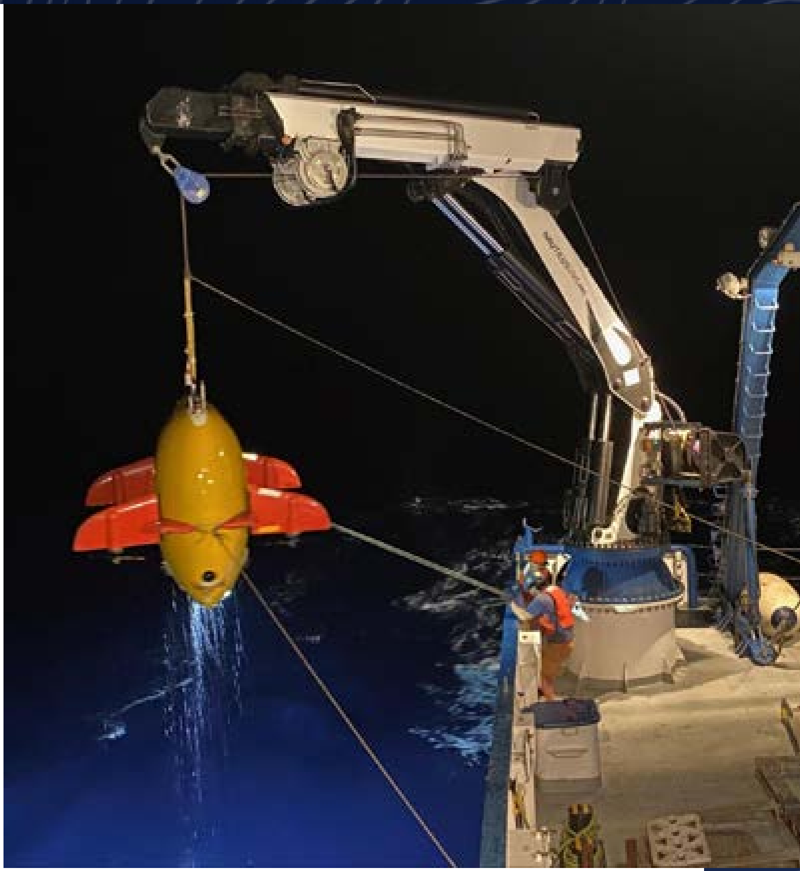


Figure 6. In addition to ROV dives and seafloor mapping using the E/V *Nautilus* systems, the *E Mamana Ou Gataifale II* expedition included surveys using AUV *Sentry* from Woods Hole Oceanographic Institution.

Figure 7. In addition to mapping previously unsurveyed seafloor, the NA166 expedition included topside surveys for seabirds and other marine mammals across over 7,000 kilometers of poorly surveyed portions of the Pacific.

SEAFLOOR MAPPING OFFSHORE HOWLAND & BAKER ISLANDS (NA166)

From September 28–October 25, E/V *Nautilus* conducted an expedition to map seafloor around the islands of Howland and Baker, as well as other unmapped areas along the transit route between American Samoa and Palau. Funded by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, the expedition mapped over 55,151 square kilometers of seafloor, including 11,484 square kilometers in the US Exclusive Economic Zone around Howland and Baker, where seven different seamounts were mapped for the first time. In addition to dedicated mapping around Howland and Baker, the expedition included transit mapping operations in American Samoa, Kiribati, Tokelau, Republic of Marshall Islands, Federated States of Micronesia, and Palau. Furthermore, the expedition also included topside surveys for seabirds and other marine animals, which documented over 1,300 individuals from 26 species of seabirds, two species of shorebirds, one species of landbird, five species of cetaceans, dolphins, and manta rays (Figure 7).

LEBUU'S VOYAGE: EXPLORATION OF THE PALAU NATIONAL MARINE SANCTUARY (NA167–NA168)

From October 29–November 22, E/V *Nautilus* conducted two back-to back expeditions focused on exploring the Palau National Marine Sanctuary. Funded by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, these two expeditions mapped over 19,052 square kilometers of seafloor, and completed 13 successful ROV dives that explored depths between 575–3,200 meters. Noteworthy ROV observations included high-density coral gardens at eight different locations (Figure 8), the collection of several new species of fishes and invertebrates, the first-ever live observations of two species of anglerfish, and the documentation of large areas of fossilized coral reefs that will contribute to our understanding of previous conditions of the region. The expedition also included the collection of 142 eDNA samples to support the monitoring program of the Palau National Marine Sanctuary, including the first-ever samples collected at depth.

Figure 8. The *Lebuu's Voyage* expeditions included the first-ever dedicated surveys of the deep-sea biodiversity of the Palau National Marine Sanctuary.

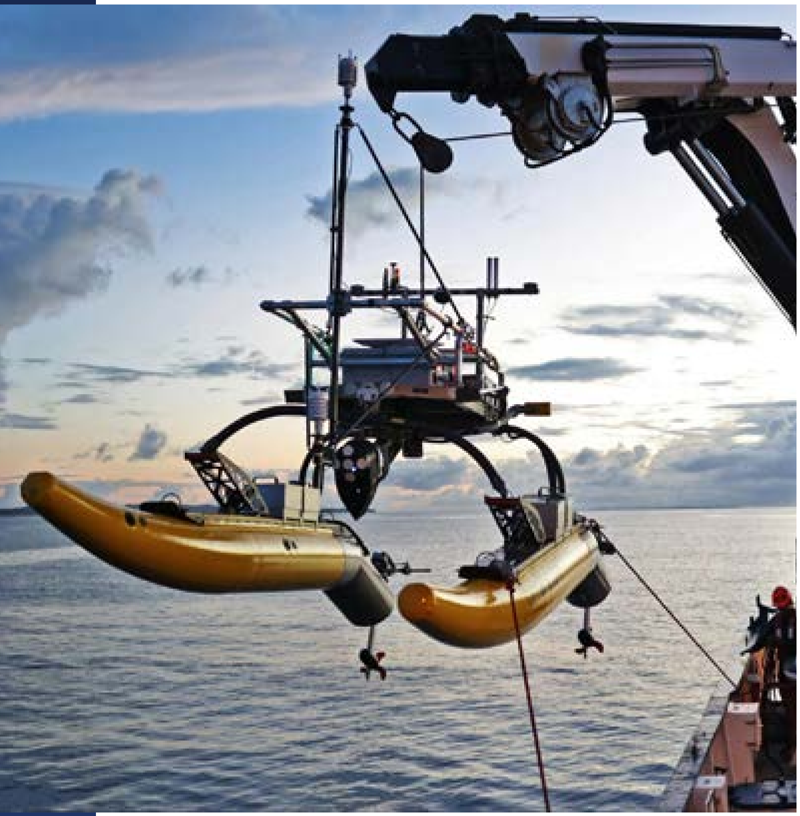


Figure 9. The NA169 expedition focused on exploring the oceanography around the Palauan Islands using various uncrewed vehicle assets from the Scripps Institution of Oceanography, including deployments of the WAM-V uncrewed surface vehicle.

MAPPING & WATER COLUMN EXPLORATION AROUND PALAU (NA169)

Between November 25–December 12, E/V *Nautilus* explored the physical and biological oceanography around Palau using the ROV and mapping systems of E/V *Nautilus*, in combination with various uncrewed vehicle assets from the Scripps Institution of Oceanography. Funded by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, with additional support from the Office of Naval Research, the expedition completed four successful ROV dives that explored depths between 170–760 meters. Additionally, the expedition successfully completed 10 WAM-V uncrewed surface vehicle deployments (Figure 9), two wave glider deployments, and five buoyancy glider deployments, in addition to mapping the seafloor and the water column using the mapping systems of E/V *Nautilus*. The concurrent operations of E/V *Nautilus* with uncrewed assets enabled a unique capability for densely sampling the complex oceanography of the region, achieving a level of resolution and coverage unattainable by other methods.

MAPPING HIGHLIGHTS
OF E/V *NAUTILUS* EXPEDITIONS IN 2024

Derek Sowers, Daniel Wagner, Renato Kane, Lynette Davis, and Kris Krasnosky

E/V *Nautilus* mapping operations in 2024 were completed as part of 11 multi-disciplinary expeditions that spanned across the Pacific Ocean, focusing on high-priority areas in British Columbia, Hawai'i, American Samoa, Howland and Baker Islands, and Palau (Figure 1). Seafloor mapping was also completed while transiting across large expanses of international waters between these destinations. Using the vessel's Kongsberg EM302 multibeam sonar, the Ocean Exploration Trust mapped a total of 150,833 square kilometers of seafloor during 2024 expeditions. In terms of area mapped, this was E/V *Nautilus*' third most productive year since the multibeam sonar was first installed in 2013, just behind 2022 and 2023.

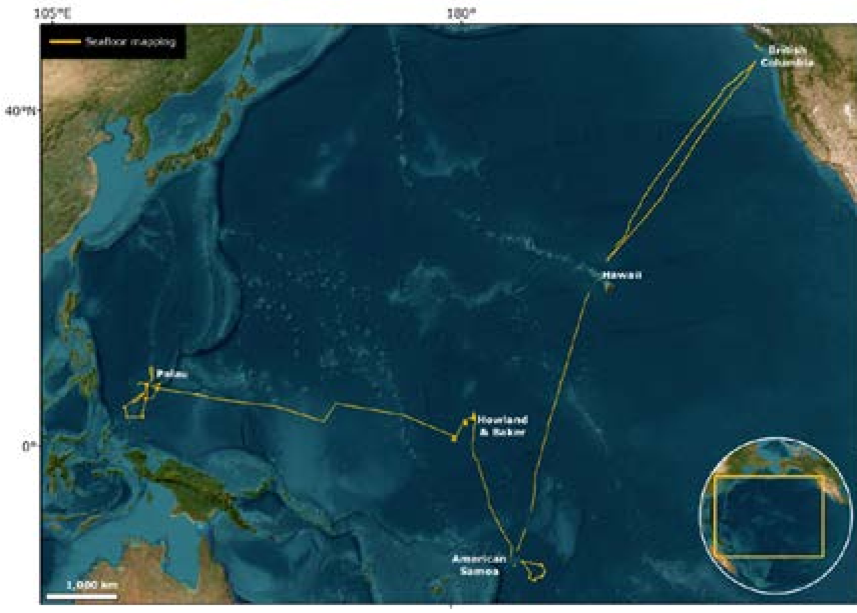
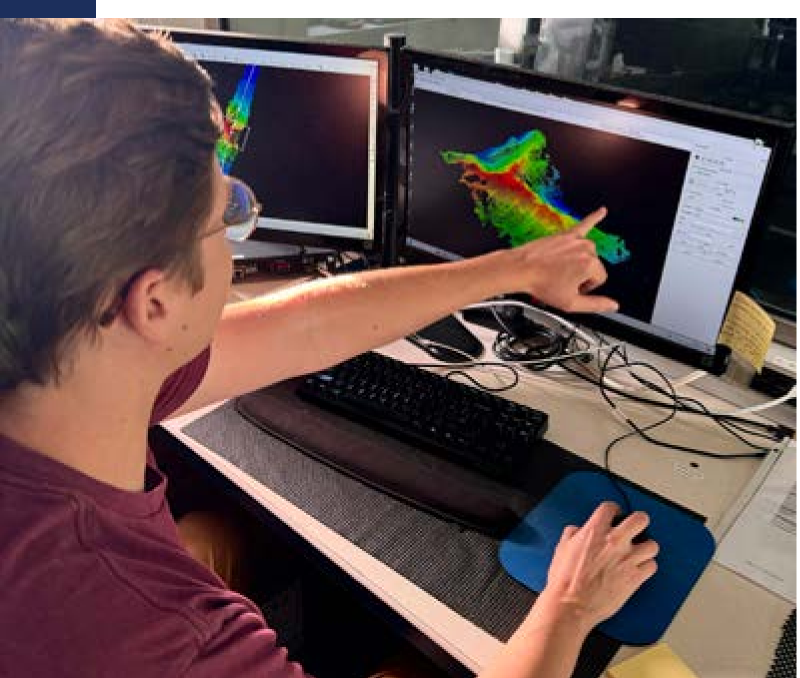


Figure 1. Map showing areas mapped using the multibeam sonar on E/V *Nautilus* during expeditions in 2024.

The field season began in May 2024 with a week-long shakedown expedition conducted around the Main Hawaiian Islands (NA159). 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, noise testing, and four accuracy surveys at seafloor depths of 650, 2,500, 2,600, and 4,800 meters.



Following the season shakedown, E/V *Nautilus* conducted two expeditions that mapped the seafloor during transits between British Columbia and Hawai'i, focusing on areas that had not previously been mapped (NA160 and NA162). These two expeditions mapped over 42,653 square kilometers of seafloor, including unmapped portions of the Mendocino, Pioneer and Murray fracture zones, as well as several unmapped seamounts. In June, E/V *Nautilus* conducted an expedition in support of Ocean Networks Canada's NEPTUNE Cabled Observatory (NA161), which mapped over 692 square kilometers of seafloor, focusing on previously unmapped areas between Barkley Canyon and Clayoquot Slope.

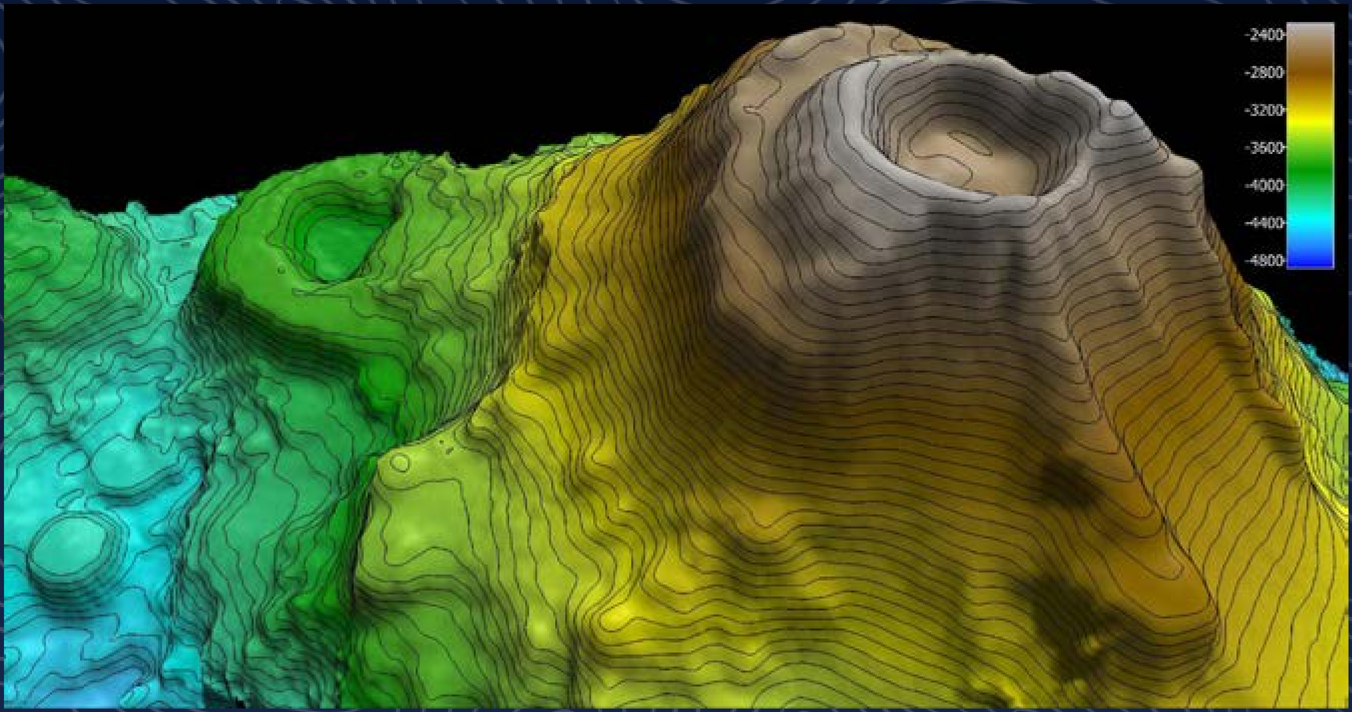
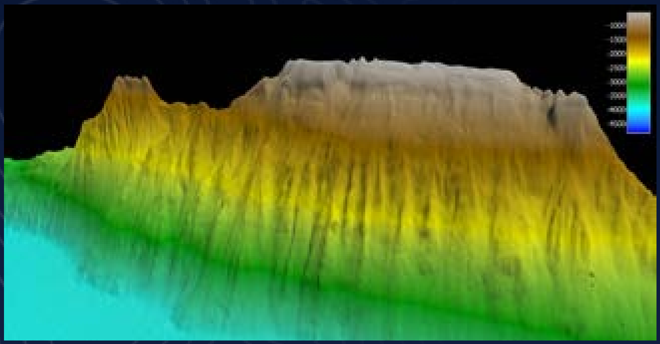


Figure 2. Three-dimensional view of an unnamed seamount with a distinctive caldera mapped in the southern portion of the US Exclusive Economic Zone in American Samoa on NA165. The color ramp represents depth in meters, and the black lines are 40-meter contours. Image created with QPS Fledermaus software with a three-times vertical exaggeration.

Following the work completed for Ocean Networks Canada, E/V *Nautilus* completed a transit mapping expedition across the Central Pacific between Hawai'i and American Samoa (NA163). Accomplishments included mapping 18,680 square kilometers of seafloor, including 6,555 square kilometers in the US Exclusive Economic Zone around Hawai'i, Palmyra, and American Samoa.

In August 2024, E/V *Nautilus* completed the *E Mamana Ou Gataifale I* expedition focused on integrating exploration technologies from NOAA Ocean Exploration Cooperative Institute partners (NA164). In addition to multi-vehicle operations, the expedition mapped 651 square kilometers of seafloor, including a previously unmapped area located southeast of Tutuila Island, and the entirety of Vailulu'u Seamount, an active underwater volcano that had not been explored since 2019. In September 2024, E/V *Nautilus* completed the *E Mamana Ou Gataifale II* expedition focused on ROV and AUV exploration of deep-sea habitats in American Samoa (NA165). Seafloor mapping focused on filling data gaps in the Muliava Unit of the National Marine Sanctuary of American Samoa and the southeastern corner of the US Exclusive Economic Zone in American Samoa. A total of 8,458 square kilometers of seafloor were mapped over the course of the expedition, including 2,249 square kilometers inside the National Marine Sanctuary of American Samoa. This included filling mapping gaps over seven different seamounts (Figure 2) to develop new bathymetric maps that were critical in planning ROV surveys on these previously unexplored features. The expedition also completed 10 successful dives using Woods Hole Oceanographic Institution's AUV *Sentry* to complete high-resolution mapping of abyssal plain regions and the Vailulu'u Seamount caldera (see Kelley in this report).

During the month of October, E/V *Nautilus* conducted a dedicated mapping expedition to map seafloor around the islands of Howland and Baker, as well as other unmapped areas along the transit route between American Samoa and Palau. This expedition mapped the largest area of any expedition in 2024, mapping over 55,151 square kilometers of seafloor. Mapped areas included 11,484 square kilometers in the US Exclusive Economic Zone around Howland and Baker Islands, where seven different seamounts were mapped for the first time. In addition, the expedition included transit mapping operations in American Samoa, Kiribati, Tokelau, the Republic of the Marshall Islands, the Federated States of Micronesia, and Palau.



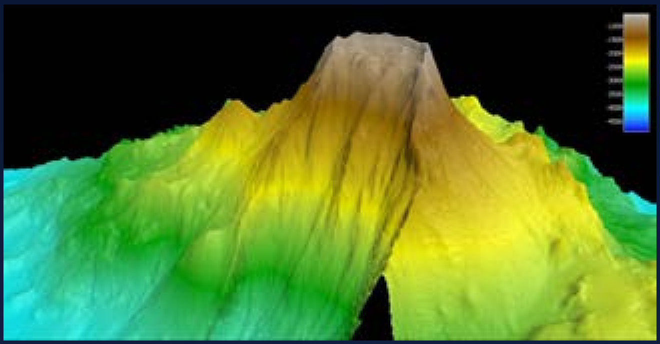


Figure 3. Three-dimensional view of an unnamed seamount mapped within the southeastern region of the Palau National Marine Sanctuary on expedition NA168. The color ramp represents depth in meters. Image created with QPS Fledermaus software with a three-times vertical exaggeration.

Figure 4. Three-dimensional view of an unnamed seamount mapped within the southwestern region of the Palau National Marine Sanctuary. The color ramp represents depth in meters. Image created with QPS Fledermaus software with a three-times vertical exaggeration.

From late October to late November, E/V *Nautilus* conducted two back-to-back expeditions focused on mapping and characterizing deep-sea habitats in the Palau National Marine Sanctuary (NA167–NA168). A total of 19,052 square kilometers of seafloor were mapped over the course of the expedition, an area that is over 41 times larger than the total land area of all Palauan Islands combined. This included mapping over 14,781 square kilometers of seafloor inside the Palau National Marine Sanctuary, where 11 seamounts were mapped for the first time (Figures 3–4). Seafloor mapping focused primarily on ROV survey sites without publicly-accessible mapping data, providing crucial detailed bathymetry maps as the basis for the 13 successful ROV dives completed on those expeditions.

The final expedition of the 2024 season focused on exploring the physical and biological oceanography around the Palauan Islands (NA169), which also opportunistically mapped 2,850 square kilometers of seafloor using E/V *Nautilus*' mapping sonars.

As part of OET's ongoing commitment to train the next generation of explorers, four seafloor mapping interns sailed on 2024 expeditions. These early career scientists stood science watches and were trained on all aspects relating to acquiring and processing seafloor mapping data (Figure 5).

As in previous years, mapping data collected during 2024 expeditions were submitted to the Rolling Deck to Repository, the Marine Geoscience Data System, 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.

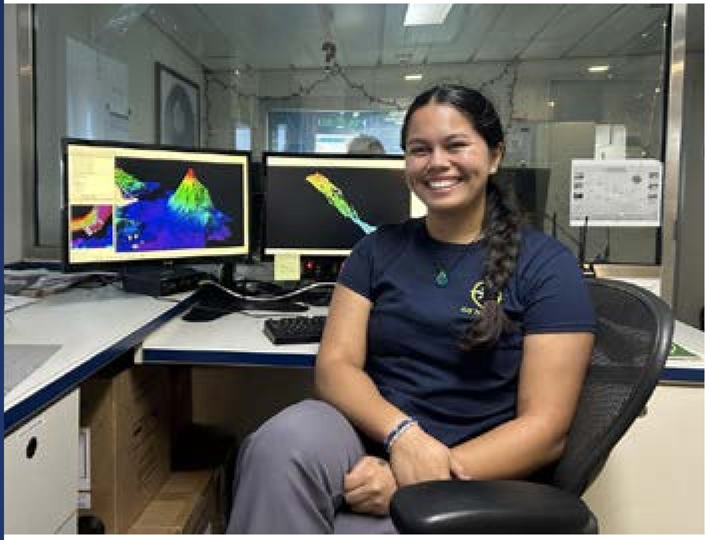


Figure 5. Seafloor mapping intern Julia Hill (left) in the data lab onboard E/V *Nautilus* processing multibeam sonar data. United States Naval Academy Midshipman and seafloor mapping intern Victoria Trevino (right) aboard E/V *Nautilus*.

OCEAN NETWORKS CANADA
#ONCABYSS SUMMER 2024 EXPEDITION ABOARD E/V *NAUTILUS*

Meghan Paulson, Dirk Brussow, Yuko Lin, Mike Gregory, and Robyn Meyer

From June 4–27, 2024, Ocean Networks Canada (ONC) embarked on a 24-day expedition aboard E/V *Nautilus* (NA161), marking the eighth year of a successful partnership between ONC and the Ocean Exploration Trust (OET) to service the NEPTUNE cabled ocean observatory. Located off the west coast of Canada, the NEPTUNE observatory consists of an 800-kilometer loop of fiber optic cable that connects numerous scientific instruments, providing high-resolution and near real-time observations as deep as 2,600 meters below the sea surface. As with other ONC observatories, data collected by the NEPTUNE observatory can be accessed freely from anywhere in the world via the ONC data management system Oceans 3.0.

Figure 1. Map showing NEPTUNE observatory locations visited during #ONCabyss Summer 2024 expedition aboard E/V *Nautilus* (image credit: Ocean Networks Canada).

The expedition culminated in a total of 265 hours of remotely operated vehicle (ROV) dive surveys, which covered seafloor depths ranging between 370 and 2,664 meters. ROV dives mainly focused on the deployment, recovery, and maintenance of scientific instruments, while also conducting visual surveys at six different NEPTUNE observatory sites, including Barkley Canyon, Cascadia Basin, the Circulation Obviation Retrofit Kit (CORK) 1024C site, Endeavour Hydrothermal Vent Field, Middle Valley, and Clayoquot Slope (Figure 1). A total of 58 samples were collected during ROV dives to support ongoing studies on the physical and biological processes across ONC's observatory sites, including larval traps, biological specimens, sediment pushcores, water samples, and gas-tight hydrothermal plume samples (Figure 2). The expedition also included 61 hours of deck operations not associated with ROV dives, including three CTD rosette casts, the deployment and recovery of two moorings, the deployment of six sediment traps, the recovery of three sediment traps, and the deployment of five autonomous ocean bottom seismometers.

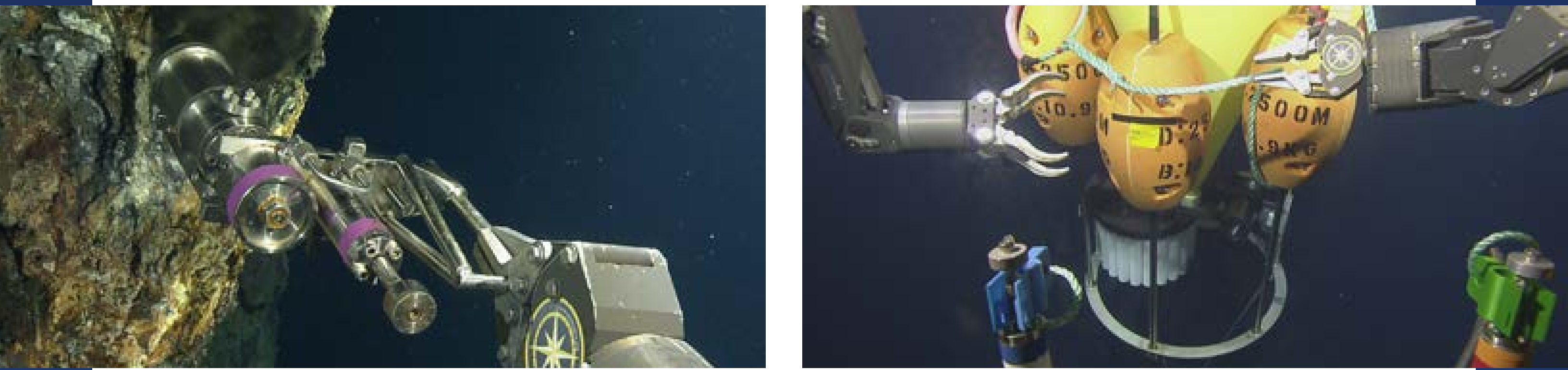


Figure 2. ROV *Hercules* collecting a gas-tight sample from a hydrothermal vent during the #ONCabyss Summer 2024 expedition aboard E/V *Nautilus* (left). A sediment trap being repositioned on the seafloor (right).

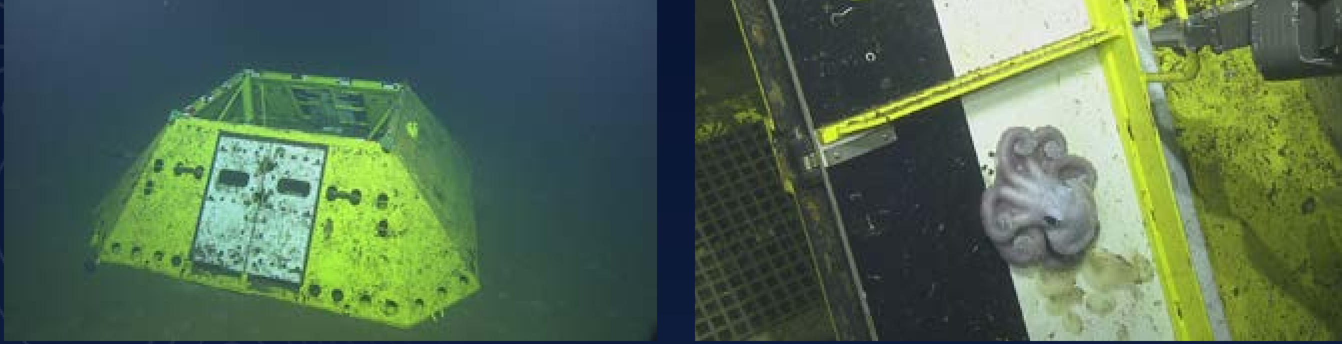


Figure 3. Middle Valley's trawl-resistant frame (left). A brooding deep-sea octopus (*Granelodone pacifica*) on the frame (right).

WELCOMING CANADA'S NEWEST MARINE PROTECTED AREA

While the expedition was at sea, news broke of Canada's newest and now largest marine protected area,Tang.ɢ̱wan – ḥačxʷiqak – Tsig̱is, covering an area of 133,017 square kilometers, including the 97 square kilometers that are part of the Endeavour Hydrothermal Vents Marine Protected Area. The newly designated protected area overlays the NEPTUNE observatory's Cascadia Basin, Middle Valley, and Endeavour sites that ONC has been monitoring for many years, reinforcing the importance of ONC's commitment to ocean monitoring that supports a healthy ocean.

PREPARING FOR FUTURE INSTALLATIONS AT MIDDLE VALLEY

Using ROV *Hercules*, a visual survey was performed on the trawl-resistant frame that is currently deployed at the Middle Valley site. Future plans include installing a node at this site that will bring power and communications, making it possible to populate this dynamic site with scientific instrumentation and adding to ONC's efforts to monitor the Tang.ɢ̱wan – ḥačxʷiqak – Tsig̱is Marine Protected Area. Interestingly, ROV surveys at the site recorded a deep-sea octopus (*Granelodone pacifica*) brooding on the trawl-resistant frame (Figure 3). In addition to visual surveys, ROV *Hercules* also mapped the seafloor along the transit from the trawl-resistance frame to the Dead Dog vent field using a Norbit multibeam sonar mounted on the ROV.

RUMBLINGS AT ENDEAVOUR

Similar to the Middle Valley site, high-resolution seafloor mapping data was collected over the Main Endeavour Vent Field and High Rise Vent Field using a Norbit sonar on ROV *Hercules*. This resulted in the development of high-resolution maps of the vent fields (Figure 4). These maps will not only make future explorations of the sites easier and safer, but will also allow researchers to track seafloor changes from ongoing seismic activity.

Three months prior to the #ONCabyss Summer 2024 expedition, ONC's instruments recorded a peak of 200 earthquakes per hour at the Endeavour segment of the Juan de Fuca Ridge. While no visible changes were observed on the seafloor during the #ONCabyss expedition, ONC will continue to closely monitor the heightened seismic activity. Additionally, five autonomous ocean bottom seismometers were deployed at Endeavour to supplement the existing network of cable-connected seismometers, providing deeper insights into the recent seismic activity.

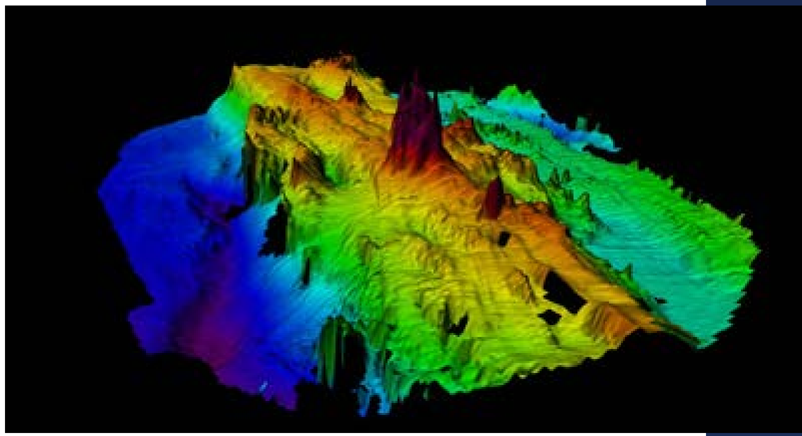


Figure 4. Three-dimensional map of the High Rise Vent Field generated using high-resolution multibeam data collected by the Norbit sonar mounted on ROV *Hercules*. The shallowest areas are indicated in red, while the deepest areas are shown in purple.

Figure 5. ONC senior project engineer Jeb Dexter fabricating a new temperature probe for ROV *Hercules* using parts from a recently-recovered sensor.

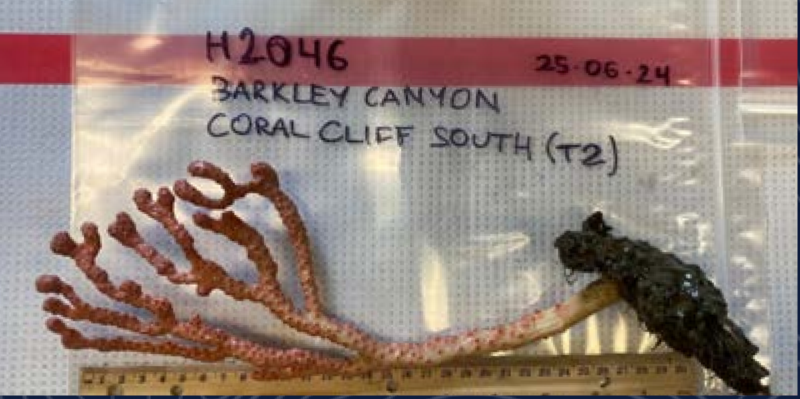


Figure 6. Bubblegum coral (*Sibogagorgia cauliflora*) collected at Barkley Canyon during the #ONCabyss expedition aboard E/V *Nautilus* (image credit: Ocean Networks Canada).

Figure 7. C/S *Cable Innovator* next to the E/V *Nautilus* during dual-ship operations to lay a secondary replacement cable at Cascadia Basin.

While taking temperature measurements of superheated hydrothermal vent fluid at Endeavour, temperature probes on ROV *Hercules* melted. With some quick thinking and hard work, the onboard ONC and OET engineers fabricated a new temperature probe using parts from a recently-recovered sensor that were then modified and integrated onto ROV *Hercules* (Figure 5). The quick turnaround ensured that operations could continue, contributing to the success of the mission.

BARKLEY CANYON'S CORAL CLIFFS

British Columbia's offshore waters are home to diverse ecosystems of deep-sea corals and sponges, including particularly dense aggregations that ONC has been surveying for several years in an area known as Barkley Canyon Coral Cliffs. During the 2024 expedition, ONC scientists collected several coral specimens at Barkley, including a stunning bubblegum coral (*Sibogagorgia cauliflora*; Figure 6). The coral samples will be analyzed to support taxonomic studies, as well as for carbon and nitrogen stable isotopes to better understand the food sources reaching the deeper parts of the Barkley Canyon.

A NEW CABLE AT CASCADIA BASIN

In a dual-ship operation with Global Marine's cable ship C/S *Cable Innovator*, a new 3,169-meter long cable was laid at Cascadia Basin. This replacement cable took a total of 36 hours of ROV dive time that involved the coordinated and careful maneuvering of both the E/V *Nautilus* and C/S *Cable Innovator* (Figure 7).

CLAYOQUOT SLOPE'S DEEP-SEA OASIS

Since 2012, ONC has been monitoring a whale fall located at Clayoquot Slope at a depth of 1,250 meters. During the 2024 expedition, the team conducted ROV photogrammetry surveys to generate a three-dimensional model of the site, which provides fine details of the whale fall down to a scale of one millimeter. By comparing models generated at different points in time, researchers can learn about the decomposition process in the deep sea, and the role of whale falls as deep-water oceanic oases. Using such models created over time, ONC senior staff scientist Fabio De Leo noted that the tubeworms (*Lamellibrachia cf. barhami*) seen on the whale's jaw bones are likely the same individuals observed when the skeleton was first discovered in 2009 (Figure 8), and estimated that they are now at least 26 years old today.

OUTREACH

ONC and OET invited ocean enthusiasts from all over the world to join this deep-sea exploration remotely via various education and outreach programs. Over the course of the expedition, live-stream video feeds received over 170,000 views and highlight videos garnered over 57,000 views. Expedition content on ONC's and OET's social media channels attracted close to one million impressions. While at sea, the team hosted 63 live ship-to-shore interactions with schools, community events, and professional meetings, reaching over 2,190 people across North and South America, Europe, and Oceania, including connecting with a World Ocean Day celebration at the Fisherman's Wharf in Victoria, British Columbia.

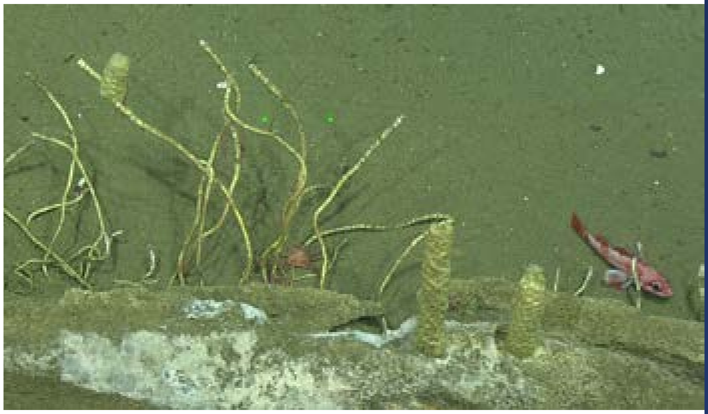


Figure 8. *Lamellibrachia cf. barhami* tubeworms documented on the whale fall at Clayoquot Slope.

SUPPORTING WHALE MONITORING
IN AMERICAN SAMOA

Ann Allen

The Cetacean Research Program of the NOAA Pacific Islands Fisheries Science Center is responsible for monitoring whale and dolphin populations in the US Pacific Island Region, a vast area that covers US waters around the Hawaiian Islands, the Mariana Archipelago, American Samoa, and several other remote islands in the Central Pacific. Using NOAA ships, the program has been conducting dedicated expeditions to survey cetacean populations using both topside visual surveys, and towed hydrophone arrays that listen for cetaceans. However, conducting such dedicated expeditions is costly and labor intensive, and can therefore only be executed every 3–5 years. Additionally, these methods only provide information about the presence of cetaceans at the time the survey is conducted, and do not provide information about the temporal dynamics of cetacean populations on finer time scales.

To address these gaps, the Cetacean Research Program has been using high-frequency acoustic recording packages (Figure 1), which are placed on the seafloor at depths between 700–1,000 meters, and left for a year or more continuously recording whale and dolphin calls. Since 2005, the Cetacean Research Program has been

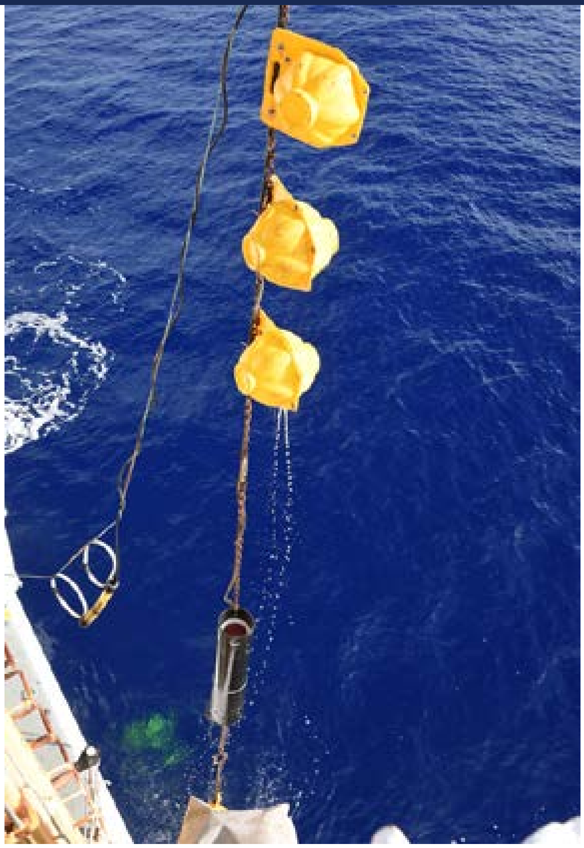


Figure 1. A high-frequency acoustic receiver package, including the hydrophone that detects sounds on the left, large yellow floats, and the data recorder inside the black tube (image credit: NOAA Fisheries).

Figure 3. The high-frequency acoustic recording package being successfully deployed from E/V *Nautilus* east of Tutuila Island, American Samoa on the last day of the NA163 expedition.

deploying and recovering such acoustic recorders at various sites across the US Pacific (Figure 2), and thereby generated important long-term records on the geographical and temporal distribution of cetaceans. This includes a monitoring site in American Samoa, which was first established in 2023 in partnership between the NOAA Office of National Marine Sanctuaries and the NOAA Pacific Islands Fisheries Science Center. An initial deployment at the American Samoa site recorded data from July 2023–May 2024, and documented large numbers of humpback whales, beaked whales, and Risso's dolphins. However, no data had been collected at the site since that initial receiver was retrieved in May 2024.

Figure 2. Map showing the locations where the Cetacean Research Program has deployed high-frequency acoustic recording packages, including both instruments that are still recording data, and historic deployment sites.

With the monitoring site being close to Pago Pago Harbor, which E/V *Nautilus* used during the 2024 season, the Cetacean Research Program partnered with the Ocean Exploration Trust in hopes of once again deploying an acoustic recorder at the site. For this purpose, a high-frequency acoustic recording package was loaded onto E/V *Nautilus* in Honolulu prior to the start of the NA163 expedition, which included the 4,200-kilometer transit from Hawai'i to American Samoa. On the last day of the NA163 expedition, the acoustic mooring was successfully deployed east of Tutuila Island (Figure 3). The receiver will remain on the seafloor until the Cetacean Research Program plans to retrieve it in December 2025, providing important continuity to cetacean monitoring efforts in American Samoa, a region recognized as an important birthing area for humpback whales. The acoustic network of receivers of the Cetacean Research Program, and the rich datasets it creates, is only possible through partnerships with institutions that also work in remote areas of the Pacific, like the Ocean Exploration Trust.

EXPLORATIONS OF THE MAKAPUʻU PRECIOUS CORAL BED

Beth Lumsden, Frank Parrish, and Meagan Putts

Located off the eastern tip of Oʻahu Island in waters 200–600 meters deep, the Makapuʻu precious coral bed is home to commercially-important pink, red, and gold corals that have been harvested commercially in the past. It also hosts a variety of other corals, sponges, fishes, and many other deep-water species. Commercial coral harvesting ending in 2001. Since that time, NOAA has been unable to conduct a survey to assess the recovery of the Makapuʻu bed, confirm its boundaries, or quantify maximum sustainable yield, which is required to establish an area as essential fish habitat.

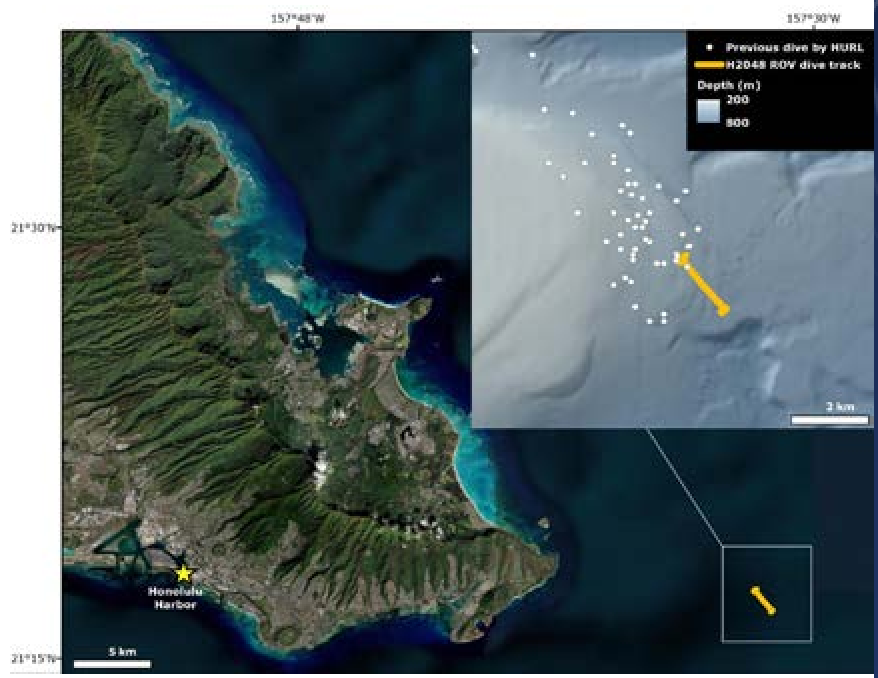


Figure 1. Map showing the location of ROV *Hercules* dive H2048 conducted off E/V *Nautilus* to survey the Makapuʻu precious coral bed (orange line), along with previous dive surveys conducted by human occupied submersibles and ROVs operated by the Hawaiʻi Undersea Research Laboratory (HURL).

With the Makapuʻu bed being located so close to Honolulu Harbor (Figure 1), which E/V *Nautilus* used during the 2024 season, scientists from the NOAA Pacific Islands Fisheries Science Center and the Deep-Sea Animal Research Center at the University of Hawaiʻi partnered with the Ocean Exploration Trust in hopes of achieving these long awaited science goals. While the Makapuʻu bed had been surveyed using human occupied submersibles and remotely operated vehicles operated (ROV) by the Hawaiʻi Undersea Research Laboratory (HURL) in 1981–2017, the 2024 E/V *Nautilus* survey marked the first time a telepresence-enabled ROV system was used to study the bed. It was the ideal tool to better define the boundaries of the precious coral bed, and enhance our understanding of essential fish habitat.

The conditions found at Makapuʻu can be extreme, with current velocities frequently reaching 0.6 knots. Deepwater precious corals require such high-current environments, because they expose hard substrate for corals to settle on, and provide a steady stream of food resources flowing past coral colonies. While precious corals thrive in these conditions, they can make managing an ROV and moving it forward on the seabed challenging. True to its reputation, after ROV *Hercules* landed on the seafloor of the Makapuʻu bed on July 22, 2024, it was a difficult day on the bottom.

ROV dive H2048 began its survey at the southeastern edge of the coral bed at about 500 meters, exploring a previously unexamined area. The substrate was a carbonate hardpan with several low profile ledges, and occasional boulders. The ROVs documented numerous different corals (*Enallopsammia rostrata*, *Enallopsammia* cf. *pusilla*, *Chrysogorgia* sp., *Acanella dispar*, *Kulamanamana haumeaae*, unbranched Keratoisididae, Anthomastinae, Coralliidae, Primnoidae, Acanthogorgiidae, and Antipatharia) and sponges (*Poecillastra* sp., *Geodia* sp., *Regadrealla* sp., and *Bolosoma* sp.), as well as many other invertebrate species (*Sympagurus dolfleini*, *Brisinga* sp., *Hymenaster* sp., Gorogonocephalidae, Ophiuroidea, Cidariae, Octopodidae, and Goniasteridae) that make use of this productive habitat. The surveys also revealed several species of fish (*Polymixia japonica*, *Chlorophthalmus* sp., *Sladenia reminger*, and *Scalicus* sp.), including many species of rattails, a swordfish, and the Hawaiian spurdog shark (*Squalus hawaiiensis*).

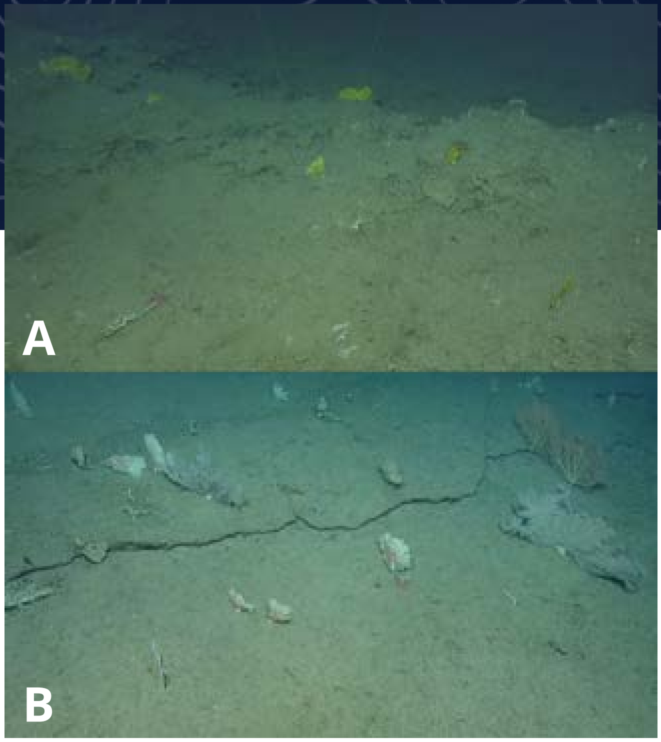
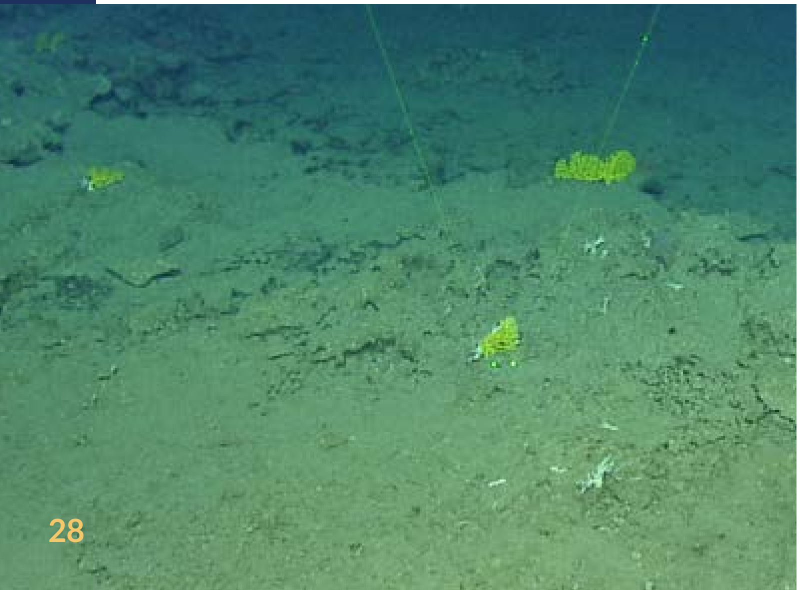
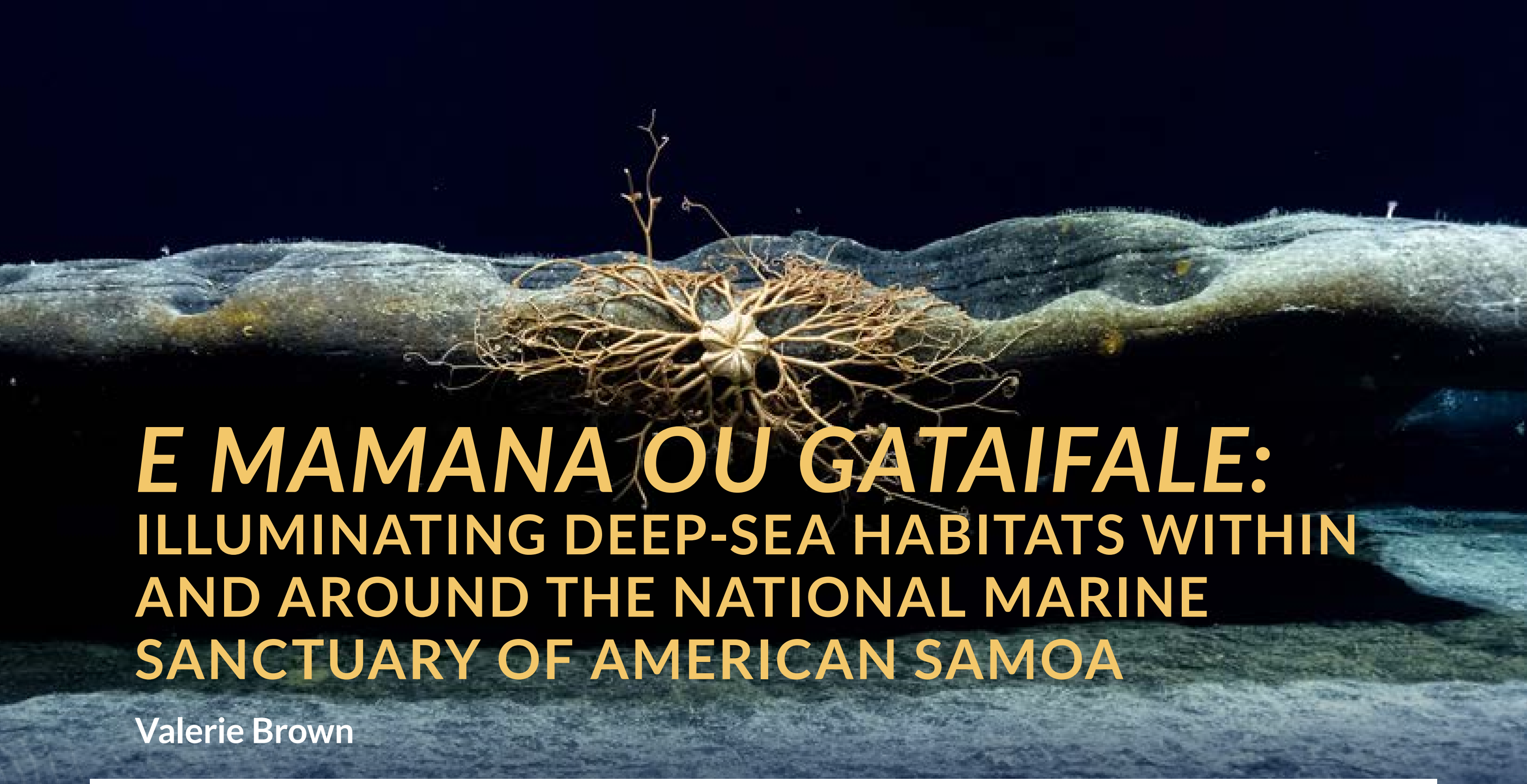


Figure 2. (A) Initial community observed along the survey transect consisting primarily of the deepwater reef-building coral (*Enallopsammia rostra*) and sponges with very few precious corals. (B) Near the end of the dive the ROVs documented a higher density and diversity of corals, including pink, black, and gold corals.

At the start of the ROV transect, coral density and diversity was low, featuring mainly reef-building deepwater corals (*Enalopsammia rostrata*). As the ROVs moved upslope to the northwest, the density and diversity of corals began to increase. At about 450 meters, the team observed the first precious coral, a pink coral (Figure 2A). Near the end of the dive, the community consisted primarily of pink, black, bamboo, and corals in the family Acanthogorgiiae (Figure 2B), with some colonies of the gold coral (*Kulamanamana haumeaae*). This community composition indicates that the transect had indeed intercepted the southeast edge of the Makapuʻu precious coral bed.

After surveying about 1.7 kilometers of seafloor, high current velocities made forward movement of the ROV impossible, and so we had to resort to moving the vehicles laterally back and forth. Unfortunately, current velocities continued to rise throughout the dive, making even lateral movements impossible. Thus, the survey ended after about 4.5 hours on the seafloor, and the ROVs were recovered to the surface. Although the survey did not reach the center of the precious coral bed, the mission succeeded in refining the Makapuʻu bed boundaries, providing new insights into the communities that inhabit it, and exploring previously unsurveyed portions of the bed.





E MAMANA OU GATAIFALE: ILLUMINATING DEEP-SEA HABITATS WITHIN AND AROUND THE NATIONAL MARINE SANCTUARY OF AMERICAN SAMOA

Valerie Brown

The 2024 *E Mamana Ou Gataifale* expeditions (NA164–NA165) brought together an unprecedented array of experts, technologies, and tools to explore the greatly understudied deep-water habitats of American Samoa. Located in the South Pacific, the US Territory of American Samoa is comprised of five volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u) and two atolls (Rose and Swains), which are surrounded by over 405,000 square kilometers of seafloor. The deep sea within this remote region remains largely unexplored. Expeditions like those conducted by E/V *Nautilus* in 2024 slowly illuminate the hidden depths, and the unique biological communities found there. During the 39 days at sea, the two expeditions mapped a total of 9,109 square kilometers of seafloor, conducted 17 successful remotely operated vehicle dives, 34 deployments of other robotic vehicles, and collected 707 samples to support studies on the biodiversity and geological context of the region (Figure 1).

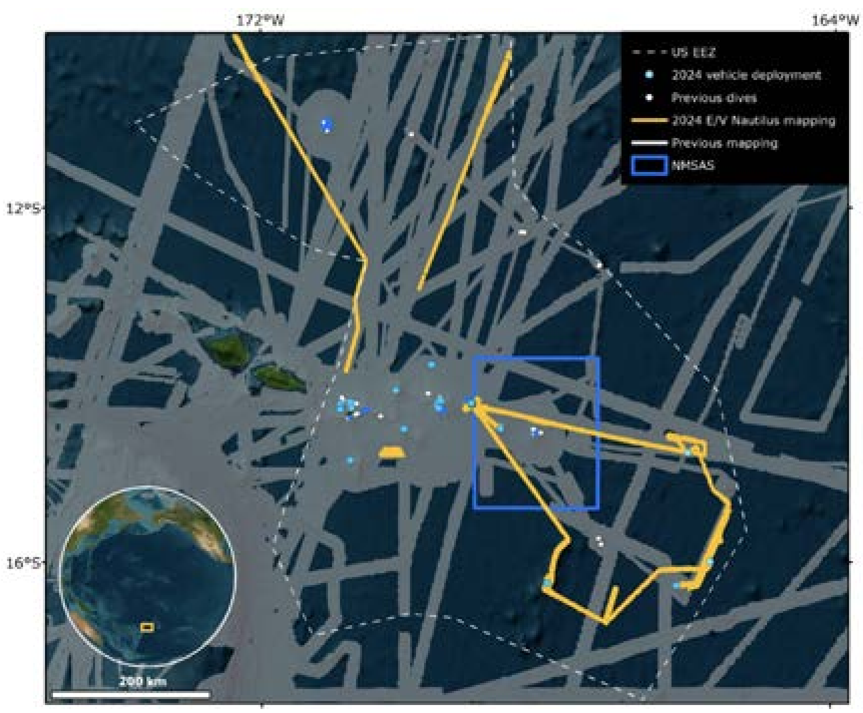


Figure 1. Map showing the locations of seafloor mapping and deep-sea vehicle surveys conducted in American Samoa to date, including those conducted during the 2024 E/V *Nautilus* expeditions to the region.

National Marine Sanctuary of American Samoa supported these deep-sea exploration efforts as part of its mission to understand and protect the diverse ecosystems within the sanctuary. Covering 35,175 square kilometers of nearshore and offshore environments, the sanctuary consists of six units, including two on Tutuila Island (Fagatele Bay and Fagalua/Fogāma'a), adjacent areas to Aunu'u, Ta'u, and Swains, as well as the large Muliāva Unit, a management area that overlaps with Rose Atoll Marine National Monument, and includes Vailulu'u, Malulu, and other seamounts. While the sanctuary is best known for its striking shallow-water reefs, most of the sanctuary

Figure 2. The onboard team of the NA164 expedition to American Samoa. Together with the subsequent NA165 expedition, the missions brought together researchers from many different institutions, including NOAA Ocean Exploration, University of Rhode Island, University of New Hampshire, Woods Hole Oceanographic Institute, Lehigh University, National Marine Sanctuary of American Samoa, and Ocean Exploration Trust.

lies in deeper waters below 200 meter depths. Gathering data to improve the management of these deep-sea ecosystems is a high priority for the sanctuary, and one that can only be accomplished with partnerships.

Planning for the *E Mamana Ou Gataifale* expeditions started well in advance of the expeditions. The Ocean Exploration Trust coordinated researchers from partner institutions of the NOAA Ocean Exploration Cooperative Institute who could address key research questions related to better understanding deep-sea and midwater ecosystems in the region, bringing together the expertise from the University of Rhode Island, University of New Hampshire, Woods Hole Oceanographic Institute, and Lehigh University (Figure 2). At the same time, National Marine Sanctuary of American Samoa worked closely with Ocean Exploration Trust to recruit local students, educators and scientists that could sail on these expeditions, and supported a planning workshop hosted at the Tauese P.F. Sunia Ocean Center in March 2024. The workshop brought together local stakeholders from a broad range of backgrounds, and set the stage for a highly collaborative effort informed by community input that included fisheries, oceanographic, and historical research objectives, as well as cultural protocols (see Moffitt et al. in this report).

Midwater ecosystems were the research focus for the first leg of the *E Mamana Ou Gataifale* expedition (NA164). Besides fisheries targets like tuna, very little is known about the biodiversity of pelagic ecosystems in American Samoa. During the NA164 expedition a suite of vehicles were deployed to comprehensively examine biodiversity in the water column, including uncrewed surface vehicle *DriX* (see Schmidt et al. in this report), autonomous underwater vehicle *Mesobot* (see Yoerger et al. in this report), and the *Deep Autonomous Profiler* (see Roman et al. in this report). Collectively, these complementary technologies opened up an entirely new area of study for the region by gathering large amounts of environmental data, including extensive environmental DNA (eDNA) samples, which will inform the most thorough assessment of pelagic biodiversity ever conducted in American Samoa (see Govindarajan in this report).

Deep-sea benthic communities and geological features were in the spotlight for the second leg of the *E Mamana Ou Gataifale* expeditions (NA165). ROV *Hercules* and *Atalanta* became the primary exploration vehicles, allowing for exciting telepresence opportunities and discoveries, including hydrothermal vents, ocean sunfish, and unexpected predation events (see Soule & Sowers in this report). Autonomous underwater vehicle *Sentry* also was a significant part of this second leg, searching once more for the final resting place of the *Samoan Clipper*, and conducting the deepest surveys to date in American Samoa (5,500–5,800 meters) in some of the most remote and deepest places found within the entire US Exclusive Economic Zone of American Samoa (see Kelley in this report).

Figure 3. Vailulu'u Seamount was the target of numerous dedicated surveys conducted during the NA164–NA165 expeditions. This included mapping the entire seamount using the sonars of uncrewed surface vehicle *DriX*, as well as conducting six dives using autonomous underwater vehicle *Mesobot*, two deployments of the *Deep Autonomous Profiler*, five dives using autonomous underwater vehicle *Sentry*, and seven dives using the dual body-ROV system consisting of *Hercules* and *Atalanta*.

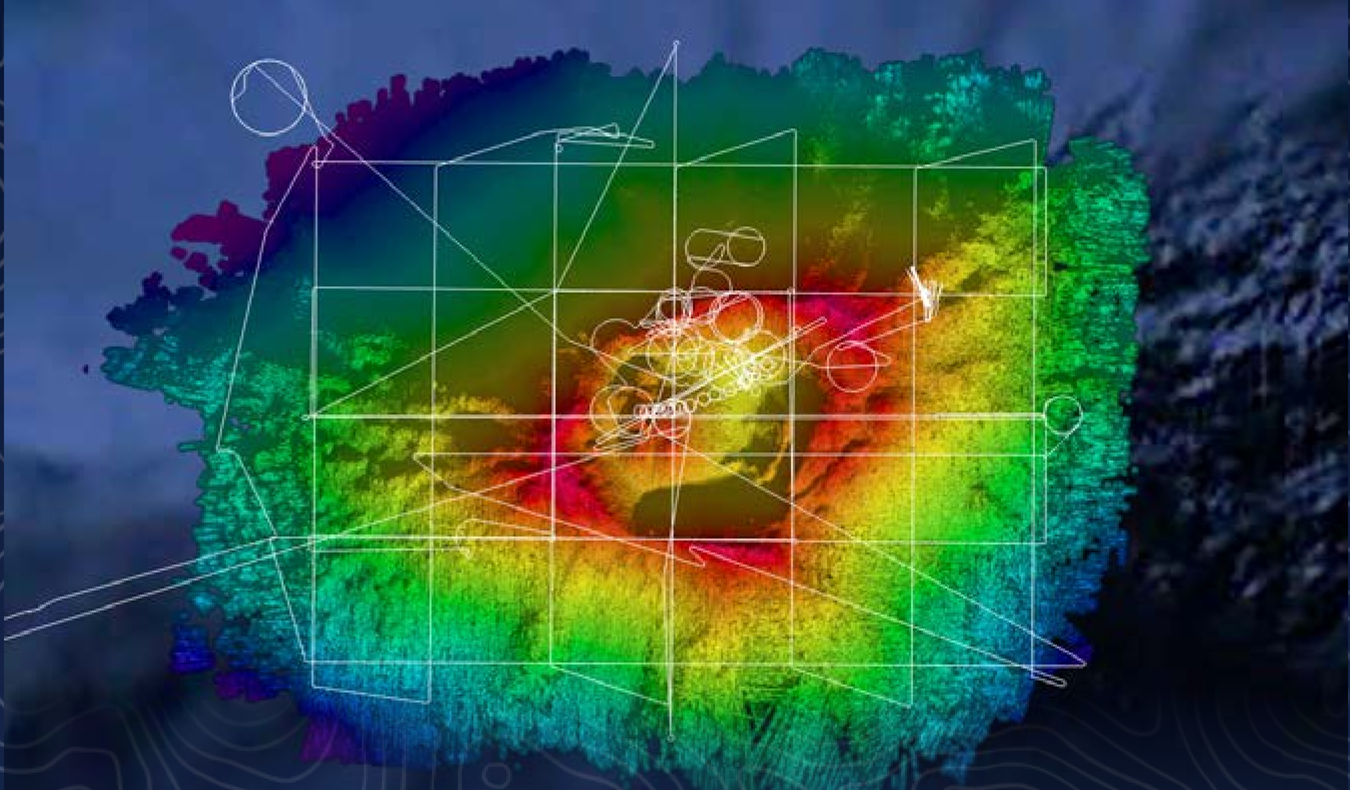
Figure 4. On August 29–30, NOAA Ocean Exploration, in collaboration with the American Samoa Department of Education, National Marine Sanctuary of American Samoa, and Ocean Exploration Trust hosted a professional development workshop that brought together 41 middle and high school teachers from American Samoa for dedicated training on lesson plans designed specifically to bring back information from the American Samoa expeditions into classrooms.

But the *E Mamana Ou Gataifale* expeditions were not just about basic exploration and mapping. One of the most exciting priorities was the targeted investigation of Vailulu'u Seamount (Figure 3). Vailulu'u has fascinated scientists since it was first mapped in 1975. This dynamic feature sits over the Samoan Hot Spot, which fuels hydrothermal vents and a rich assemblage of midwater and epipelagic species, including oceanic white tip sharks, false killer whales, and pilot whales. This feature was a high priority for visiting scientists, and they brought a diverse set of technologically-advanced tools to better understand the geology, oceanography, and biology of this special place. ROV *Hercules* carried new instruments like the Sensor for Aqueous Gases in the Environment (see Burkitt-Gray et al. in this report) and Isobaric Gas-Tight Samplers to understand the chemistry of Vailulu'u's hydrothermal vents, and an eDNA autosampler to capture eDNA from benthic and midwater communities (see Govindarajan in this report).

Figure 5. NOAA National Marine Sanctuary of American Samoa student interns Talofa Fe'a and Ella Ashford conduct a live ship-to-shore interaction with a school in American Samoa during the NA164 expedition.

As the teams explored new locations, viewers from all around the world joined expedition live streams, which received close to 300,000 views, and 141 ship-to-shore interactions that connected the onboard team with schools, community events, and professional meetings. Local educators, student interns, and other onboard mission personnel interacted with the public. They created exciting social media posts, including a Samoan Word of the Day series and Instagram takeovers, which received over 2.6 million views. In addition, NOAA Ocean Exploration teamed up with Ocean Exploration Trust, National Marine Sanctuary of American Samoa, and American Samoa Department of Education to host a professional development workshop for teachers from American Samoa, as well as hosting public tours of E/V *Nautilus* in Pago Pago. Furthermore, National Marine Sanctuary of American Samoa supported coordination with its sister sanctuary site, Palau National Marine Sanctuary, where E/V *Nautilus* operated later in the 2024 season (see Moffitt et al. in this report).

Collectively, the *E Mamana Ou Gataifale* expeditions helped illuminate many previously unexplored ocean areas in American Samoa, while also deepening the connections between local communities and the ocean. These expeditions also showcased the power of partnerships and collaboration, and collected new information that will inform future decisions at the sanctuary and inspire our younger generations for many years to come.



OVER THE HORIZON:

SHORE-BASED UNCREWED SURFACE VEHICLE OPERATIONS IN SUPPORT OF SEAFLOOR MAPPING AND EDNA SAMPLING

Val Schmidt, Larry Mayer, Kenneth Fairbarn, Avery Muñoz, Natalie Cook, Andy McLeod, Roland Arsenault, Jenna Ehnot, Basile Rose, Simon Pannetier, Jason Fahy, Eric Hayden, Dana Yoerger, Jordan Stanway, and Annette Govindarajan

The NA164 expedition to American Samoa (NA164) marked a major advance in operational models for multi-vehicle exploration. In support of the NOAA Ocean Exploration Cooperative Institute mission to advance exploration technologies, the uncrewed surface vehicle *DriX* was operated entirely from shore during the mission (Figure 1), meeting E/V *Nautilus* more than 100 nautical miles away for collaborative multi-vehicle operations. *DriX* is a 7.7-meter long uncrewed surface vehicle equipped with a EM712 multibeam sonar, EK80 fisheries sonars (70 and 200 kilohertz), and a Sonardyne HPT3000 ultra-short baseline positioning system, all housed within a gondola located 2 meters below the sea surface. The vehicle is powered by a diesel engine, with a typical endurance of 72 hours at 7 knots. *DriX* is operated under supervised autonomy from a remote control center that connects to the vehicle either via radio, or more recently via satellite.

Above. Map showing the trackline of the final *DriX* deployment of the NA164 expedition, overlaid on a 10-meter resolution seafloor map created using the EM712 multibeam sonar on *DriX*.

In past years, *DriX* has been deployed from E/V *Nautilus* to conduct independent seafloor mapping, or in tandem with other vehicles like *Mesobot* to map the water column and conduct collaborative sampling operations. An initial E/V *Nautilus* mission in 2022 (NA136) focused on developing protocols for safe operations of the then newly-acquired *DriX* vehicle. During a subsequent E/V *Nautilus* expedition in 2022 (NA139), the team developed the verified directed sampling technique, in which the water column echosounders of *DriX* provide precise localization of the *Mesobot* in the context of scattering layers, allowing researchers aboard the ship and ashore to direct *Mesobot* in real time for targeted eDNA sampling and visual surveys. The verified directed sampling technique marked a watershed moment in understanding *Mesobot* measurements by providing the contextual information as to where precisely those measurements were taken in relation to scattering layers in the water column.

Figure 1. Uncrewed surface vehicle *DriX* in Pago Pago Harbor, American Samoa (image credit: Dana Yoerger).

In 2023, the University of New Hampshire *DriX* became the first vehicle in the *DriX* fleet equipped with a Starlink Low Earth Orbit Antenna and Internet. Although *DriX* was still operated from E/V *Nautilus* on the NA155 expedition that year, the team began to test the ability to operate *DriX* remotely via satellite during that mission. As the comfort level grew, E/V *Nautilus* was eventually freed from tending *DriX*, and provided the opportunity to conduct separate operations many dozens of miles away, completely independent from *DriX* operations. With the *Deep Autonomous Profiler* also being deployed on that same NA155 mission, these new capabilities allowed for simultaneous operations of what normally would have required three separate deployments, providing significant savings in ship time.

The NA164 expedition in 2024 presented a whole new challenge in the evolution of *DriX*. The primary focus site of the expedition, Vailulu'u, is a volcanically-active seamount located over 100 nautical miles to the east of Pago Pago Harbor in American Samoa. Additionally, the expedition was scheduled to occur in August, winter in the Southern Hemisphere, during which swell conditions were expected to exceed safe ranges for the deployment of *DriX* via the E/V *Nautilus* crane. Thus, *DriX* would have to be deployed from shore on the NA164 expedition.

To prepare for the NA164 expedition to American Samoa, the *DriX* team conducted a shakedown mission in Honolulu, Hawai'i separate from the 2024 E/V *Nautilus* shakedown. During this time, the *DriX* team conducted detailed studies to identify subsystems whose failure might be increased in rougher weather or longer deployments, as well as failure types that could lead to particularly negative consequences. To the extent possible, these systems were modified or upgraded to mitigate risk. The *DriX* team established two remote operating centers at the University of Hawai'i Marine Facility, and the Center for Coastal and Ocean Mapping at the University of New Hampshire. Dual remote operating centers were required to increase reliability in the event of a network or power outage at any one place. During the *DriX* shakedown mission, the team conducted test exercises to prepare for the most severe scenarios, such as engine or communications failure, and to develop emergency procedures for shore-based, over-the-horizon operations. Furthermore, the *DriX* team developed models to predict vehicle endurance, and then conducted two 48-hour deployments west of O'ahu to test those theoretical models in the field.

Lessons learned during the Honolulu shakedown mission were immediately put to use during the NA164 expedition in American Samoa. Similar to the shakedown, dual remote operating centers were established, this time in American Samoa and New Hampshire, each staffed by watch teams for 24-hour operations. The developed endurance models were adjusted to allow for safe *DriX* deployments of up to 100 hours, which would be required to navigate *DriX* from Pago Pago to Vailulu'u and back. After all these preparations, E/V *Nautilus* departed Pago Pago Harbor on August 10, 2024 to start the NA 164 expedition. While dual multi-vehicle operations were planned early in the NA164 expedition, significant wave heights exceeding 3 meters prevented safe operations, forcing E/V *Nautilus* back into port on August 14–16 to await better weather conditions. During their time in port, the *DriX* team worked with the E/V *Nautilus* team to further test backup systems whose operation would be critical in the event of a Starlink outage or *DriX* engine failure.

As weather conditions improved, E/V *Nautilus* departed Pago Pago on August 17 to restart the NA164 expedition. That day, *DriX* was also deployed, meeting E/V *Nautilus* in the lee of Tutuila Island for collaborative operations.

Figure 2. Map showing the *DriX* track during the deployment and subsequent Starlink antenna failure 80 nautical miles from Pago Pago. The team later determined that the antenna failure was the result of severe motion in rough seas, which prevented the tracking of satellites, an issue that has since been fixed in more recent generations of Starlink antennas.

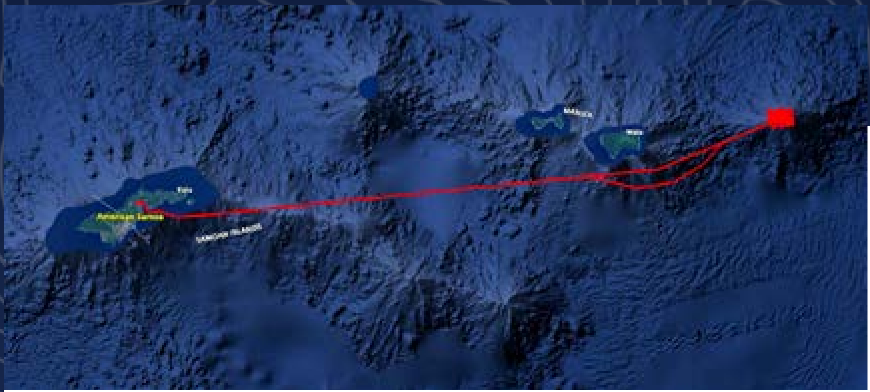


Figure 3. Map showing the complete *DriX* track on August 24–28 during transits between Pago Pago and Vailulu'u Seamount.

Although wave heights that day were forecasted to remain below 3 meters, *DriX* experienced peak-to-peak heave in excess of 4 meters during the transit out to the study site, causing *DriX* to roll from side-to-side by up to 30 degrees. *DriX* persevered through these challenging conditions, meeting E/V *Nautilus* for the first collaborative multi-vehicle operations of the NA164 expedition on August 17. These involved collaborative operations between *Mesobot* and *DriX* focused on system testing and interoperability (see Yoerger et al. in this report). Unfortunately, these multi-vehicle operations could only extend for 36 hours, as wave heights continually increased and eventually reached heights of over 3 meters, forcing *DriX* back into port.

August 19 provided the next favorable weather window of the NA164 expedition. *DriX* was deployed early that day, this time to meet E/V *Nautilus* at Vailulu'u Seamount. During the transit and while *DriX* was located approximately 80 nautical miles offshore (Figure 2), SpaceX queued a firmware update for the *DriX* Starlink system, causing the Starlink antenna to fail to establish a network connection. This significantly reduced the ability of the *DriX* team to communicate with the vehicle, limiting *DriX* control to sending text messaging via Iridium. As a result, *DriX* was piloted towards Ofu Island, where a 4G cellular connection was established. The *DriX* was commanded to remain near Ofu Island until the Starlink connection was finally restored some 8 hours after the firmware update. *DriX* then returned to port so the team could troubleshoot the issue and replace the Starlink antenna.

While all issues were quickly fixed in port, the next deployment of *DriX* had to be delayed until August 25 due to wave heights exceeding 3 meters. *DriX* arrived at Vailulu'u Seamount on August 26 (Figure 3), and conducted a seafloor mapping survey using its EM712 sonar. After completing a high-resolution survey of the entire seamount, *DriX* used its EK80 sonar to map the water column above the seamount. The water column mapping transects focused on areas with suspected hydrothermal vent plumes. Verified directed sampling operations with *Mesobot* continued until August 28 (Figure 4; see Yoerger et al. and Govindarajan et al. in this report), when E/V *Nautilus* and *DriX* conducted their final transit into port to conclude the NA164 expedition. Many innovative methods and systems were developed to make NA164 a safe and successful mission. These successful developments will help inform future shore-based *DriX* operations, as well as help improve the overall performance of *DriX* as a critical tool to support ocean exploration and science.

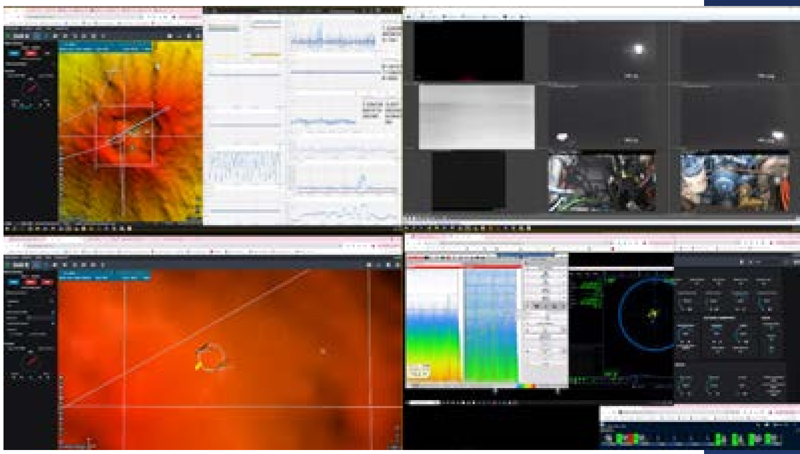


Figure 4. *DriX* operator computer screen during verified directed sampling operation over Vailulu'u Seamount. *DriX* position data can be seen on the left and *Mesobot* positions are shown in the blue-green diagram in the lower right inset.

MESOBOT MEETS THE VOLCANO: MIDWATER BIODIVERSITY EXPLORATIONS IN AMERICAN SAMOA

Dana R. Yoerger, Eric Hayden, M. Jordan Stanway, Annette Govindarajan, and Nina Yang

Located roughly 145 kilometers east of Pago Pago with a summit at a depth of 590 meters, Vailulu'u Seamount is the only hydrothermally-active seamount in the Samoan Islands (Figure 1). First discovered in 1975, and surveyed by several expeditions that occurred in 1999–2019, this underwater volcano has erupted recently, creating highly dynamic environments. In such settings, animals may thrive by exploiting nutrients from both hydrothermal vents on the seafloor and overlying midwater environments, while possibly transporting nutrients between those two habitats. After gaining our excitement about the great scientific potential of the site, we needed to answer a tough question: were we willing to launch *Mesobot* into a volcano to access the region of active venting? If we could do that, then we could use the suite of sensors, cameras, and environmental DNA (eDNA) samplers on *Mesobot* to collect critical data that could shed light onto these unique environments.

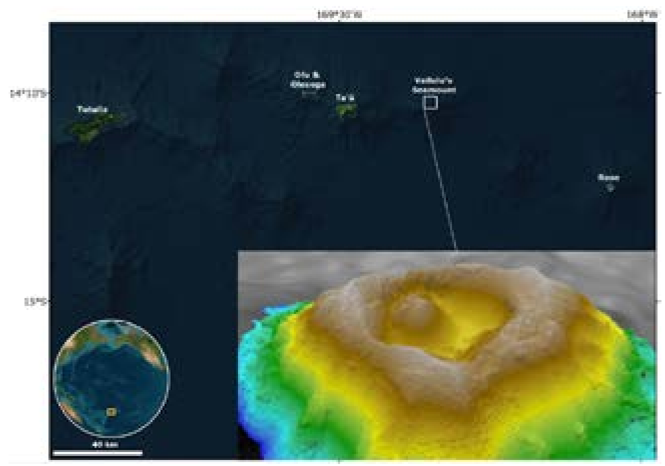


Figure 1. Map showing the location of Vailulu'u Seamount, approximately 145 kilometers east of Pago Pago and directly above the Samoan Hotspot where all islands in the Samoan Archipelago were once formed. Inset map created with QPS Fledermaus software with a two-times vertical exaggeration using high-resolution seafloor mapping data collected by uncrewed surface vehicle *DriX* during the NA164 expedition (see Schmidt et al. in this report).

Unlike ROVs *Hercules* and *Atalanta*, *Mesobot* was designed to operate in midwater settings far away from the seafloor. Similarly, autonomous underwater vehicle *Sentry* was purpose-built for seafloor exploration (see Kelley in this report). *Sentry* has multiple sensors that enable it to determine its height above the seafloor, and to detect obstacles in its path. It is highly maneuverable and employs sophisticated real-time algorithms that enables it to conduct surveys close to the seafloor without colliding into obstacles. In contrast, *Mesobot* has no such sensors or algorithms. Even if we launched *Mesobot* into the center of the Vailulu'u caldera, over a dive lasting several hours currents could push *Mesobot* into the side of the steep crater walls. While we could use acoustic commands to direct *Mesobot* away from such hazards, that was not something we wanted to rely on. Historical records of currents at depth in this region were encouraging, but not complete.

Figure 2. *Mesobot* being recovered back on deck of E/V *Nautilus* after a successful dive to explore midwater environments above Vailulu'u Seamount.

We therefore proceeded cautiously once E/V *Nautilus* departed Pago Pago to begin the NA164 expedition. On the first *Mesobot* dive of the expedition (dive 093), we launched the vehicle at the center of the caldera, and programmed it to descend no deeper than the shallowest point of Vailulu'u. We were relieved that *Mesobot*'s drift due to currents did not pose a threat and we had a successful first dive (Figure 2). A few days later, on dive 095, we sent the vehicle deep into the caldera reaching a maximum depth of 750 meters. During that dive, *Mesobot* took eDNA samples at a predefined set of depths, conducted visual surveys, and collected water column measurements that clearly pinpointed hydrothermal layers. We observed cloudy and chemically reactive seawater on multiple sensors, and at times the video appeared murky due to particulates in the water. We observed many small animals that appeared more abundant in the hydrothermal layers. While these animals were too small to allow us to identify them in our visual surveys, we expect that the eDNA samples we collected on this mission will eventually reveal their identity (see Govindarajan et al. in this report).

Mesobot is equipped with several sensors that measure light levels and detect changes in water clarity. For the NA164 expedition, we also borrowed a self-contained package called a miniature autonomous plume recorder (MAPR) that was specifically designed by the NOAA Pacific Marine Environmental Laboratory to detect hydrothermal activity. In addition to measuring optical backscatter, a measure of the presence of particles in water, MAPRs also measure oxygen reduction potential (ORP), a measure of the presence of chemicals in seawater that can be oxidized over time. Unlike light scattering anomalies, which can be highly variable around vents, ORP signals degrade very quickly as you move away from hydrothermal sources, and can therefore be used to reliably locate areas with fresh hydrothermal activity.

In addition to adding the MAPR, we made several upgrades to *Mesobot*'s imaging systems prior to the NA164 expedition. These included moving the lights out on booms to better shape the light patterns in front of its cameras (Figure 3). Our upgrades increased the amount of light on our subjects and reduced stray light close to the cameras. We also added a third light. As a result, subjects were better lit, particularly when using red light. Red light is important in ocean exploration as most midwater animals cannot see it, so avoidance of animals is reduced. During the NA164 expedition we made some important observations with red light, including a large aggregation of small animals that correlated with the hydrothermal layers in the caldera of Vailulu'u Seamount.

We also added an optical lure to *Mesobot* prior to NA164 (Figure 4). The lure resembles a flashlight with a programmable array of blue light-emitting diodes (LEDs). While we did not conduct quantitative comparisons, dives using the lure may have enabled us to better observe the aggregation of animals seen in the hydrothermal layer. Qualitatively, the aggregation appeared more intense with the lure than without, and the animals appeared more abundant near the lure. The lure also produced some entertaining encounters with oceanic whitetip sharks in near-surface waters.

Figure 3. Several upgrades to the imaging systems of *Mesobot* were implemented prior to the NA164 expedition, including moving the lights out on booms to better shape the light patterns in front of its two cameras.

Figure 4. An optical lure was added to *Mesobot* prior to the NA164 expedition. Similar to the lures on anglerfish, *Mesobot*'s lure uses lights mounted on the front of the vehicle to attract animals near its cameras.

During *Mesobot* dives, we can supervise *Mesobot*'s progress and change its mission by sending commands via an acoustic link. During the NA164 expedition, we once again made use of this feature to conduct verified directed sampling using combined operations of *Mesobot* and uncrewed surface vehicle *DriX*. The verified directed sampling strategy takes advantage of the fact that we can see water column targets from the *DriX* sonar systems in real-time, and then *Mesobot* is directed precisely to those targets to survey or sample (see Schmidt et al. in this report). During the NA164 expedition, we made several *Mesobot* dives that were coordinated closely with *DriX* to enable verified directed sampling.

Unfortunately, weather was a big factor on the NA164 expedition. Four days into the expedition, sea states got so bad that over-the-side operations were not feasible, forcing E/V *Nautilus* back into port in Pago Pago to await better weather. While weather conditions improved in the next few days, E/V *Nautilus* worked mostly in sheltered locations around Tutuila Island. During this time, *Mesobot* conducted several dives away from Vailulu'u Seamount in waters closer to the islands that enabled us to test our new systems, as well as gather important data of interest to the National Marine Sanctuary of American Samoa, and other stakeholders in American Samoa.

Overall, we completed 16 *Mesobot* dives during the NA164 expedition, including five in the caldera of Vailulu'u Seamount (Figure 5). During these dives, we collected a total of 142 hours of video footage, continuous light and environmental data, and 222 eDNA samples. These rich data sets are currently being analyzed. We are grateful for the many collaborations that made the NA164 expedition a successful mission despite the challenging conditions, including with the Biodiversity Group at Woods Hole Oceanographic Institution and their colleagues from Lehigh University, the University of New Hampshire *DriX* team, the National Marine Sanctuary of American Samoa, and the excellent operational support from the Ocean Exploration Trust.

Figure 5. Map showing the locations of the 16 *Mesobot* dives conducted during the NA164 E/V *Nautilus* expedition to American Samoa.

DEEP AUTONOMOUS PROFILER (DAP)
OPERATIONS OFF AMERICAN SAMOA

Chris Roman, Roy Gilboa, and Julian Blanco

Building on two previous E/V *Nautilus* expeditions conducted in 2023, University of Rhode Island's *Deep Autonomous Profiler* (DAP) was once again deployed off the ship in 2024, this time to support multi-vehicle explorations in American Samoa (NA164). The DAP is a hadal water column profiler rated to a 11-kilometer depth that is capable of collecting environmental data (i.e., temperature, salinity, oxygen, and density), video and sound, as well as water samples throughout the water column, or while resting on the seafloor. The instrument is built around a 24 bottle CTD rosette, and is operated by a custom electronics package. The DAP can operate for up to about 24 hours, depending on the camera configuration, making it a suitable platform for joint operations with other vehicles.

For the 2024 season, a large-volume environmental DNA (eDNA) sampler was added to the DAP to collect filtered eDNA samples (Figure 1). The eDNA sampler takes up the space of four Niskin bottles. The filtering depth and duration can be pre-programmed prior to each DAP deployment, providing a customizable way to sample biodiversity at various scales. Additionally, water samples can be collected using the 12-liter bottles on the DAP, which can also be triggered at pre-programmed depths, and processed onboard for eDNA analyses. During the NA164 expedition, the DAP was primarily used to collect eDNA samples to support baseline biodiversity studies in American Samoa (see Govindarajan et al. in this report). A total of 159 eDNA samples were collected at depths ranging between 20–4,000 meters, including 44 samples collected using the eDNA sampler, and 115 samples obtained by filtering water collected by the DAP's Niskin bottles onboard E/V *Nautilus*.

On NA164, the video system was mainly run on the descents and at the surface, the latter of which to aid in DAP recoveries by making the instrument more visible in the dark. The lights were purposely left off while the DAP was on the bottom to minimize the potential avoidance or aggregation of organisms in response to the lighting of the instrument.

Figure Above. The *Deep Autonomous Profiler* (DAP) being deployed from E/V *Nautilus* during the NA164 expedition to American Samoa.

Figure 1. For the 2024 season the team integrated a large-volume eDNA sampler onto the *Deep Autonomous Profiler*, which enabled the collection of filtered eDNA samples at pre-programmed depths.

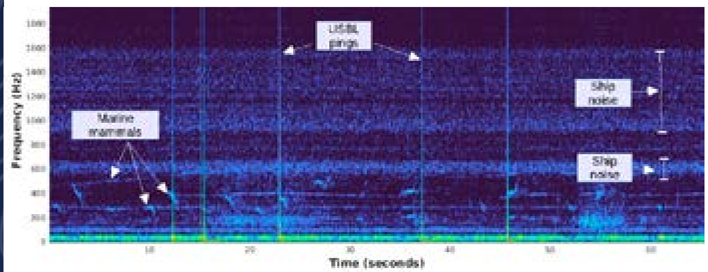


Figure 2. Spectrogram of passive acoustic data collected during a deployment of the *Deep Autonomous Profiler* near Tutuila Island during the NA164 expedition. Signals corresponding to ship noise, whale calls, and pings of the ultra-short baseline navigation system are labeled.

The DAP's 6000-meter rated [Ocean Sonics SC60-ETH icListen recorder]() was used on NA164 to collect passive acoustic data over the 10–200 kilohertz frequency range. This range allows for the detection of various natural and human-made sounds. For example, during a deployment to 1,200-meter depths near Tutuila Island, the acoustic recorder recorded numerous whale calls, as well as sounds produced by the ship's engines and ultra-short baseline navigation system (Figure 2).

Over the course of the NA164 expedition the team conducted eight successful DAP deployments to a maximum depth of 4,400 meters (Figure 3). Weather was a persistent issue during the NA 164 expedition, and thus many DAP deployments were completed with short weather windows and with the ship staying nearby. While weather limited operations, it did provide extra time to continue refining the DAP systems. One current issue with the acoustic recorder is that the sound produced by the DAP's CTD pump can obscure other ambient sounds, particularly when the instrument is on the bottom. This will be addressed prior to the 2025 season by pre-programming the CTD to turn off for long stretches of time while the DAP is resting on the seafloor. This will improve data quality and also increase the system endurance due to the reduced power draw. Furthermore, a new Aanderaa oxygen sensor will be added to the DAP in 2025 to improve data quality. After implementing these off-season improvements, we look forward to deploying the DAP on future E/V *Nautilus* expeditions in 2025 and beyond.

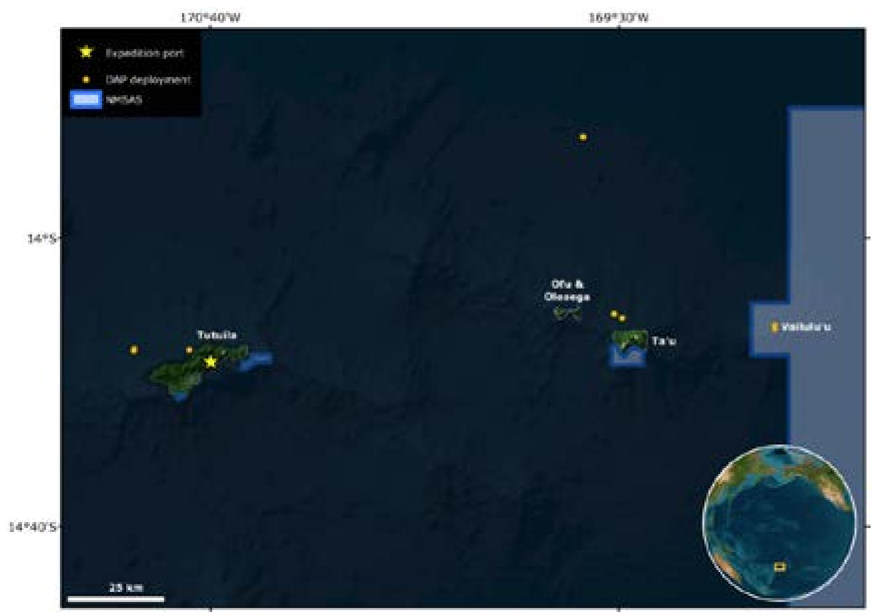


Figure 3. Map showing the location of the eight successful deployments conducted during the NA164 E/V *Nautilus* expedition to American Samoa including two deployments within the National Marine Sanctuary of American Samoa (NMSAS).

DEEP-SEA BIODIVERSITY EXPLORATION

IN AMERICAN SAMOA WITH ENVIRONMENTAL DNA

Annette Govindarajan, Nina Yang, Valerie Brown, Jason Fahy, Eric Hayden, Santiago Herrera, Larry Mayer, Luke McCartin, Chris Roman, Val Schmidt, Milan Sengthep, Adam Soule, M. Jordan Stanway, and Dana Yoerger

Over the course of two E/V *Nautilus* expeditions in 2024 (NA164–NA165), we had the unprecedented opportunity to comprehensively explore the deep-sea biodiversity in American Samoa. Our surveys included Vailulu'u Seamount, the only active volcano in the Samoan Archipelago, nearby volcanically-inactive seamounts, and abyssal plain habitats, providing an unique opportunity to increase our understanding of seafloor and water column environments in American Samoa, as well as the linkages between them.

Our biodiversity surveys were based on environmental DNA (eDNA), genetic signatures that organisms leave behind in seawater via fecal pellets, sloughed cells, and other mechanisms. On both the NA164 and NA165 expeditions, we utilized large-volume eDNA samplers that pump water *in situ* through small filters. These eDNA samplers were first deployed on AUV *Mesobot* dives conducted off E/V *Nautilus* in 2022 and 2023. During 2024 expeditions, we expanded their application by integrating these samplers on the *Deep Autonomous Profiler* and ROV *Hercules* (Figure 1) in addition to *Mesobot* (Figure 2).

Figure 1. Environmental DNA sampler mounted near the bottom of ROV *Hercules*.

We utilized two types of eDNA samplers on these missions, including Oceanic-WHOI multisamplers, which can be deployed to maximum depths of 1,000 meters, and a new Aquatic Labs Multipuffer sampler that can be deployed to 6,000 meter depths. In addition to these *in situ* samplers, we also collected eDNA samples by filtering seawater collected by the Niskin bottles on the *Deep Autonomous Profiler* and ROV *Hercules*. Using these various sampling methods, we collected over 600 eDNA samples over the course of the NA164–NA165 expeditions, which are now in our laboratory at the Woods Hole Oceanographic Institution for processing and analysis.

We employed several different eDNA sampling strategies in American Samoa. On the NA164 expedition, we used AUV *Mesobot* to conduct vertical transects between depths of 20 to 750 meters, collecting eDNA samples along the way. Transects were conducted both during day and night time to capture differences in animal distributions due to diel vertical migration, a light-driven movement up and down the water column that many species undergo on a daily basis. A highlight of the NA164 expedition was deploying *Mesobot* into the crater of Vailulu'u Seamount to obtain eDNA samples from the hydrothermal vent plume and overlying water (see Yoerger et al. in this report). Furthermore, we used acoustic backscatter data collected by uncrewed surface vehicle *DriX* to identify layers of high biomass in the water column, and then directed *Mesobot* to sample in those layers using the verified directed sampling approach that was developed on a previous E/V *Nautilus* expedition in 2023 (see Schmidt et al. in this report).

Figure 2. Nina Yang retrieving sample collected by the eDNA multisampler on *Mesobot*.

Figure 3. Nina Yang retrieving eDNA filters from their capsules to reduce the size of samples needed for storage and transport.

On the NA164 expedition we also sampled eDNA using the *Deep Autonomous Profiler*, which is capable of going to the deepest ocean depths, thereby enabling sample collections well below the operational depth limit of *Mesobot* (1,000 meters). Using the Multipuffer sampler and Niskin bottles mounted on the *Deep Autonomous Profiler*, we collected a total 168 eDNA samples between depths of 20 to 4,000 meters, thereby providing a broad cross section of water column environments in American Samoa.

On the NA165 expedition, we collected eDNA samples using the Oceanic-WHOI and Multipuffer samplers integrated onto ROV *Hercules*, in addition to the six Niskin bottles mounted on the ROV. In total, we collected 193 eDNA samples over a depth range of 50–2,981 meters. Using the ROV to collect eDNA allowed us to collect samples in areas where visual surveys found high biodiversity, such as dense deep-sea coral and sponge communities recorded on various seamounts, as well as active hydrothermal vents on Vailulu'u Seamount. The high-resolution video and physical specimens collected during ROV dives will provide an important dataset to compare with our eDNA data.

The number of eDNA samples collected on these missions was a new record for our team, which then faced the challenge of safely transporting them across the globe to the Woods Hole Oceanographic Institution for processing. To reduce our sample volume for storage and shipping, we dissected the eDNA sampler filters out of their capsule enclosures and re-packaged them into sterile plastic bags, which then could be stored in the limited space in the ship's freezers. Because eDNA analysis is based on minuscule genetic fragments, it is inherently sensitive to contamination. Therefore, our team thoroughly sterilized our work area in the ship's wetlab before processing every sample. To remove the eDNA filters from their capsules, they had to be opened using pipe cutters to expose the filter attached to an inner spool. Then, using sterile scalpels and forceps, the filters were carefully removed (Figure 3). Some of the filters were discolored, reflecting the rich geochemical environment of the sampled water (Figure 4). Our team processed all of our capsule filters in this manner. Upon return to Pago Pago, the samples were hand-carried on ice to Honolulu, where they were shipped on dry ice back to Woods Hole.

Our extensive dataset represents one of the most comprehensive eDNA surveys of deep-sea midwater and seafloor habitats conducted in American Samoa to date. These surveys could have not been possible without the use of multiple advanced technologies that have been developed by the NOAA Ocean Exploration Cooperative Institute and industry partners over the last several years. This work also required the hard work and dedication by many collaborators, including the National Marine Sanctuary of American Samoa, and other stakeholders in American Samoa. As we move forward with sequencing the many DNA samples that were collected during the NA164–NA165 expeditions, we look forward to learning more about the biodiversity of this rich but poorly studied region.

Figure 4. Environmental DNA filter stained yellow, likely from iron oxides associated with hydrothermal venting (image credit: Annette Govindarajan).

HIGHLIGHT ROV OBSERVATIONS IN AMERICAN SAMOA

Adam Soule and Derek Sowers

The waters around American Samoa contain a wide diversity of deep-sea environments, including submerged banks, seamounts, abyssal plains, and an active submarine volcano. Although still only marginally explored, these deep-sea environments host many productive ecosystems, including coral and sponge gardens, bottom fish nurseries, and chemosynthetic ecosystems. During the NA165 expedition to American Samoa, we had the opportunity to survey many of these deep-sea environments for the first time. Over the course of 17 successful ROV dives (Figure 1), we collected a large number of new observations and samples that will increase our understanding of the geological, biological, and chemical processes shaping deep-water habitats in American Samoa.

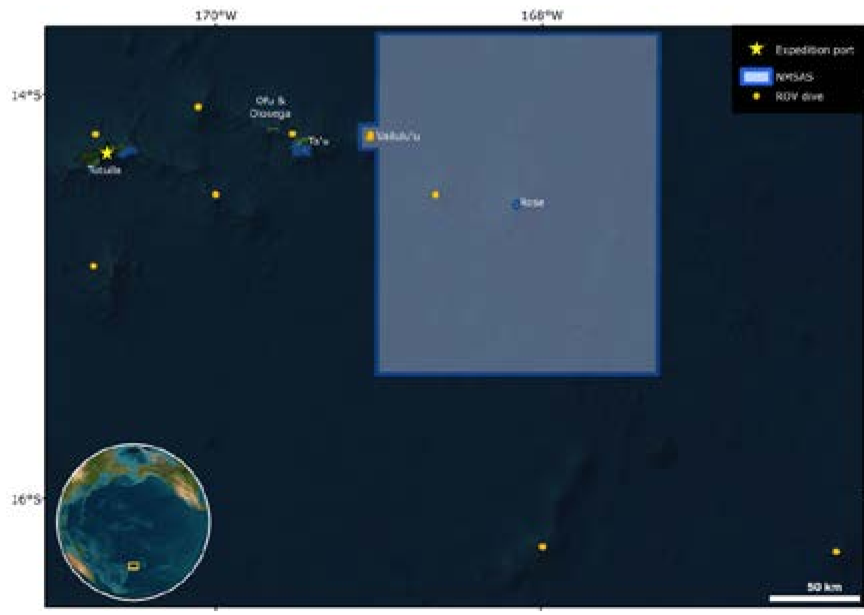


Figure 1. Map showing the locations of ROV dives conducted during the NA165 expedition to American Samoa, which included nine dives inside the National Marine Sanctuary of American Samoa (NMSAS).

GEOLOGICAL OBSERVATIONS

American Samoa is part of the Samoan Archipelago is made up of hotspot volcanoes with activity currently centered on Vailulu'u Seamount (see Yoerger et al. in this report). However, the region also contains numerous other volcanic seamounts that are significantly older and were generated elsewhere, including by other mantle plumes, or at the spreading center during crust formation. The majority of the ROV dives on the NA165 expedition visited these more ancient seamounts. In most cases, these sites were constructed of volcanic deposits that were heavily encrusted with iron-manganese crusts, along with heavily-sedimented slopes.

During the NA165 expedition we also conducted seven ROV dives on Vailulu'u Seamount, which has known hydrothermal vents and documented volcanic activity over the past 15 years. Detailed mapping data collected by AUV *Sentry* on the same expedition (see Kelley in this report) guided our ROV operations within the seamount crater. The AUV mapping data revealed details of the newly formed Nafanua dome that had not been previously visible. At these sites, the ROVs found fresh, glassy deposits of pillows lavas (Figure 2), along with fragmental deposits. Across the caldera, we observed a thin deposit of fine-grained volcaniclastic material that we infer was produced during the Nafanua eruptions, and transported in hydrothermal upflow across the volcano.

Figure Above. An ocean sunfish (*Mola mola*) documented at a depth of 580 meters during a ROV *Hercules* dive H2052, which explored the Manu'a Ridge, a volcanic ridge between the islands of Ta'u and Olosega.

Figure 2. Large pillow lavas documented at a depth of 711 meters during ROV *Hercules* dive H2059, which explored the Nafanua Cone of Vailulu'u Seamount.

Figure 3. Vent fluid filled with bubbles documented at a depth of 666 meters during ROV *Hercules* dive H2053, which explored the eastern edge of the caldera of Vailulu'u Seamount.

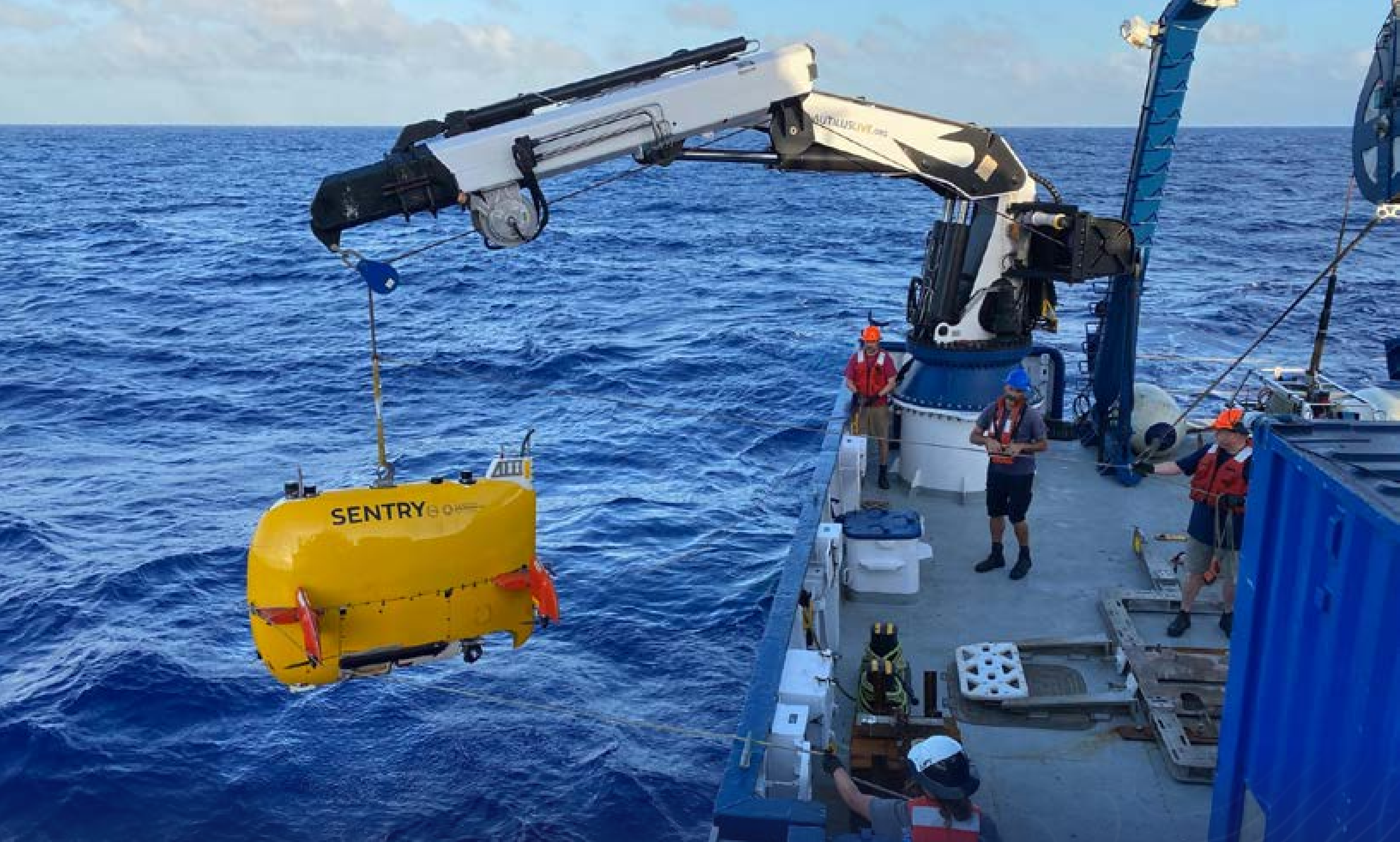
HYDROTHERMAL OBSERVATIONS

ROV dives at Vailulu'u Seamount explored two active hydrothermal systems, both of which had been documented on previous expeditions. The two vent systems were relocated with AUV *Sentry* (see Kelley in this report), enabling detailed measurements of fluid composition (see Burkitt-Gray et al. in this report), and physical properties (see Xu et al. in this report). The sites had not changed significantly since the last visits by E/V *Nautilus* in 2019. At the eastern end of the crater, the hydrothermal site occupied a bench near the crater rim and had a number of areas of fluid flow. Around the periphery of the site, fluid temperatures measured 156˚C, and were emitted from small vent structures made up of iron oxide. At the center of the site, fluid temperatures measured 240˚C, and the ROVs documented a highly friable vent structure composed mostly of anhydrite. At this site, the ROVs imaged vent fluids containing bubbles presumed to be filled with carbon dioxide (Figure 3). The other site was located at the base of the crater wall, and emanated through the recent Nafanua lavas. Temperatures at this site reached ~35˚C, and only a few iron oxide vent structures were observed along cracks within the lava flows.

BIOLOGICAL OBSERVATIONS

At older seamounts and ridges, benthic communities were dominated by aggregations of cold-water corals and deep-sea sponges. Urchins, sea stars, crinoids, crabs, and sea cucumbers were all observed frequently in these environments, along with deep-sea fishes including halosaurs and cusk eels. Noteworthy observations included a moray eel and one of the deepest reported sightings of a *Mola mola* near 580 meters. Hydrothermal vents were colonized by chemosynthetic bacteria as well as crabs, snails, and scale worms. However, cooler vents dominated by iron-oxide seemed to host much less chemosynthetic fauna. At Nafanua, the newly erupted cone within the crater, we observed a number of species that were known to have colonized these fresh surfaces from previous years, including soft corals, anemones, and carnivorous sponges, although the organisms appeared larger than during earlier visits. In addition, the ROVs documented dead fish around the base of Nafanua Cone (Figure 4), similar to observations made at the site during submersible dives by the Hawai'i Undersea Research Laboratory in 2005.

Figure 4. Bones of dead fish documented at a depth of 749 meters during ROV *Hercules* dive H2058, which explored the Nafanua Cone of Vailulu'u Seamount.



AUV *SENTRY* OPERATIONS
OFF E/V *NAUTILUS*

Sean Kelley

The NA165 E/V *Nautilus* expedition to American Samoa marked a significant achievement for AUV *Sentry* (Figure 1), an autonomous underwater vehicle operated by the National Deep Submergence Facility, showcasing the vehicle's capacity to operate under challenging conditions and contribute to numerous scientific objectives. The expedition took place from September 1–24, 2024, and focused on exploring poorly known deep-sea habitats around American Samoa. The mission successfully demonstrated the collaborative potential of advanced uncrewed systems by integrating AUV *Sentry* with E/V *Nautilus* operations, including ROV dives, seafloor mapping, and telepresence-based exploration.

During the NA165 expedition, AUV *Sentry* completed 10 dives, accumulating over 142 hours of underwater operations. These dives mapped over 309 kilometers of seafloor, focusing on critical areas identified by the scientific and management community. Among these were abyssal plains and seamounts, including active vents on Vailulu'u Seamount. The primary goals were to characterize deep-sea habitats, search for hydrothermal vents, and investigate the location of the *Samoan Clipper*, a historically-significant aircraft that crashed off American Samoa in 1938. Although the *Samoan Clipper* was not located, AUV *Sentry* surveys provided high-resolution mapping data at a sub-20 centimeter resolution, uncovering many previously unseen geological features.

One of the highlights of the expedition was AUV *Sentry*'s work on Vailulu'u Seamount (Figure 2). The vehicle carried out comprehensive mapping survey of the summit crater, which contributed valuable geological data related to recent eruptions on its cone. This mapping effort was crucial in providing the most detailed view of the volcanic structure to date. Moreover, AUV *Sentry* was instrumental in detecting hydrothermal venting plumes, relaying data to the shore-side team in near real-time—a new feat for a fully autonomous system.

Figure 1. AUV *Sentry* and E/V *Nautilus* during the mobilization in American Samoa.

The expedition underscored AUV *Sentry*'s capability to handle operational difficulties. Surveys of the abyssal plain near the operational depth limit of AUV *Sentry* (6,000 meters) posed significant challenges, such as communication interferences and difficulties with releasing the weights. Nevertheless, the team managed three successful surveys in these remote abyssal environments, collecting high-quality sidescan sonar, bathymetric, and video data. This accomplishment was crucial for the Bureau of Ocean Energy Management's ongoing efforts to characterize deep-sea habitats for resource management.

In addition to fulfilling its scientific mission, AUV *Sentry* served as a test platform for new technological advancements. During the NA165 expedition, AUV *Sentry* helped to test innovative algorithms designed to locate hydrothermal plumes (see Xu et al. in this report), and field tested a new carbon dioxide sensor for plume characterization (Figure 3; see Burkitt-Gray et al. in this report). The vehicle's performance in transmitting data to shore-based participants in near real-time illustrated its utility for future remote science operations, setting a precedent for untethered vehicles in ocean exploration.

The NA165 expedition was a testament to AUV *Sentry*'s versatility, technical resilience, and scientific value. Its contributions not only advanced our understanding of American Samoa's deep-sea ecosystems, but also demonstrated the value of using both autonomous and remotely operated systems to explore the biggest and least known parts of our ocean. The expedition exemplified the future of ocean exploration—collaborative and technologically advanced operations that are driven by engagements with numerous stakeholders.

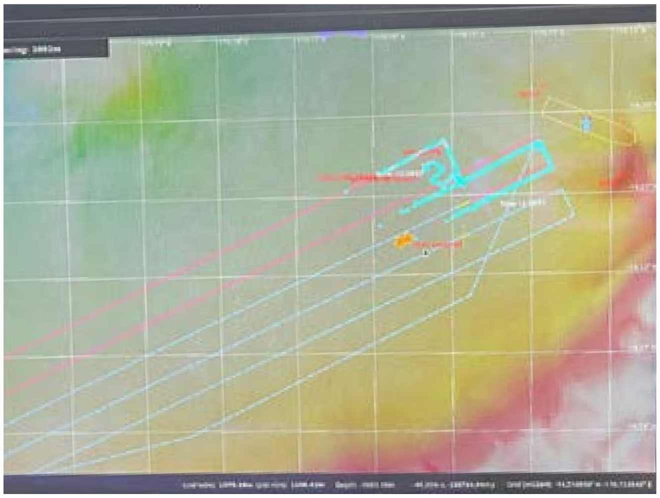


Figure 2. Navigation interface on AUV *Sentry* dive 736, during which it helped test innovative algorithms designed to locate hydrothermal plumes on Vailulu'u Seamount (image credit: Sean Kelley).

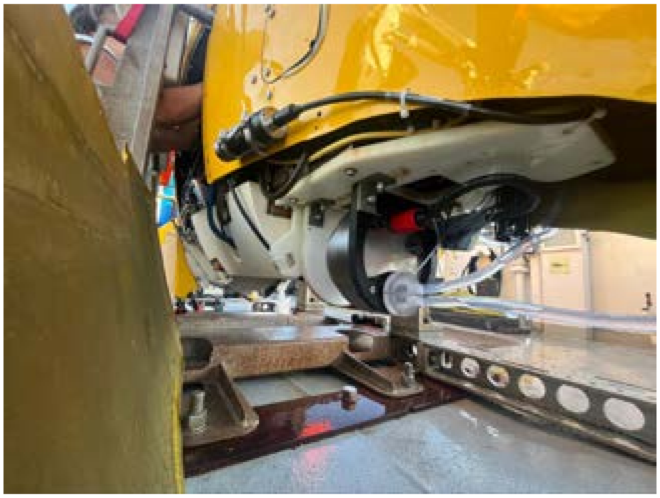
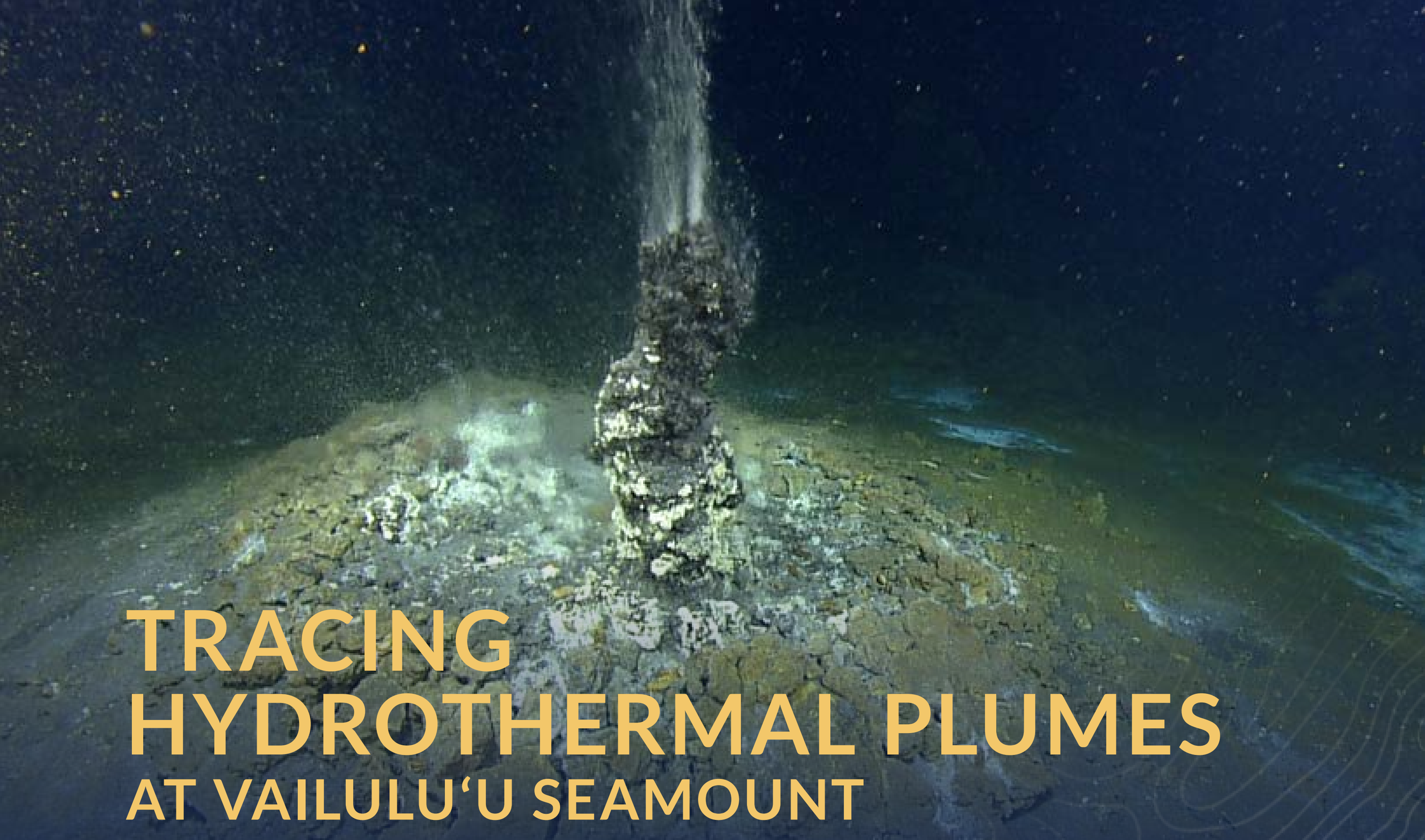


Figure 3. AUV *Sentry* carrying a recently developed carbon dioxide sensor (image credit: Sean Kelley).



TRACING HYDROTHERMAL PLUMES AT VAILULUʻU SEAMOUNT

Guangyu Xu, Christopher German, Andrew Branch, Mary Burkitt-Gray, and Victoria Preston

During the NA165 E/V *Nautilus* expedition to American Samoa, the autonomous underwater vehicle (AUV) *Sentry* (Figure 1) was used to test the prototype of an autonomous algorithm designed to locate hydrothermal plumes. This project was funded by NOAA Ocean Exploration via their competitive grants program. Once fully implemented, the algorithm will trace biogeochemical signatures that indicate the presence of hydrothermal fluids in the water column, guiding vehicles to the vent source and facilitating vent sampling, all without human intervention.

The algorithm testing was carried out during two AUV *Sentry* dives on Vailuluʻu Seamount conducted on September 15–16 and September 17–18. Each dive began with a broad survey conducted several tens of meters above the seafloor along pre-programmed track lines around the eastern rim of the summit crater (Figure 2). This area hosts several known hydrothermal sources, including a prominent vent that releases hot fluids and gas bubbles enriched in carbon dioxide (Figure 3). The vent was first discovered during an E/V *Nautilus* expedition in 2019, and its activity was confirmed early in the NA165 expedition during an ROV *Hercules* dive.

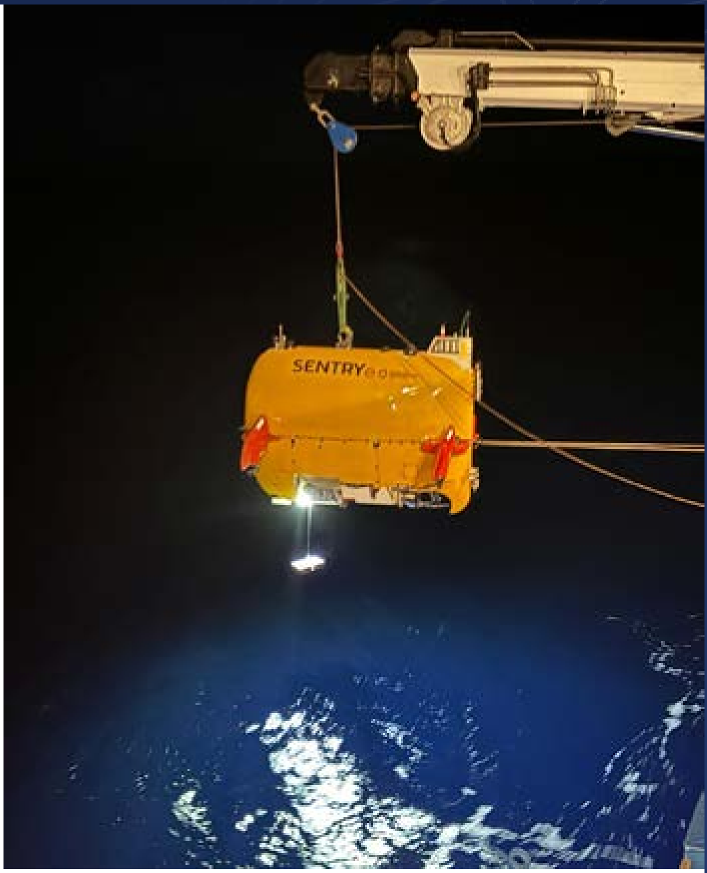


Figure 1. AUV *Sentry* being deployed from E/V *Nautilus* during the NA165 expedition for a dive to survey the water column over Vailulu'u Seamount (image credit: Christopher German).

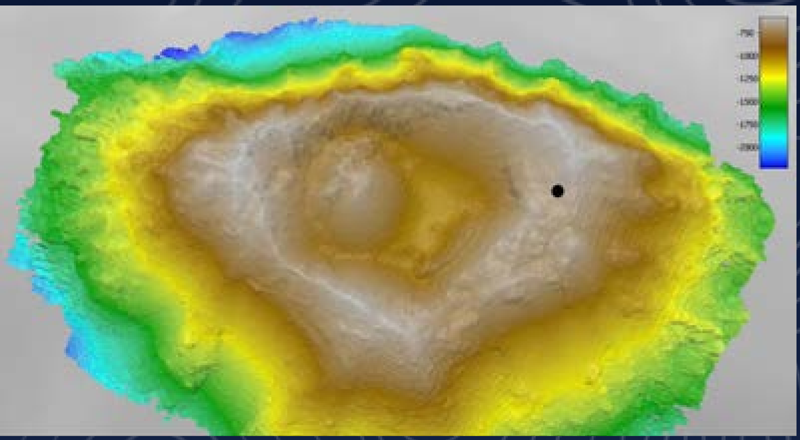


Figure 2. Map of Vailulu'u Seamount, with the black dot indicating the location of a hydrothermal vent on the eastern rim of the volcano. Map created with QPS Fledermaus software with a two-times vertical exaggeration. The color ramp indicates depth in meters.

Figure 3. A hydrothermal vent located on the eastern rim of the crater of Vailulu'u Seamount, which was the target site for the AUV *Sentry* surveys conducted to test a prototype of the autonomous plume-tracing algorithm.

During the initial *Sentry* survey, data from the sensors on the AUV were transmitted in near real-time using underwater acoustic communication, first to the ship and then via the Internet to a team on shore. These datasets were processed by the plume-tracing algorithm on a shoreside workstation, which identified likely hydrothermal vent sources, and defined areas for follow-up surveys targeting these vents. The algorithm's decisions were continually adjusted based on new data received from *Sentry*. The final algorithm decisions, specifically the coordinates of survey centers and boundaries, were relayed to the *Sentry* navigator onboard E/V *Nautilus*, who was then able to set trajectories for follow-up surveys (Figure 4).

The prototype autonomous plume-tracing algorithm performed as anticipated. Its decisions regarding the centers and boundaries of follow-up surveys aligned closely with those human watchstanders with extensive experience in hydrothermal plume tracing would have made in a traditional human-guided mission. Among the multiple seawater properties measured by the *in situ* sensors on AUV *Sentry*, significant decreases in oxidation-reduction potential proved to be the most sensitive and reliable indicator of hydrothermal fluid, which is typically enriched in chemically reducing elements.

Another notable achievement of this mission was the near real-time data transmission from the AUV in the deep ocean to a remote shore-based center, followed by the relay of algorithm-driven guidance back to the AUV (see Kelley et al. in this report). To our knowledge, this marks the first successful AUV-to-shore communication while the vehicle remained submerged and operational. This achievement holds significant potential for the future exploration using uncrewed systems, both on Earth and beyond. Overall, the testing results represent a positive step towards further development of the algorithm, and its integration into *Sentry*'s command and control system for fully autonomous plume tracing on future missions.

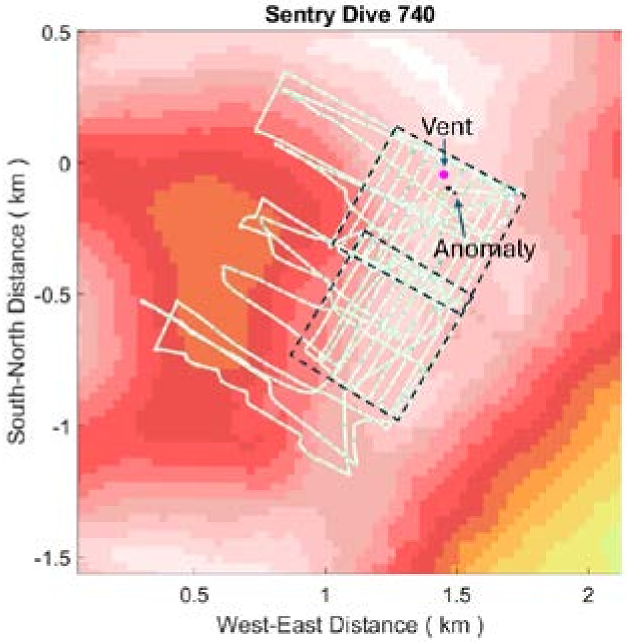


Figure 4. AUV survey trajectories (white lines) during the testing of the plume-tracing algorithm on *Sentry* dive 740. Darker segments along the trajectories indicate significant drops in oxidation-reduction potential, suggesting the likely presence of hydrothermal fluid. The two dashed boxes outline the boundaries of the follow-up surveys identified by the plume-tracing algorithm.

CHEMICAL EXPLORATION OF THE VAILULU'U SEAMOUNT WITH THE SAGE SENSOR

Mary Burkitt-Gray, Jason Kapit, Adam Soule, and Anna P. M. Michel

The *E Mamana Ou Gataifale II* expedition (NA165) took E/V *Nautilus* to the Samoan Hotspot, a region where upwelling magma under the Pacific Tectonic Plate has created a chain of active and dormant volcanoes. This chain includes the islands that comprise Samoa and American Samoa, as well as the seamount Vailuluʻu at the eastern extent of the chain.

Located about 145 kilometers east of Pago Pago, the capital of American Samoa, Vailuluʻu Seamount is an active deep-sea volcano with both recent volcanic eruptions and ongoing hydrothermal venting, where seawater is superheated to hundreds of degrees Celsius. The hydrothermal fluid is enriched in carbon dioxide from the underlying magma and infused with metals such as iron and manganese from water-rock reactions, before being expelled back into the ocean as hot, acidic fluids. Sites where these fluids are expelled are called hydrothermal vents, which create a massive influx of nutrients and chemical energy that forms the foundation of diverse deep-sea ecosystems around these underwater volcanic sites.

To understand the dynamic processes taking place at Vailuluʻu Seamount, carbon dioxide emissions and dispersal have to be studied across the whole site. Up until recently, this has been challenging to achieve, because gases were typically measured by taking indiviual bottle samples and anlyzing them in the lab. This gave limited scope to study a very large and highly variable volcanic system.

On the NA165 expedition, the science team mapped volcanic emissions across the entire Vailuluʻu Seamount by deploying a new *in situ* carbon dioxide sensor on ROV *Hercules* (Figure 1) and autonomous underwater vehicle (AUV) *Sentry* (Figure 2) operated by the National Deep Submergence Facility (see Kelley et al. in this report). The Sensor for Aqueous Gases in the Environment (SAGE) was first developed at the Woods Hole Oceanographic Institution to measure dissolved methane in the deep sea. In 2024, a new generation of SAGE that can measure deep-sea carbon dioxide was developed and deployed for the first time during the NA165 expedition. SAGE has a membrane-capped inlet that allows gas to be

Figure 1. Woods Hole Oceanographic Institution researcher Mary Burkitt-Gray and ROV Engineering Intern Esteban Jose Juan Torres install the SAGE carbon dioxide sensor onto ROV *Hercules*.

Figure 2. AUV *Sentry* being recovered after a successful dive on Vailulu'u Seamount, during which SAGE measured the carbon dioxide venting from the volcanic system (Image: Mary Burkitt-Gray).

extracted from seawater into a hollow optical fiber inside the instrument. A laser is directed through this fiber, and the concentration of carbon dioxide or methane is determined by analyzing how much of the light is absorbed at a wavelength range that is specific to each gas. Because the core of the optical fiber is so small in diameter, about half the thickness of a human hair, only a tiny amount of gas is needed to determine how much carbon dioxide or methane is present.

By deploying SAGE on several AUV *Sentry* dives, scientists were able to map the carbon dioxide distribution across the whole of the Vailulu'u Seamount, spanning the crater, rim, and the recently erupted Nafanua cone. During these dives, the science team on E/V *Nautilus* was able to continuously monitor the carbon dioxide concentrations by receiving regular acoustic messages sent by AUV *Sentry*. This also helped to facilitate real-time exploration for new vent sites, even by shore-based scientists located thousands of kilometers away (see Xu et al. in this report).

During explorations of Vailulu'u with SAGE on ROV *Hercules*, scientists aboard E/V *Nautilus* could guide their sampling based on the real-time carbon dioxide concentration at the seafloor. This provided valuable chemical context to the biological and geological systems observed during dives, such as revealing correlations between hydrothermal venting, deep-sea biodiversity, and the formation of iron-rich inorganic deposits. Using ROV *Hercules* to manipulate a pumped sampling wand (Figure 3), the carbon dioxide concentration could also be measured directly at regions of diffuse emissions, close to biological fauna, or inside vents. This enabled the team to identify new regions of carbon dioxide flow on the external walls of Vailulu'u Seamount that had not previously been known.

By combining the SAGE data from both ROV *Hercules* and AUV *Sentry* dives, researchers are able to construct an unprecedented map of the carbon dioxide distribution at this site—with the scale ranging from centimeter-size vent sites measured with ROV *Hercules* to kilometers-long AUV *Sentry* surveys across the cone. Collectively, this will allow a comprehensive estimation of the influx of carbon dioxide into the surrounding ocean, and will provide critical context to the chemical, geological, and biological processes at this active deep-sea volcano.

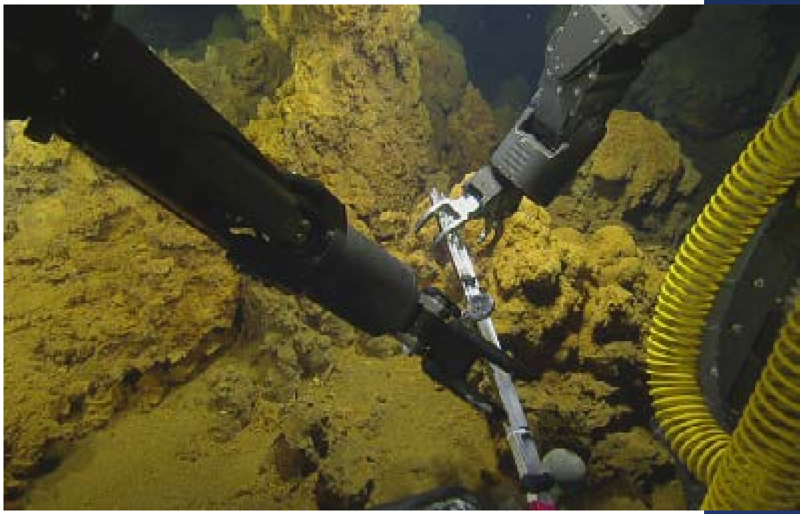


Figure 3. ROV *Hercules* manipulating the SAGE inlet wand to measure the concentration of carbon dioxide flowing from hydrothermal sources on Vailulu'u Seamount.

MAPPING SEABIRD AND TOPSIDE MARINE FAUNA

Chris Gaskin and Karen Baird

While E/V *Nautilus* expeditions are primarily dedicated to exploring poorly known parts of our deep ocean, these expeditions also provide unique opportunities to collect scientific information above the sea surface. This is of particular importance to explorations in the Central Pacific, which include some of the most remote and poorly studied areas on Earth. The Seafloor Mapping Offshore Howland and Baker Islands expedition (NA166) transited through many such areas, including passage through waters that are under eight different jurisdictions (Figure 1). While the primary goal of the mission was to map previously unsurveyed seafloor, we aimed to provide a topside contrast by conducting surveys for seabirds and other marine animals. Throughout this 26-day expedition, we spent over 360 hours on the observation deck of E/V *Nautilus*, during which we documented over 1,300 individuals in 29 bird species.

Figure 1. Map showing the track of E/V *Nautilus* during the NA166 expedition, which transited over 7,000 kilometers of ocean in the Pacific, including passage through eight different exclusive economic zones (EEZ).

MIGRATING BIRDS

As seabird researchers, we use tracking technologies to trace the movement of birds across large ocean areas. While such tracking data provides a lot of useful information about the movement of individual species, surveys like the ones we conducted on the NA166 expedition, provides a lot of additional information about the abundance, diversity, and behaviors of multiple species. We documented several migrating seabird species on our journey, including Mottled Petrels and Short-tailed Shearwaters. These species spent considerable time foraging in highly productive waters at higher latitudes. Mottled petrels breed in islands off Aotearoa and Short-tailed shearwaters off Australia. During breeding they can venture deep into the Southern Ocean, and have even been seen feeding amongst the pack ice in Antarctica. Once they finish breeding, they head north in May, crossing the equator. We had the spectacle of seeing hundreds of these migrating

Figure Above. The red-tailed tropicbird was often found foraging alone. Seabirds typically do not have the colourful plumage that is found in many land birds. The tropicbirds are an exception to this trend, as these birds are characterized by pairs of elegant central tail feathers.

Figure 2. Near the islands of Howland and Baker, we documented large numbers of Short-tailed Shearwaters on their migration back south towards the Southern Ocean.

shearwaters pouring through in groups of fifty or more while E/V *Nautilus* conducted mapping operations near the islands of Howland and Baker (Figure 2). We also saw Stejneger's Petrels from Chile, as well as Black-winged Petrels, Kermadec Petrels, and Cook's Petrels from Aotearoa.

Rather surprisingly, the only storm petrel species seen during the entire expedition was the Leach's Storm-petrel, which is easily distinguished from other storm petrels by its double white rump patches. Storm petrels are some of the smallest oceanic seabirds and appear so fragile, yet they are supremely adapted to life at sea. Bulwer's Petrels are a bit larger than storm petrels, and were commonly seen during the second half of our journey while we were north of Papua New Guinea and the Solomon Islands. Their small size for a petrel, combined with their distinctive wing moult, made them easy to pick out even in poor light conditions.

Other noteworthy observations included recording two species of shorebirds far away from land, including golden plover (Figure 3), and the spectacularly patterned ruddy turnstones. Golden plovers migrate from their summer breeding grounds in the Arctic to tropical island locations during the winter. They often circled E/V *Nautilus* a few times before continuing on their way.

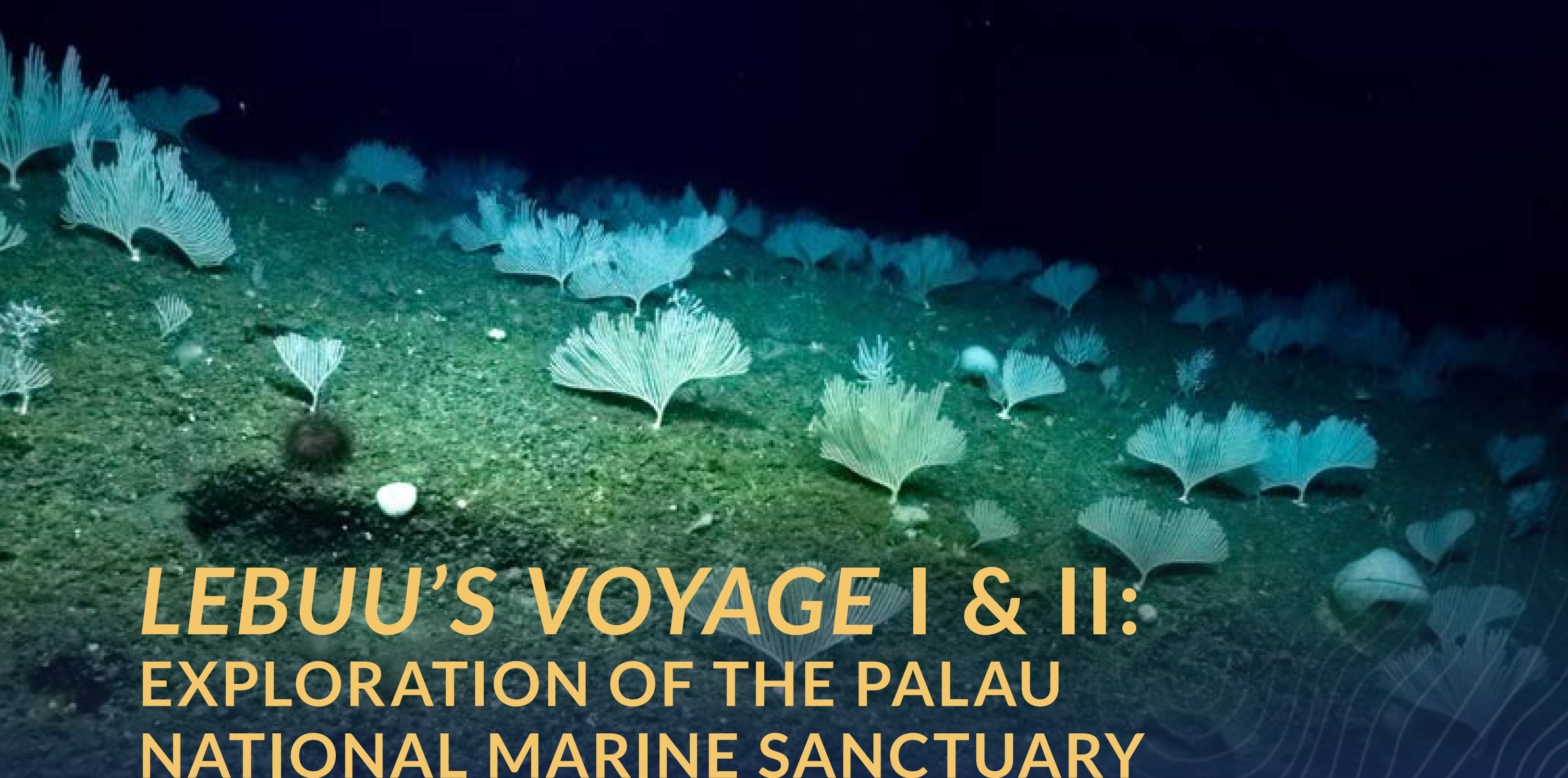
OCEAN BOUNDARIES

The expedition transit route took us through many interesting ocean areas, including a 175-nautical mile gap between the Gilbert Islands in Kiribati, and the Marshall Islands. Both of these island groups run perpendicular to major ocean current systems, including the westward-flowing Equatorial Current, and the eastward-flowing Equatorial Counter Current. As E/V *Nautilus* moved across this region, we were clearly able to see the sharp boundary between both current systems, with one side being completely smooth, and the other having many whitecaps and standing waves. As E/V *Nautilus* moved across this boundary, we could see many seabirds and fish schools, with numerous feeding aggregations.

FEEDING ASSOCIATIONS

Boobies are some of the best-known tropical seabirds breeding on islands throughout the Pacific. They are also notoriously attracted to vessels, which provide convenient resting platforms. We always knew when a tuna school was nearby, as the boobies would desert their posts on E/V *Nautilus*, and head off in a hurry to join the rest of the birds taking advantage of small prey being driven to the surface by a foraging tuna school. Birds seen in such feeding associations included terns, noddies, boobies, and frigatebirds, which along with wedge-tailed and tropical shearwaters made for some spectacular foraging action. We also often witnessed flying fish leaping into the air, whereupon the boobies would swoop down and pluck them out of the air. Brown boobies and to a lesser extent masked boobies also used this technique.

Figure 3. We documented golden plovers far away from land on the NA166 expedition. At the time the expedition started, these shorebirds started arriving in American Samoa on their long migrations from breeding grounds in the Arctic.



LEBUU'S VOYAGE I & II: EXPLORATION OF THE PALAU NATIONAL MARINE SANCTUARY

Brian R.C. Kennedy, E. Ikelau Otto, Jeffrey C. Drazen, Harold K. Carlson, Piera Biondi, Maikani Andres, Mae Lubetkin, Elsei Tellei, Greta Sartori, Renato Kane, Noelle Helder, and Daniel Wagner

In October–November 2024, the Ocean Exploration Trust had the honor and privilege to partner with the Palau International Coral Reef Center to conduct the first-ever project dedicated to exploring deep-sea habitats of the Palau National Marine Sanctuary. Funded by NOAA Ocean Exploration as a contribution to the US Government commitment to support mapping of the Sanctuary, these expeditions (NA167–NA168) explored never-before surveyed ocean areas around Palau. Throughout the two-year planning for the mission, the Ocean Exploration Trust worked closely with Palauan stakeholders to ensure that expedition activities addressed local management and science priorities. This included working with the Palau Council of Chiefs, the Society of Historians, the Koror House of Traditional Leaders, and others to incorporate local knowledge and customs into the implementation of the expedition. This led to the expedition being gifted the name [*Lebuu's Voyage*, honoring one of Palau's first ocean explorers]().

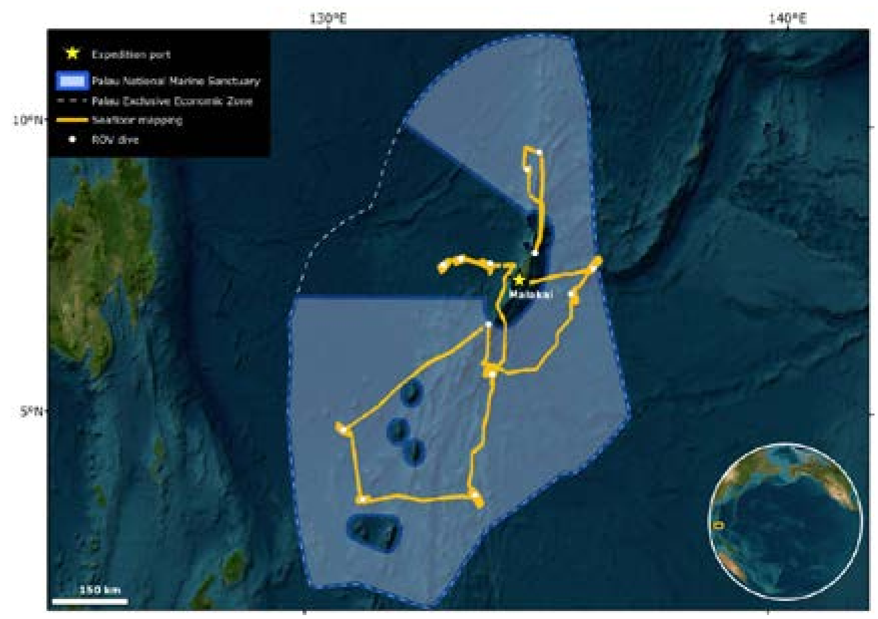


Figure 1. Map showing the locations of seafloor mapping operations and ROV dives conducted during the *Lebuu's Voyage* expeditions in Palau (NA167–NA168).

Across two back-to-back expeditions spanning 21 days at sea, which included the at-sea participation of eleven Palauan-based team members, we documented a wide range of deep-sea habitats, made several novel observations, and collected scientifically valuable

Figure Above. A high density, low diversity community made up exclusively of large primnoid corals.

Figure 2. Palau International Coral Reef Center researcher Elsei Tellei retrieving a water sample from a Niskin bottle mounted on ROV *Hercules* that will support the eDNA monitoring program of the Palau National Marine Sanctuary.

samples, contributing to a better understanding of the deep-water natural and cultural resources of Palau. Collectively, the two expeditions mapped 19,052 square kilometers of seafloor, completed 13 successful ROV dives for a total of 156 hours exploring the seafloor at depths ranging between 528–3,038 meters (Figure 1), and collected 367 samples to support studies on the biodiversity, biogeography, and geological context of the region. The expedition goals of mapping, characterizing, and sampling deep-sea benthic communities, particularly those found within vulnerable marine habitats with high conservation value, were successfully achieved.

To support ongoing monitoring work in the Palau National Marine Sanctuary, collaborators from the Palau International Coral Reef Center collected environmental DNA (eDNA) throughout the missions. Samples were collected, both near the surface by casting a Niskin bottle on a handline off the side of E/V *Nautilus*, and at different depths using the six Niskin bottles mounted on ROV *Hercules* (Figure 2). Sampling with the ROV targeted areas near the seafloor and in the water column, and generally occurred at depths of 2,500, 1,000, 500, 250, and 100 meters. When the maximum depth of the ROV dive was shallower than these set depths, the extra Niskin bottles were strategically triggered close to areas with high biodiversity, or near the summits of seamounts. In total, 142 eDNA samples were collected and filtered during these expeditions, data from which will help establish a biological baseline of the waters of Palau, and support marine spatial planning and resource management in Palau.

Despite several previous expeditions having surveyed deep-sea environments around Palau, depths between 500 and 4,000 meters were largely ignored, with most past research focusing either on much shallower waters, or deeper areas surrounding trenches. To help fill this gap, the *Lebuu's Voyage* team mapped and surveyed 11 different seamounts across both expeditions. Interestingly, each seamount seemed to host unique communities with no two seamounts being the same. Eight of the surveyed seamounts hosted high-density coral and sponge communities. Some of these communities were of high density and high biodiversity (Figure 3), whereas other high-density communities had

Figure 3. A high density and high-diversity coral community including numerous different coral families.

Figure 4. Fossilized aggregations of deep-water stony corals were found near the summit of several seamounts, with few live corals seen growing amidst the dead coral rubble.

a low diversity and were dominated by only one or few types of corals. Some of these high-density and low-diversity communities were dominated by large and very old bamboo corals, while others were dominated by corals in the family Primnoidae. The environmental factors driving differences between these communities will be the focus during a more detailed analysis of the data collected during the mission.

Another noteworthy observation from this mission was that several seamounts surveyed with ROV *Hercules* had extensive fossilized aggregations of deep-water stony corals (Figure 4). These large expanses of fossilized coral reefs were found near the summit of several seamounts and had very few live corals growing amidst the dead coral rubble. This mismatch in abundance between dead skeletons and live corals likely indicates that large-scale oceanographic changes occurred in this region in the past, shifting the habitat suitability for stony corals on geological time scales.

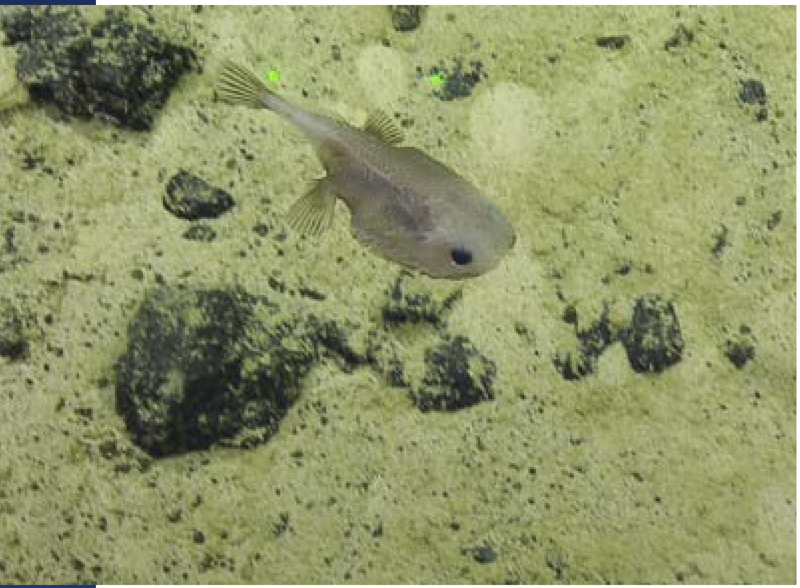


Figure 5. A batfish in the genus *Coelophrys* that has thus far eluded our ability to identify to the species level.

Throughout the expedition, particular attention was given to documenting and collecting deep-sea fish. Across both expeditions, 13 fish specimens were collected, which doubled the number of fish specimens E/V *Nautilus* has collected over its rich 15-year history. Two fish collections were particularly interesting. The first was an anglerfish in the family Gigantactidae that is either a new species in the genus *Rhynchactis*, or only the second-ever specimen of the species *Rhynchactis microthrix*, which to date is only known from the Indian Ocean. Another fish collection that captured the attention of the team was a batfish in the genus *Coelophrys* (family Ogcocephalidae), that has thus far eluded our ability to identify to the species level, and may also represent a new species (Figure 5).

Another interesting observation was the abundance of wood falls. These falls create unique communities of wood-consuming organisms that are not found in other environments. Such specialized communities can persist for many years consuming the organic material of the wood fall, thereby increasing local biodiversity. While wood falls can be found worldwide, they seem to occur at a much higher rate around Palau than in other places where deep-sea habitats have been surveyed in the Pacific Islands region.

Beyond ROV dives, E/V *Nautilus* collected extensive mapping and environmental data on this mission, adding over 19,000 square kilometers of high-resolution seafloor mapping data to the region, including 14,781 square kilometers mapped inside the Sanctuary. The extensive data that was collected during the *Lebuu's Voyage* expeditions will help establish a baseline for the deep waters of the Palau National Marine Sanctuary, and has already sparked ideas for several follow-up studies that will help us better understand the unique geologic setting, oceanographic conditions, and biologically abundant and diverse waters of Palau.

ISLAND WAKES AND OCEAN PRODUCTIVITY

AROUND THE PALAUAN ISLANDS: INSIGHTS FROM THE NA169 E/V *NAUTILUS* EXPEDITION

Eric J. Terrill and Sophia T. Merrifield

The oceanography around Palau is shaped by complex interactions between large-scale ocean currents and local bathymetric features. While the region's nearshore waters have been relatively well studied, offshore environments remain mostly unexplored. The NA169 expedition aimed to address this knowledge gap by deploying an array of complimentary oceanographic instruments to study island wakes and their impact on regional productivity. Sponsored by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute and the Office of Naval Research, the mission used several advanced technologies to enhance our understanding of the physical-biological interactions in the highly dynamic environments offshore Palau.

Figure 1. Slocum buoyancy glider being prepared for launch from the E/V *Nautilus*.

BACKGROUND

The island mass effect is a phenomenon in which oceanic islands modify surrounding oceanographic conditions, enhancing biological productivity through interactions between currents, bathymetry, and atmospheric forcing. This phenomenon is widespread, with over 90% of surveyed coral reef ecosystems having enhanced productivity associated with the island mass effect. Around Palau, the interaction of the westward-flowing North Equatorial Current and the eastward-flowing North Equatorial Countercurrent with the steep topography of the islands generates island wakes, turbulence, and upwelling, which redistribute nutrients into the photic zone. These processes increase primary production downstream, supporting diverse marine ecosystems. Satellite observations have revealed enhanced productivity extending far beyond Palau's nearshore waters, particularly within the Palau National Marine Sanctuary, where localized eddy formations and nutrient entrainment play a key role in sustaining pelagic food webs. The NA169 expedition deployed several uncrewed systems from the Scripps Institution of Oceanography, including buoyancy gliders (Figure 1), wave gliders (Figure 2), a WAM-V autonomous surface vehicle (Figure 3), and a vertical microstructure profiler, to quantify the physical and biological effects of these island-driven processes, providing new insights into how ocean circulation modulates productivity in this dynamic region. Complementing these observations, E/V *Nautilus*' mapping and remotely operated vehicle systems were deployed during the NA169 expedition.

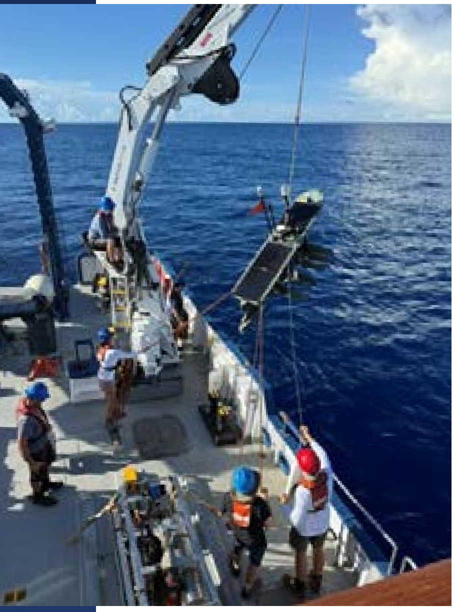


Figure 2. A wave-powered wave glider being deployed from the E/V *Nautilus* (left) and the vehicle sampling ocean waters in Palau during the NA169 expedition (above).

Figure 3. The WAM-V being launched from the back deck of the E/V *Nautilus* (left), and the WAM-V team members Charlie Brooks, Jacob Springman, and Derek Ung (right).

UNCREWED SYSTEM DEPLOYMENTS

The Liquid Robotics Wave Gliders are long-duration, autonomous surface vehicles that use wave-powered propulsion and solar energy to [collect oceanographic and meteorological data in the upper ocean](). Two systems were deployed and operated continuously while the E/V *Nautilus* was underway, one of which was equipped with a chlorophyll sensor. We also deployed four Teledyne Webb Research Slocum Buoyancy Gliders, each of which was equipped with a CTD sensor for measuring temperature, salinity, and depth, and configured to profile the upper 250 meters of the ocean. Two of the buoyancy gliders were also equipped with optical sensors for measuring dissolved oxygen, chlorophyll-a fluorescence, optical backscatter, and photosynthetically active radiation. Furthermore, we deployed the WAM-V autonomous surface vehicle, which is powered by electric motors with lithium-ion batteries, and equipped with a retractable sensor pole carrying a 500 Hertz Nortek Acoustic Doppler Current Profiler, a CTD sensor, and a chlorophyll fluorometer. The speed of the platform, coupled with the sensing payload, enables high-resolution measurements of currents, hydrography, and biological productivity. In addition, we used the WAM-V to measure wind speed and direction, air temperature, relative humidity, and barometric pressure at two different elevations above the water level to document the atmospheric boundary layer.

SHIP-BASED MAPPING AND PROFILING

Multibeam bathymetry and acoustic Doppler current profiling (ADCP) were conducted using the E/V *Nautilus*' hull-mounted Kongsberg EM302 and EK80 sonars. A first for the E/V *Nautilus* was the configuration of the EK80 sonar to operate with interlaced acoustic pings to allow for simultaneous ocean current profiling and high-resolution mapping of acoustic backscatter at 200 kilohertz. This frequency can detect small biological targets such as zooplankton, making it a useful tool for assessing biological productivity, biomass distribution, diel vertical migration, and trophic interactions in the water column.

Complimenting the hull-mounted sonar was the installation of a small specialized deck winch on the aft of the ship to support a vertical microstructure profiler. This system descends through the water column at a speed of approximately 1 meter per second, and collects fine-scale profiles of temperature, salinity, chlorophyll, dissolved oxygen, and shear microstructure. Once the profiler reaches the programmed depth, it is rapidly winched to the surface, only to be released and free fall again. These water column measurements were used on NA169 to assess turbulence and vertical mixing processes across various island wake regions.

WAM-V OPERATIONS

WAM-V deployments complemented shipboard sampling by performing high-resolution mapping and *in situ* sampling. The lightweight and wave-adaptive nature of the vehicle allowed it to operate at speeds similar to the E/V *Nautilus* in areas with strong currents and near the complex shorelines of the Palauan Islands. The

Figure 4. Sighting of *Nautilus belauensis* during a dive at German Channel (left). Coral Reef Research Foundation researchers Pat and Lori Colin contributed remotely as scientists ashore, providing real-time expertise throughout the discovery process (right).

WAM-V conducted repeated transects in the German Channel. Additionally, it was utilized off Sonsorol Island to examine wake-driven mixing processes, enabling real-time adaptive sampling that complemented the ship-based and other autonomous vehicle observations. Daily operations of the WAM-V were conducted via crane launches from the deck of the E/V *Nautilus*, with deployment durations ranging from 18–24 hours. Upon recovery, the lithium-ion batteries were swapped for a fresh set, a process taking approximately two hours. A dedicated watch team monitored operations and executed piloting adjustments as needed.

REMOTELY OPERATED VEHICLE SURVEYS

A series of remotely operated vehicle dives explored deep-sea habitats, focusing on Shark City, Angaur Slope, and German Channel. These dives documented geomorphological structures and collected physical samples, revealing high biodiversity in the benthic communities of the region. Large sand waves at depths exceeding 500 meters were observed in the German Channel, indicative of strong ocean currents which can lead to seabed dynamics. The strong dynamics of the area result in vertical transport and mixing of nutrient rich waters to shallow depths, leading to high biological diversity. Both pelagic tuna and *Nautilus belauensis* cephalopods were observed at the German Channel dive site, the latter of which represented the first sighting of nautiloids on an E/V *Nautilus* expedition (Figure 4). Planning and execution of these dives was closely coordinated with the Coral Reef Research Foundation, a Palau-based organization with decades of research experience in Palau's waters.

KEY FINDINGS

During the 17 days at sea, the NA169 expedition mapped 2,850 square kilometers of seafloor, and conducted 85 hours of casts using the vertical microstructure profiler. The expedition successfully executed 17 deployments and recoveries of uncrewed vehicles, along with 4 successful remotely operated vehicle dives, which resulted in the collection of 33 primary samples. The German Channel was identified as a hotspot of oceanographic activity, driven by strong tidal flows and upwelling processes from baroclinic tidal motions. Vertical microstructure profiler and ADCP data confirmed the presence of internal waves modulating nutrient fluxes into the German Channel, supporting a diverse ecosystem that includes manta rays and pelagic fish aggregations. Measurements

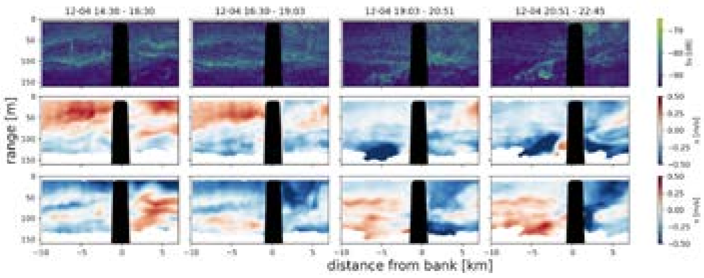


Figure 5. Transects over Hydrographer's Bank, located at the center of the channel between the islands of Angaur and Peleliu, show variability in ocean current vertical structure and acoustic backscatter.

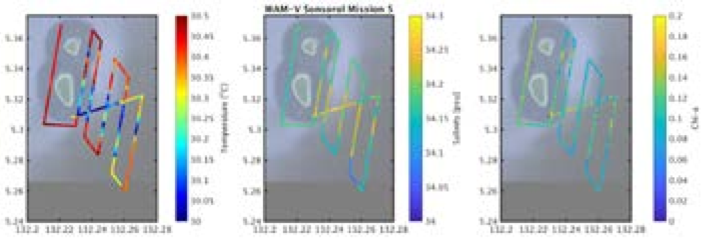


Figure 6. WAM-V data collected around Sonsorol and Fana show that cold and salty water is upwelled in the wake of the islands.

between the islands of Angaur and Peleliu, revealed that the complex topography of Hydrographer's Bank generates strong flow acceleration and mixing, significantly impacting nutrient availability (Figure 5). ADCP and waveglider data indicated the formation of persistent eddy structures, which likely contribute to enhanced primary production downstream of the bank. Data collected off Sonsorol and Fana (Figure 6) showed that the islands have strong interactions with the North Equatorial Countercurrent, generating sub-mesoscale eddies and wake turbulence. The combination of ADCP and remote sensing data revealed significant vertical nutrient transport, reinforcing the importance of island-driven mixing in sustaining offshore productivity.

FUTURE DIRECTIONS

The NA169 expedition provided several novel insights into the role of island wake physics in shaping oceanographic processes around Palau. The combination of ship-based, autonomous and remotely operated vehicle surveys has advanced our understanding of the region's marine environment. Future research should focus on long-term monitoring and expanding exploration efforts to adjacent offshore areas. The rich datasets collected during this mission will be available to support ongoing oceanographic research, resource management, and conservation initiatives. As ocean exploration technology continues to evolve, collaborative expeditions like NA169 will remain useful for exploring our ocean's dynamic systems.

OECI COLLABORATION
IN 2024 AND BEYOND

Aurora C. Elmore and Adam Soule

The Ocean Exploration Cooperative Institute (OECI) brings together five world-class research organizations to support the National Oceanic and Atmospheric Administration (NOAA) mission. Through OECI, NOAA Ocean Exploration works together with experts from the University of Rhode Island, Woods Hole Oceanographic Institution, University of New Hampshire, University of Southern Mississippi, and Ocean Exploration Trust to accelerate the pace of ocean exploration, advance exploration technologies, increase the utility of ocean data, and train the next generation of ocean explorers. We are excited to continue growing this important partnership, which has now been renewed for another five years, extending through 2029.

2024 marked another exciting year for the OECI, which included 123 days at sea on E/V *Nautilus* expeditions that supported OECI projects around Hawai'i, American Samoa, Howland, Baker, and Palau. These expeditions helped support NOAA's new campaign, Beyond the Blue: Illuminating the Pacific, which seeks to coordinate federally-sponsored ocean exploration activities within the central and western Pacific, align those activities with priority needs of local communities, and catalyze capacity growth for this vast and mostly unexplored part of the world. The three E/V *Nautilus* expeditions in Palau (NA167–NA169) also made a significant contribution to the US Government commitment to help Palau map and explore its pristine ocean environment (see Kennedy et al. and Terrill & Merrifield in this report). This extended well beyond the collection of data and included the participation of Palauan government officials, scientists, and educators in the design and execution of these expeditions (Figure 1). The Ocean Exploration Trust is exceptional at working with communities in the Pacific and serves as a model for future activities of the Beyond the Blue campaign (see Moffitt et al. in this report).

Figure 1. Throughout the planning and execution of the 2024 E/V *Nautilus* expeditions to Palau, the Ocean Exploration Trust worked closely with Palauan stakeholders to ensure that expedition activities addressed local management, science, and education priority needs (image credit: Hiromi Ito).

This was also another banner year for the OECI in terms of using multiple complementary exploration technologies, including Ocean Exploration Trust's ROV *Hercules*, University of New Hampshire's

Figure 2. The NA164 expedition to American Samoa used uncrewed surface vehicle *DriX* launched from a shore-based station in Pago Pago (left), in combination with autonomous underwater vehicle *Mesobot* and Deep Autonomous Profiler launched from E/V *Nautilus* (right), to conduct one of the most comprehensive surveys of midwater habitats in American Samoa to date.

uncrewed surface vehicle *DriX* (see Schmidt et al. in this report), Woods Hole Oceanographic Institution's autonomous underwater vehicles *Mesobot* (see Yoerger et al. in this report) and *Sentry* (see Kelley in this report), University of Rhode Island's *Deep Autonomous Profiler* (see Roman et al. in this report), and various uncrewed vehicle systems from the Scripps Institution of Oceanography (see Terrill et al. in this report). All told, OECI supported 99 deployments of uncrewed vehicles from E/V *Nautilus* that provided critical deep-sea information for science, policy, and public engagement.

The two E/V *Nautilus* expeditions in American Samoa (NA164–NA165) expanded OECI's commitment to simultaneous, multi-vehicle operations in order to enhance our ability and efficiency to explore the deep ocean. On the NA164 expedition, collaborative explorations using *DriX*, *Mesobot*, and the *Deep Autonomous Profiler* enabled one of the most comprehensive surveys of midwater habitats in American Samoa to date (Figure 2; see Govindarajan et al. in this report). That same expedition also featured the operation of *DriX* completely from shore, with deployments that explored areas over 100 nautical miles from port (see Schmidt et al. in this report). This represents a significant advancement that enabled operations that otherwise would not have been possible, since the extremely challenging sea conditions on that expedition would have prevented ship-based *DriX* deployments. The following NA165 expedition to American Samoa included the simultaneous use of AUV *Sentry* and ROV *Hercules*, a multi-vehicle approach that saved many days of ship time to explore priority areas for science and resource management in American Samoa, including the hydrothermally-active Vailulu'u Seamount, other seamounts, and abyssal plain habitats.

In 2024, OECI and the Ocean Exploration Trust continued to spread the wonder and excitement of deep-sea exploration with audiences of all ages through live streaming, social media, and various other education and outreach programs (see Cook et al. in this report). This year's projects focused on inspiring local communities whose histories, lives, and livelihoods are inseparably tied to the waters around the Pacific Islands. Beyond these efforts in the Pacific, OECI targets engagement across the spectrum of future ocean explorers. Our colleagues at the University of Southern Mississippi continue to expose more students from the US Gulf Coast to the ocean science realm. At the University of Rhode Island, OECI supports an internship program that helps community college students enter the blue economy workforce. An effort led by the University of New Hampshire enables sponsorship of the SeaPerch ROV competition, where middle school students from across the globe participate in a robotics competition with test courses based on OECI activities.

The successes of the OECI have resulted in expanded partnerships across NOAA, as well as the broader Federal Government enterprise. This year, our partnerships included the NOAA Office of National Marine Sanctuaries, NOAA OMAO Uncrewed Systems Operations Center, the Bureau of Ocean Energy Management, and the US Geological Survey. We look forward to continue expanding these exciting scientific endeavors for many years to come.

SHARING OCEAN EXPLORATION WITH THE WORLD THROUGH EDUCATION AND OUTREACH

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

2024 was an exciting year for the Ocean Exploration Trust and our tens of millions of followers from around the globe. Celebrating one of our widest-ranging seasons ever, we shared our explorations in Canada, Hawai'i, the US Pacific Remote Islands, American Samoa, and Palau, with audiences of all ages via our live streams, ship-to-shore interactions, social media, and press coverage.

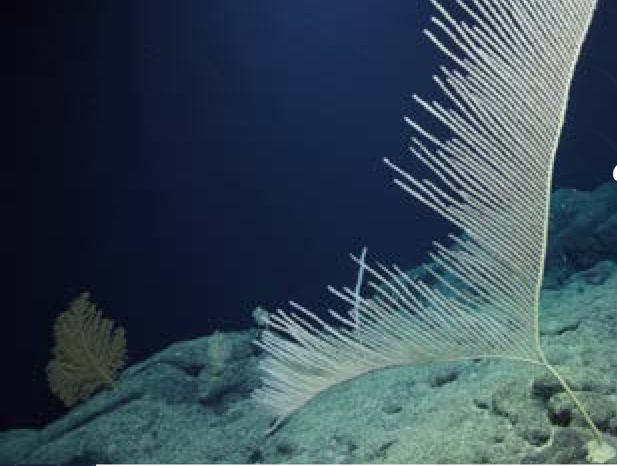
BRINGING STUDENTS AND EDUCATORS TO SEA

As we explore the Pacific, we aim to host a cohort of scientists, educators, and students as diverse as the places we visit. This year's Corps of Exploration included the highest-ever participation from Pacific Islander explorers, a group with extremely low participation in ocean science and STEAM due to historical barriers.

Figure 1. Ocean Science Intern Erica Jonette Leon Guerrero learns to process a deep-sea coral sample alongside Science Manager Christopher Ryen aboard E/V *Nautilus*.

Our Science and Engineering Internship Program provided at-sea opportunities for 16 early career professionals in ocean science, seafloor mapping, ROV engineering, and video systems through paid at-sea internships, during which they are embedded in the expedition team (Figure 1). More than 80% of participants self-reported identities that have been historically underrepresented in STEAM, and a third of participants were Pacific Islander early career professionals. Ocean Exploration Trust's exceptional at-sea programs introduce talented young professionals to the field, growing their professional networks, and providing important pathways to professional STEAM work.

The Science Communication Fellowship program invites formal and informal educators to sail onboard E/V *Nautilus* as expedition storytellers and work together to bring ocean exploration to their communities. The 2024 cohort included 13 fellows from across Oceania and North America. Teaching diverse learners in schools from elementary to college, informal learning nonprofit organizations, and community aquaria, over 75% of fellows directly impact low-income and historically marginalized groups. All of the 2024 fellows represented historically marginalized groups, including eight fellows teaching in Hawai'i, American Samoa, and Palau.



"I really believe that this interaction opened my students' eyes to the world outside our small community. It brought up some potential career choices that my students may not have even thought of for themselves. And, to see someone that came from their hometown is very special, and really shows them that they can dream big, too."

– Live interaction participant educator

SHARING THE DEEP THROUGH MEDIA

Bringing the ocean to the public in a digestible format, our social media channels remain central to our outreach. Social media coverage across six popular platforms elevated expedition discoveries, at-sea stories, and *Nautilus* Corps of Exploration role models (Figure 2). Our social media channels have drawn more than 1.7 million followers, with the most active engagement on YouTube and TikTok, both with extensive youth participation. On Instagram, we hosted 22 story takeovers this year, allowing explorers to share their unique perspectives, including features of the ship's crew and our word of the day series in Samoan and Palauan languages.

Echoing global media trends, we saw exponential growth on platforms that highlight shorter, vertical-cut videos, such as TikTok and Instagram. Videos of deep-sea creatures and ocean explorers stunned audiences of all ages, and our popular TikTok channel drew more than 48 million views this year alone.

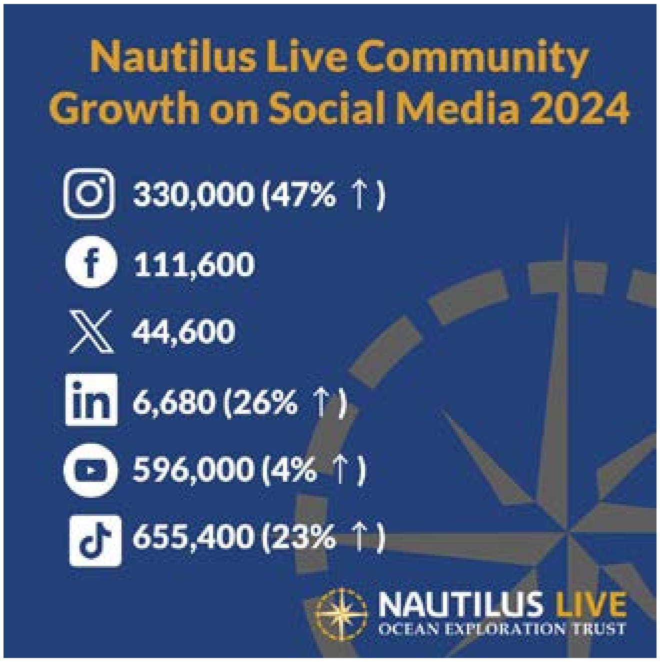


Figure 2. 2024 saw increased social media followers across most OET platforms.

Figure 3. Media and news coverage of our ocean exploration adventures in 2024 included 1,722 articles across 68 countries and in 31 languages.

The Nautilus Live website provides many ways for public audiences to engage with ocean exploration, including our 24-hour live streams. Across the 2024 season, our live streams attracted over one million views. Additionally, the team received and answered over 15,800 questions from audiences watching live. We also produced 55 blogs, 11 photo albums, 13 educational lessons, as well as 51 highlight and education videos. While many highlight videos feature beautiful deep-sea biology, media production also provides an accessible opportunity for audiences to engage with technology stories and learn about the places and cultures that the ship explored this season.

Media and news coverage of our ocean exploration adventures in 2024 included 1,722 articles published in 68 countries and in 31 languages (Figure 3). Popular stories brought ocean wonder into the global news cycle, including our first-ever sighting of nautiloids from E/V *Nautilus*, many new scientific publications, and our collaboration with Ocean Networks Canada to explore the seafloor after an earthquake swarm (see Paulson et al. in this report). Local media coverage of Corps of Exploration members serves our goals of elevating these role models within their communities long after their at-sea experiences.

Figure 4. Science Communication Fellows Isabel Halatuituia, DJ Pevey, and Setefano Umaga connect with learners in a ship-to-shore interaction from the broadcast studio aboard E/V *Nautilus*.

CULTIVATING CURIOSITY IN YOUNG OCEAN EXPLORERS

One of our signature programs, live ship-to-shore interactions, connects at-sea role models for personal conversations with onshore audiences in K-12 classrooms, universities, science centers, and community events (Figure 4). In 2024, explorers hosted 545 ship-to-shore interactions in English, Samoan, and Palauan language, reaching more than 19,560 learners in 46 US states, four US territories, and 20 countries. More than 130 Corps of Exploration members participated in these interactions helping to showcase a broad range of career opportunities and backgrounds. Interactions also helped support broader national STEAM programs providing mentoring for 60 First LEGO League teams as they designed solutions for ocean challenges.

"The Nautilus video commentary is worth listening to all the way through. You'll learn about the iconic sea animals and witness the scientists' collective sense of wonder."

– Forbes Magazine

CELEBRATING CULTURE AND FOCUSING ON UNIQUE COMMUNITY PARTNERSHIPS

OET's co-development process centers community partners' voices in developing educational resources and experiences (see Moffitt et al. in this report). This collaboration resulted in localized science and language products, including publishing the first Palauan ocean exploration vocabulary, endorsed by the Palau Language Commission. The team also developed a series of classroom posters on the global phenomena of hotspot volcanism using the local example of Vailulu'u Seamount, and addressing specific teaching needs for American Samoa.

Public ship tours in American Samoa and Palau welcomed local educators, students, officials, and community members to E/V *Nautilus* for the first time since the pandemic. In American Samoa, we hosted a professional development for 41 educators in collaboration with NOAA Ocean Exploration, the National Marine Sanctuary of American Samoa, and local partners.

Other partnerships continued our mission to share ocean exploration widely. We welcomed eleven students and educators from the Science, Technology, Engineering, And Math Student Experiences Aboard Ships (STEMSEAS) program aboard E/V *Nautilus*, and mentored students in the Ocean Exploration Cooperative Institute's Bridge to Ocean Exploration program. Our education and outreach team was active nationwide leading school visits, mentoring robotics competitions, and showcasing best practices for inclusive ocean outreach at conferences like AGU Ocean Sciences, SIGGRAPH, and the White House Science & Technology Demo Day.

After 16 years, the Ocean Exploration Trust remains committed to exploring poorly known parts of our global ocean, and sharing the excitement of discovery with people of all ages to inspire the next generation of ocean explorers. We look forward to continuing this critical work in 2025 and beyond. In 2024, Ocean Exploration Trust's education programs were made possible through generous support from the Office of Naval Research, NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, and CITGO.

CATALYZING COLLABORATIVE OCEAN EXPLORATION:
THE OCEAN EXPLORATION TRUST SCIENTIST ASHORE PROGRAM

Noelle Helder and Daniel Wagner

The Ocean Exploration Trust is advancing deep-sea exploration through the Scientists Ashore Program, which leverages telepresence technology to create a global, collaborative platform for multi-disciplinary research. This program allows scientists from around the world to actively contribute to the planning, execution, and analysis of E/V *Nautilus* expeditions, which is central to our model of community-driven science and exploration.

Traditionally, ocean exploration has required researchers to be physically present at sea, greatly limiting the size of expedition teams, as well as the diversity of expertise available during an expedition. Telepresence technology has shifted this paradigm. Through our Scientists Ashore Program, the Ocean Exploration Trust connects shore-based scientists with E/V *Nautilus* operations via low-latency video streams, real-time data feeds, and various two-way communication tools. Anyone can view live streams or other web resources via the *Nautilus* Live website, but people who register as scientists ashore are able to take their participation to the next level, opening two-way communications with personnel at sea to guide expedition planning and implementation. Researchers who register as scientists ashore receive regular email updates on expedition plans, access to our science portal with real-time information on ship operations and data feeds, as well as a text-based chat that enables communications with the shipboard team and other scientists ashore (Figure 1).

This platform allows researchers, regardless of location, to engage directly with operations at sea, thereby greatly expanding the potential for discovery. Telepresence also greatly expands the breadth of scientific questions that can be pursued by bringing together experts from various scientific disciplines, including natural scientists, social scientists, resource managers, traditional knowledge holders, and others with relevant expertise

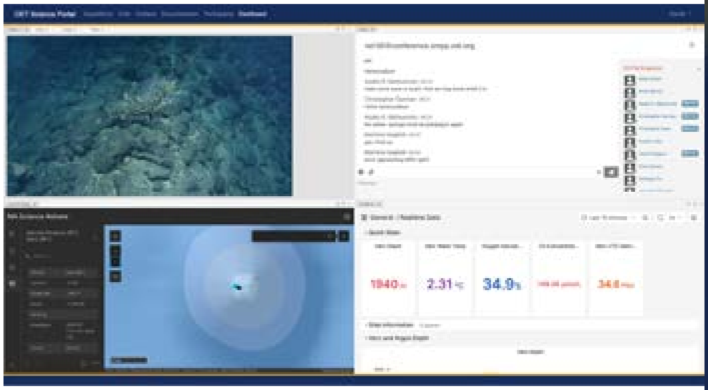


Figure 1. Screenshot of the Ocean Exploration Trust Science Portal, which provides registered scientist ashore real-time access to low-latency video streams from the cameras on E/V *Nautilus* and its ROVs, data feeds from the sensors on the ROVs, a map displaying the current location of the ship and the ROVs, and a text-based chat that enable communications with the team onboard E/V *Nautilus* and other scientist ashore.

to the objectives of a mission. Furthermore, it provides a powerful capacity-building tool that provides a window into the process of field research to anyone with an Internet connection, whether they are seasoned experts with many decades of sea-going experience, or early-career researchers that have not yet been to sea. By engaging a geographically and professionally diverse network of experts, the program taps into a wealth of knowledge, ensuring comprehensive and multi-disciplinary ocean exploration.

SCIENTISTS ASHORE IN ACTION

Scientists ashore play an active role in shaping the scientific objectives of E/V *Nautilus* expeditions. Every year, the Ocean Exploration Trust releases its call for science input, which allows the broader scientific community an opportunity to provide input into expedition planning, including identifying scientific objectives, mapping priorities, ROV dive targets, and sampling requests. Information received through this call is then supplemented with feedback obtained

Figure 2. During ROV dives, mission teams inside the E/V *Nautilus* control van are in direct communications with scientists ashore, who can relay critical information to the team onboard.

during meetings with relevant stakeholders, including resource managers in agencies with jurisdiction over the planned area of operations, researchers who have worked or are working in those regions, and others. Information obtained through this process is then used to develop expedition plans, which are circulated with registered scientists ashore to solicit further feedback and refine plans, ensuring that missions serve the priority needs of the broader scientific community. While expeditions are underway, registered scientists ashore can communicate directly with the shipboard team, helping with scientific identifications, interpretations, or providing other contextual information to help guide the mission (Figure 2).

During the 2024 season, a total of 179 scientists participated on *Nautilus* expeditions from shore, including seasoned experts, early-career researchers, and graduate students representing 88 different institutions that joined expeditions remotely from 20 different countries. Their collective input guided discoveries across a wide range of scientific disciplines, including marine biology, geology, oceanography, archaeology, engineering, as well as the social sciences, showcasing the highly interdisciplinary and collaborative spirit of the program.

The Scientist Ashore Program not only enables remote participation, but can also advance the pace of discovery. Throughout the year, scientists ashore provided critical insights that helped shape the scientific findings of expeditions. For example, during the *Lebuu's Voyage* expeditions to the Palau National Marine Sanctuary (NA167-NA168), scientists ashore were instrumental in identifying several potential new species of deep-sea corals spotted during an ROV dive. The two-way chat room and low-latency video streams provided a platform where experts ashore spotted an unknown species, and were quickly able to request the close-up imagery and physical sample needed to document the find, which would have been missed without the participation of scientists ashore.

As so much of the deep sea remains unexplored, we are making new discoveries nearly every time the ROV enters the water, from identifying new species to observing known species in new places to documenting novel behaviors. Scientists ashore exponentially expand the range of expertise available to evaluate these observations, improving the chances that we can recognize novel discoveries quickly.

BUILDING A COMMUNITY-DRIVEN RESEARCH MODEL

The success of the Scientists Ashore Program underscores the value of a multi-disciplinary, community-driven approach to ocean exploration. Unlike traditional expeditions that focus on the scientific interests of a single principal investigator, the Scientist Ashore Program fosters collaboration, drawing on the expertise of a global scientific community to guide exploration. Scientists ashore contribute to expedition planning, data analysis, and hypothesis generation, breaking down barriers to participation, and enabling researchers with limited resources or logistical challenges to engage with field research. Moreover, the Scientist Ashore Program provides critical opportunities for students and early-career professionals to get valuable exposure to field research, thereby helping to build a more robust workforce for the future.

LOOKING TO THE FUTURE

As we look ahead to 2025, the Scientist Ashore Program will continue to catalyze community-driven ocean exploration. We are interested in continuing to expand the Scientific Ashore Program, with a focus on increasing the number of registered Scientists Ashore, particularly from the geographies where E/V *Nautilus* expeditions will take place, to ensure that our expeditions address local management and science priority needs. We encourage researchers from all sectors, including early career scientists, graduate students, and local management agencies, who want to contribute to expedition planning and implementation to register for the 2025 E/V *Nautilus* season.

FORGING NEW HORIZONS:
COLLABORATIVE COMMUNITY ENGAGEMENT IN AMERICAN SAMOA AND PALAU

Nerelle Que Moffitt, Atuatasi Lelei-Peau, Gene Brighouse, Lucy Dickie, Geraldine Rengiil, King Malsol Sam, Adeeshia Imade Tellei, Megan Cook, Allison Fundis, and Daniel Wagner

The Pacific Ocean is both the largest and least explored portion of our planet, and a bridge connecting many cultures, nations, and ecosystems. Ocean exploration expeditions provide unique opportunities to not only gain profound knowledge about one place but also to connect different places with each other. In a groundbreaking initiative, the National Marine Sanctuary of American Samoa and the Palau International Coral Reef Center joined forces to co-develop E/V *Nautilus* expeditions with the Ocean Exploration Trust that combine scientific exploration, traditional knowledge, community engagement, and regional unity.

Building on a sister-site agreement established between the National Marine Sanctuary of American Samoa and the Palau National Marine Sanctuary in 2020, managers, scientists, and educators from both of these island regions worked together to co-develop goals for the NOAA-funded 2024 E/V *Nautilus* expeditions to American Samoa and Palau. By combining the expedition planning process in American Samoa and Palau, the team sought to create expeditions that would be more broadly relevant across the region, strengthen regional collaborations, and demonstrate the value of combining cutting-edge science, local traditional knowledge, and meaningful community engagement.

A SHARED OCEAN, A SHARED RESPONSIBILITY

Both American Samoa and Palau are surrounded by rich ocean ecosystems that sustain their island communities and define their personal identities. However, the challenges of understanding, managing, and conserving the deep sea—the least explored environment on Earth—require specialized expertise and resources, which are often scarce across the Pacific Islands. Throughout its 16-year history, the Ocean Exploration Trust has acquired such specialized expertise by using its advanced exploration technologies to collect scientific information in support of resource management in many places around the globe, work that has always required close collaborations with local stakeholders.

Building on this legacy, ocean stakeholders in Palau and American Samoa worked with the Ocean Exploration Trust to co-create expedition goals that would use E/V *Nautilus*' advanced technologies to address local management, science, and education priorities. These collaborations focused on shared scientific priorities in both places—understanding deep-sea biodiversity and mapping uncharted seafloor—and on meaningfully sharing this work with local communities. Building this

Figure Above. Public ship tours were held during port stops of the *E Mamana Ou Gataifale* (left) and *Lebuu's Voyage* expeditions.

Figure 1. Planning workshops and meetings held in Palau (left) and American Samoa (right) to discuss how the capabilities of E/V *Nautilus* should be best deployed to address local science, management, and education priorities.

partnership around an early and genuine commitment to include local priorities and traditional knowledge was critical.

With this approach in mind, ocean stakeholders from both nations participated in expedition planning workshops and meetings held in American Samoa and Palau many months before the 2024 E/V *Nautilus* season (Figure 1). In addition to gaining a better understanding of the capabilities of E/V *Nautilus*, workshop participants, which included many stakeholders from government agencies, academic institutions, and community organizations, were invited to share their insights about their marine environments, historical connections to the ocean, and help prioritize how to deploy the E/V *Nautilus*' capabilities to best address local science, management, and education priorities. While each workshop focused primarily on defining the goals of E/V *Nautilus* expeditions in each place, adding participants from the sister sanctuary in meetings led to much deeper conversations about what it means to do this work in the Pacific Island region and strengthen regional partnerships. For instance, during the workshop to plan the E/V *Nautilus* expeditions to American Samoa, a new emblem was unveiled for the sister sanctuaries of American Samoa and Palau, with remarks from the managers of both sanctuaries that reflected on how the planning process for the 2024 E/V *Nautilus* expeditions was helping to strengthen collaborations between both sites (Figure 2).

Figure 2. National Marine Sanctuary of American Samoa Superintendent Atuatasi Lelei Peau and Palau National Marine Sanctuary Program Manager King Malsol Sam unveil a new emblem to represent the sister sanctuary collaboration during an E/V *Nautilus* expedition planning workshop held in American Samoa on March 14, 2024 (see Moffitt et al. in this report).

Workshop discussions highlighted many commonalities in how the people of Palau and American Samoa view the ocean as a source of life and spiritual sustenance. Further, these discussions emphasized that while exploration using modern technologies has been limited in many Pacific Islands, the people in these places have a long and rich seafaring history. Honoring this rich history, respected historical practitioners worked during the period leading up to each E/V *Nautilus* mission to craft expedition names. *E Mamana Ou Gataifale*, Samoan for your waters have power, was selected as the name for the E/V *Nautilus* expeditions to American Samoa (NA164–NA165) to reflect the deeper relationships of many Pacific Island communities with the ocean. *Lebuu's Voyage* was selected for the E/V *Nautilus* expeditions to Palau (NA167–NA168), honoring Prince Lebuu who is regarded as one of Palau's first ocean explorers.

CONNECTING WITH BROAD AUDIENCES TO INSPIRE THE NEXT GENERATION

A key goal of the collaboration was to share this work with communities throughout American Samoa and Palau, particularly with youth, to inspire them to pursue careers in marine science and stewardship. The Ocean Exploration Trust worked closely with partners in both sanctuaries to develop programming to reflect these priorities. This included dedicated communication campaigns that sought to expose American Samoa and Palau communities to this work via print, web, television, and radio media outlets, particularly those broadcasting in Palauan and Samoan languages. Additionally, the team held ship tours while E/V *Nautilus* was docked in American Samoa and Palau to provide the public an opportunity to interact with the technologies and mission personnel of E/V *Nautilus*.

Another key aspect of the partnership was ensuring that people from Palau and American Samoa were well represented aboard E/V *Nautilus* expeditions. The *E Mamana Ou Gataifale* expeditions sailed with five members from American Samoa, whereas the *Lebuu's Voyage* expeditions brought onboard eleven members from Palau. These ambassadors sailed on E/V *Nautilus* expeditions as scientists, communication fellows, cultural liaisons, and interns, contributing to all aspects of the missions in coordination with many more local shore-based experts. In particular, these local participants contributed to numerous education and outreach efforts aimed at ensuring that this work was communicated to local communities in a relevant way. This included social media posts, web stories, highlight videos, and the development of educational resources generated around local audiences' priorities. Additionally, these ambassadors participated in numerous live ship-to-shore interactions that connected the role models aboard E/V *Nautilus* with schools, and community events in American Samoa and Palau, many of which were held in Samoan and Palauan language. Through these intimate conversations, communities were able to witness live exploration footage and speak with onboard personnel from their communities and in their language (Figure 3). During these expeditions, the team held close to 70 live ship-to-shore interactions with schools, community events, and professional meetings in American Samoa or Palau, reaching over 2,000 people, including students from 21 schools in Palau, and 10 schools in American Samoa.

A MODEL FOR THE PACIFIC

The sister sanctuary collaboration between American Samoa and Palau, with efforts driven in partnership with the Ocean Exploration Trust, serves as a model for how future deep-sea explorations in the Pacific can meaningfully address shared goals and challenges. By blending science, regional cooperation, and community engagement, this partnership demonstrates the power of collective action to better understand and communicate the importance of deep-sea exploration. As the expedition's findings continue to be analyzed, the lessons learned from this collaboration will guide future efforts to explore and understand the deep ocean. For the people of American Samoa and Palau, the initiative represents a scientific achievement and a reaffirmation of their shared identity as stewards of the ocean. The message is clear: when we work together, guided by our traditional values and driven by scientific curiosity, the possibilities are as deep as the ocean itself.

Figure 3. Live ship-to-shore connections hosted by onboard mission personnel from American Samoa and Palau were critical to connecting this work with communities in both regions where E/V *Nautilus* operated in 2024.

E MAMANA OU GATAIFALE: CENTERING SAMOAN WORLDVIEW IN DEEP-OCEAN EXPLORATION

Nerelle Que Moffitt, Isabel Gaoteote Halatuituia, Atuatasi Atuatasi-Lelei Peau, Peseta Vaaelua T. Sunia Seloti, and Megan Cook

Located in the heart of the Pacific, the National Marine Sanctuary of American Samoa and surrounding ocean holds immense ecological, cultural, and spiritual significance. These waters, which include some of the least explored regions on Earth, are not just scientific frontiers, they are integral to the Samoan worldview. Recognizing this importance, the 2024 E/V *Nautilus* expeditions to American Samoa (NA164-NA165) were planned and executed with an intentional emphasis on integrating Samoan traditional knowledge, worldview, and local priorities. *E Mamana Ou Gataifale*, Samoan for your waters have power, was selected as the name for these expeditions to reflect the deeper relationships of many Pacific Island communities with the ocean, and with each other.

A COLLABORATIVE VISION

The planning for *E Mamana Ou Gataifale* began with a commitment to partnership. The Ocean Exploration Trust, supported by NOAA Ocean Exploration via the Ocean Exploration Cooperative Institute, worked closely with the NOAA National Marine Sanctuary of American Samoa, government agencies, local leaders, and communities in American Samoa to co-create the mission goals through several planning meetings held months ahead of the expeditions. Central to this process was the recognition of *Fa'a Samoa*, the Samoan way of life, and its emphasis on respect, communal decision-making, as well as the interconnectedness of people with each other and with the natural world. Consistent with the Samoan proverb that serves as a guiding principle for the National Marine Sanctuary of American Samoa, *O le fogāva'a e tasi* (we are of one canoe), this collaborative approach sought to bring together ocean stakeholders with different expertise, and overlapping interests, to co-create a mission that would address local priorities.

Figure 1. On March 13, the National Marine Sanctuary of American Samoa and Ocean Exploration Trust co-hosted a workshop at the Tauese P.F. Sunia Ocean Center that brought together over 50 stakeholders from government agencies, academic institutions and the private sector. Workshop discussions focused on understanding how the E/V *Nautilus* capabilities could best be applied to address priority management, science and outreach needs of local stakeholders in American Samoa.

LISTENING TO THE WISDOM OF ELDERS AND THE COMMUNITY

The voices of *matai* (chiefs), cultural practitioners, and community members played a pivotal role in shaping the 2024 E/V *Nautilus* expeditions to American Samoa. On March 13, the Ocean Exploration Trust and the National Marine Sanctuary of American Samoa co-hosted a workshop at the Tauese P.F. Sunia Ocean Center that brought together over 50 stakeholders from government agencies, academic institutions, and the private sector (Figure 1). It was through *talanoa* (dialogue sessions) that community members were able to share their own perspectives and traditional ecological knowledge about the deep sea, or *gataifale loloto*, which were included into expedition planning. Stories and anecdotes passed down through generations provide important insights into the cultural and practical significance of the ocean. For example, many environmental features in American Samoa are linked to ancestral legends, fishing grounds, and sacred pathways. Input received during the workshop directly informed decisions about which areas to prioritize for exploration with the variety of technologies available during the E/V *Nautilus* expeditions.

SCIENCE MEETS CULTURE

The expedition science team worked closely with local experts in American Samoa to design research that reflected Samoan community priorities. This included studying the health of deep-sea ecosystems to better understand their role in supporting fisheries, which are vital to food security in American Samoa. By aligning research questions with local concerns, the expedition sought to generate knowledge that would directly address resource management priorities and benefit local communities.

Ensuring that expedition team members onboard E/V *Nautilus*, regardless of whether they had previously visited American Samoa, were familiar with Samoan customs, values, and worldview, was also a critical component to mission planning. In preparation for the expeditions, the National Marine Sanctuary of American Samoa worked with Peseta Vaaelua T. Sunia Seloti, an esteemed Samoan cultural liaison to develop a briefing document for the visiting expedition team that shared the significance of customs and protocols in American Samoa. Furthermore, Peseta provided an in-person briefing to E/V *Nautilus* expedition team members prior to sailing, which focused on providing relatable context that incorporates Samoan knowledge as the foundation to guide work in American Samoa.

AMPLIFYING LOCAL VOICES

Community-based expedition planning included equal attention to science and outreach activities centered on addressing local priorities of island partners. Storytelling was paramount in connecting the work at sea with local communities. Local print, radio, and film media, particularly Samoan-language media outlets, were invited to document and share the journey with the broader community. This included a focused communications campaign that started well in advance of the expeditions, extended while the missions were at sea, and continued until early results emerged in the time after the expeditions.

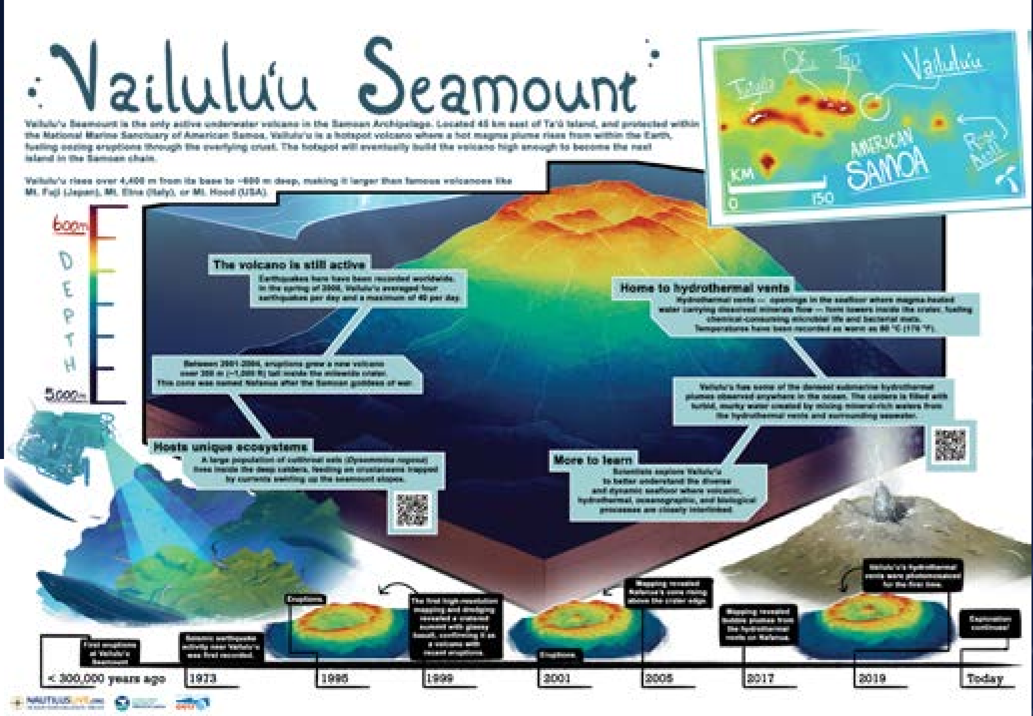
Staffing the onboard expedition team with numerous scientists, educators, and students from American Samoa was also key to the success of the mission. At-sea opportunities were identified early on in the planning process, matched with local talent that was well connected to American Samoan communities. Through Ocean Exploration Trust's Science Communication Fellowship program, local classroom, community, and district leadership educators were selected for storytelling roles onboard E/V *Nautilus*. Several local students also sailed aboard these expeditions via Ocean Exploration Trust's science internship program.

Throughout the planning and implementation of the expeditions, the mission team worked closely with the American Samoa Department of Education to ensure educators had opportunities to learn about the expeditions, the deep sea, and ocean exploration technologies. This included trainings for educators at back-to-school summits and a paid professional development workshop organized by NOAA Ocean Exploration, in collaboration with the American Samoa Department of Education, the National Marine Sanctuary

Figure 2. On August 29–30, NOAA Ocean Exploration, in collaboration with the American Samoa Department of Education, the National Marine Sanctuary of American Samoa, and the Ocean Exploration Trust held a professional development workshop that brought together 41 middle and high school teachers from American Samoa to learn about the deep sea, related technologies, and how to bring information from the American Samoa expeditions into their classrooms.

Figure 3. During the professional development workshop, educators were able to tour E/V *Nautilus* while docked in Pago Pago, and interact with expedition team members and technologies.

Figure 4. Throughout the planning and execution of the mission, the team worked closely with the American Samoa Department of Education to develop educational materials to connect expedition themes with Samoan communities, such as this educational poster on the geological significance of Vailulu'u Seamount.



of American Samoa, and the Ocean Exploration Trust. The workshop brought together 41 middle and high school teachers from American Samoa for a two-day training focused on the technologies onboard E/V *Nautilus*, and shared lesson plans designed specifically to bring back data from the American Samoa expeditions into classrooms (Figures 2–3).

These collaborations resulted in the development of several educational materials. This included, *Upu mo Su'esu'ega i le Vasa*, an illustrated seafloor vocabulary in Samoan language, an educational poster on the geological significance of Vailulu'u Seamount (Figure 4), and a poster on career pathways to ocean exploration designed specifically with American Samoa Community College students in mind.

Throughout the expeditions, students from the National Marine Sanctuary's youth programs participated in virtual ship-to-shore connections, asking scientists questions and sharing their own aspirations for ocean stewardship (Figure 5). Twenty-six different connections linked explorers onboard E/V *Nautilus* with over 650 community members in American Samoa.

Furthermore, the expedition's findings were presented first to the local community in a public forum held at the Tauese P.F. Sunia Ocean Center. This event was not just a scientific debrief, but a celebration of Samoan heritage and a reaffirmation of the community's role as caretakers of their ocean. Trusted relationships between the National Marine Sanctuary of American Samoa with the community were the foundation upon which new partnerships were built to ensure that data generated during the two E/V *Nautilus* expeditions reached communities throughout American Samoa.

Figure 5. American Samoan students Talofa Fe'a and Liualevaiosina Le'iato sailed as part of the science team. During their time at sea, these youth leaders also helped to connect the work at sea with communities throughout American Samoa by participating in numerous ship-to-shore interactions and contributing significantly to expedition outreach activities.

A MODEL FOR FUTURE EXPEDITIONS

The *E Mamana Ou Gataifale* expeditions stand as a testament to the power of centering cultural perspectives in scientific endeavors. By weaving together Samoan cultural wisdom and modern deep-sea exploration approaches, the mission not only expanded humanity's understanding of the ocean, but also strengthened the community's connection to their ancestral waters.

As ocean exploration continues to push boundaries, the lessons from American Samoa's approach offer a blueprint for how to honor cultural knowledge and local priorities. The message is clear: the most profound discoveries arise when science and culture navigate together—*O le fogāva'a e tasi*—as one canoe on a shared voyage.

PALAUAN VOICES IN OCEAN EXPLORATION: CONNECTING CULTURE, SCIENCE, AND STORYTELLING

Allison Fundis, Marley Parker, Daniel Kinzer, Megan Cook, and King Malsol Sam

In 2024, the Ocean Exploration Trust, with support from the National Geographic Society and in partnership with the Palau International Coral Reef Center, launched *Palauan Voices in Ocean Exploration*—a dynamic storytelling initiative aimed at amplifying ocean science and conservation narratives through the lens of Palauan culture. The program empowered early-career participants to share their deep cultural connections to the ocean while honing storytelling skills that promote responsible ocean stewardship.

Nine emerging professionals from organizations such as the Palau Conservation Society, Palau International Coral Reef Center, Friends of the Palau National Marine Sanctuary, and other organizations were selected for this immersive fellowship (Figure 1). Structured as a two-part experience over five months, the program blended virtual learning with an in-person workshop. Participants refined their storytelling techniques, explored how Palauan cultural values shape ocean narratives, and collaborated on individual and group projects. The fellowship culminated in a hands-on workshop where the participants synthesized their learning into powerful stories that celebrate the intersection of culture, science, and conservation.

Figure 1. The Palauan Voices in Ocean Exploration brought together nine emerging professionals over a five-month period, during which they refined their storytelling techniques, explored how Palauan cultural values shape ocean narratives, and collaborated on storytelling projects.

Figure 2. During both virtual and in-person workshop sessions, fellowship participants gained hands-on experience with key storytelling techniques, including photography, interviewing, and crafting narratives.

VIRTUAL FELLOWSHIP: CULTIVATING PERSONAL NARRATIVES

The program kicked off with a six-part virtual series that provided participants with a strong foundation in storytelling. During these sessions, they explored various approaches to constructing narratives—personal narratives, conservation messaging, and ocean science communication—while learning how to craft compelling stories. Led by four core mentors and featuring guest speakers, most of whom were Pacific Islanders specializing in ocean conservation, the series emphasized storytelling as a tool for connection and advocacy.

A key highlight of the virtual sessions was the exploration of how storytelling can bridge culture and conservation. Participants critically examined how Palauan values, traditions, and the country's deep connection to land and sea could shape the way they share environmental narratives. The series emphasized core principles of Palauan culture—empathy, reciprocity, and relationship-building—guiding participants in effectively weaving these values into their storytelling.

As the virtual sessions progressed, participants gained hands-on experience with key storytelling techniques, including photography, interviewing, and crafting narratives. By the end of the virtual phase, they had begun conceptualizing their final projects—stories to be refined and brought to life in the in-person workshop and the months following.

IN-PERSON WORKSHOP: HANDS-ON EXPLORATION AND SKILL BUILDING

The second phase of the program took place in Koror, Palau, where the cohort gathered for a two-day immersive workshop (Figure 2). This in-person experience allowed participants to deepen their understanding of storytelling techniques through hands-on activities and collaborative exercises. The workshop was designed to be a dynamic, supportive environment where participants honed their individual approaches while also building a collective narrative.

A key component of the workshop was a group storytelling project that documented the fellowship experience. Participants conducted on-camera interviews, sharing insights about their journeys, challenges, and discoveries. This process not only honed their interview skills, but also enabled them to craft a narrative that showcased their growth as storytellers collaboratively. By the end of the workshop, participants had refined their individual stories and contributed to a shared collection of interviews that reflected their collective experience and the power of storytelling in ocean science and advocacy.

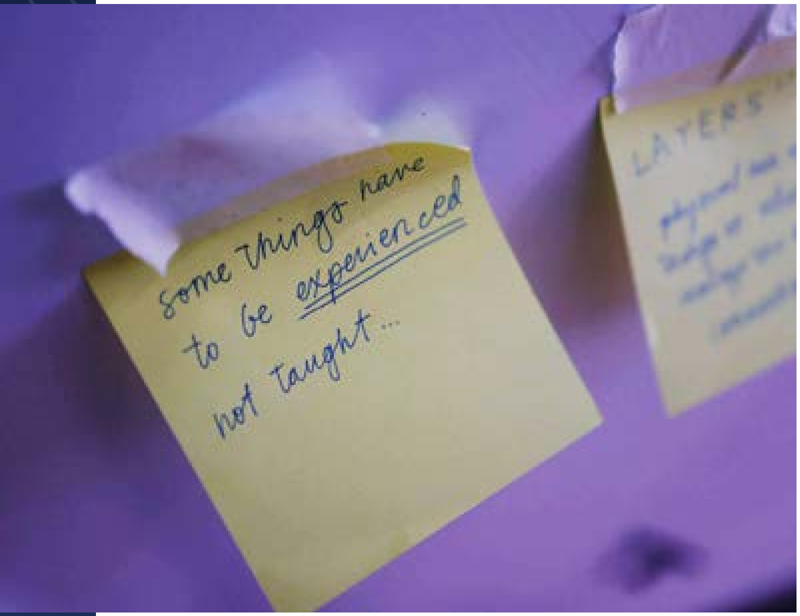


Figure 3. The in-person workshop was designed to be a dynamic environment where participants honed their individual approaches while also building a collective narrative.

DIVERSE VOICES, SHARED EXPERIENCES

One of the most significant aspects of the Palauan Voices in Ocean Exploration program was the diversity of the participants. While the focus was on Palauan culture, the cohort included early-career individuals from a range of cultural backgrounds, enriching the experience. Five participants were Palauans living and working in Palau; one had Palauan heritage and resided in the United States, and three participants came from Australia, Spain, and New Zealand, all living and working in Palau. This diversity led to profound cross-cultural exchanges throughout the program.

Palauan participants gained confidence in discussing their cultural values, while non-Palauans developed a deeper understanding and respect for Palauan traditions and perspectives. As one participant shared,

"I believe that one of the most valuable things I learned through this fellowship is how relationships are at the core of the work that we do (or hope to do) and the change we want to create. You can teach someone how to take a perfect photo or how to conduct an interview, but instilling in them the sense that empathy and reciprocity are at the forefront of the most compelling ways to communicate to your audience—well, that's something that this program did phenomenally well. It is not just something I hope to include in my professional work, but in my personal life as well."

PROGRAM IMPACT

Pre- and post-program evaluations revealed substantial growth in participants' confidence across key program goals, affirming the fellowship's success in empowering ocean storytellers. On average, confidence in leading ocean science communication in Palau increased by 32%, while the ability to integrate traditional Palauan knowledge into storytelling grew by 27%, strengthening the link between culture, ocean science, and conservation. The most notable growth—35%—was in their confidence to make ocean science more accessible, reinforcing the program's role in fostering the next generation of ocean advocates.

Beyond the numbers, participants shared that the fellowship deepened their appreciation for Palauan culture, strengthened their science communication skills, and built meaningful connections with mentors and peers. Many cited the value of hands-on experience in interviewing, photography, and public speaking, seeing these as essential tools for their careers. Ultimately, the fellowship's impact extended far beyond skill-building. It fostered a lasting network of ocean storytellers and empowered participants to champion responsible ocean stewardship—ensuring Palauan voices remain at the heart of ocean narratives for years to come.

OPTIMIZING LIVE VIDEO FEEDS FROM E/V *NAUTILUS* EXPEDITIONS

Matt Koskela and Rachel Simon

One of the key principles of the E/V *Nautilus* exploration program is to utilize telepresence technology to stream live video from its submerged ROVs and various locations around the ship. This includes three live video streams that can be viewed from anywhere in the world with an Internet connection via the *Nautilus* Live website. Historically, the primary means of transmitting live video has been through the use of high-bandwidth satellite communication via a very small aperture terminal (VSAT). The VSAT antenna onboard E/V *Nautilus* links to a satellite in high-altitude synchronous orbit with Earth, and then relays that data back to a terrestrial hub located at the Inner Space Center in Rhode Island for transmission around the world (Figure 1).

This season, we increasingly experimented with satellites in low Earth orbit (LEO), specifically Starlink. Initially, we employed this technology intermittently to decrease our reliance on VSAT (which can be quite expensive over time) by using it to transfer only high-priority files, while video feeds were still transmitted via VSAT. Data transmissions via VSAT typically employ the same satellite all the time, whereas LEO satellite transmissions are designed to shift to a new link about every five minutes. Such regular connection interruptions may pose a problem with continuous data transmission sessions, such as those required to transmit live video. There are also differences in terms of the equipment needed to transmit data via VSAT or LEO (Figure 2). VSAT connectivity requires larger equipment with several positioning motors and moving parts, whereas LEO connectivity involves a much smaller antenna with solid state electronics and no moving parts, the latter of which has some potential advantages in terms of costs, maintenance, and risk of failure.

With these differences in mind, we wanted to test whether Starlink could provide a viable alternative for our video streams. While the Inner Space Center has supported several telepresence-enabled expeditions using only Starlink in the past, all of these were in the US Gulf Coast, which has very different satellite availability, weather patterns, and sea conditions than those found in the Western Pacific where E/V *Nautilus* will be operating in coming years. Our testing was conducted at the end

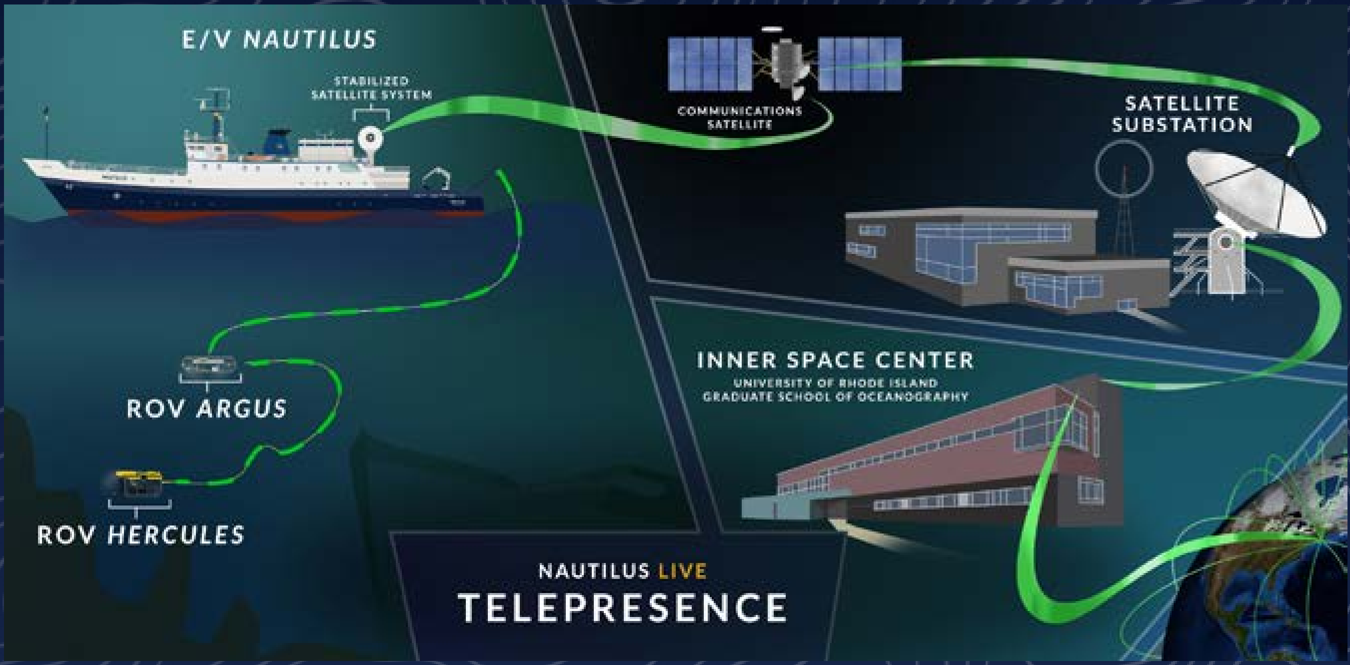


Figure 1. Schematic showing how video and other data collected by E/V *Nautilus* and its ROVs are transferred to viewers around the world. This includes transmission of data from the ship via a communication satellite that relays the data to the Inner Space Center, where it is re-transmitted for access over the Internet from anywhere in the world.

of the 2024 field season, during E/V *Nautilus* expeditions to Palau. Specifically, the testing was conducted during five ROV dives on expeditions NA168 and NA169. Out of a combined thirty hours of dive footage, three dives were transmitted without errors (H2081, H2083, H2085), one dive had about one minute of missing video (H2084), and another had about five minutes of missing video (H2082).

During our tests, we collected several layers of data, including complete recordings of the three video feeds during ROV dives, video stream health statistics from the onboard video encoders, and raw Internet performance data from the ship's router. This combination of raw data allowed us to both assess the quality of the video feeds, as well as determine whether problems were the result of Starlink transmissions, or other factors that can affect satellite transmission more broadly, such as rain events or rough sea states.

Figure 2. Photographs showing the differences in the onboard antennas required to transmit video streams via Starlink (left) and VSAT (right).

The results of our test revealed that the gaps in the video recordings aligned closely with periods of intense rain in the operating area of E/V *Nautilus*. In clear weather the Starlink performance was excellent and error-free, whereas times with intense rain events led to brief periods of total connection loss. Link outages due to weather are a known issue with both VSAT and Starlink, and are simply a function of the band in which they operate. Although link outages due to rain are unavoidable, the video streams automatically reconnected with no intervention required after the rain cleared. Overall the uptime was better than 99%.

Within its limited geographical scope, this test was quite successful, indicating that Starlink may be a viable alternative for telepresence-based exploration in the region. While additional tests will be required to verify these results, we plan to conduct those during the 2025 season, so that we can continue to improve our workflows and deliver the best quality video streams for all of our viewers around the world.

E/V *NAUTILUS* SPECIMEN COLLECTIONS AT THE MUSEUM OF COMPARATIVE ZOOLOGY:

AN ENORMOUS OPPORTUNITY FOR BIODIVERSITY RESEARCH AND DISCOVERY

Adam Baldinger

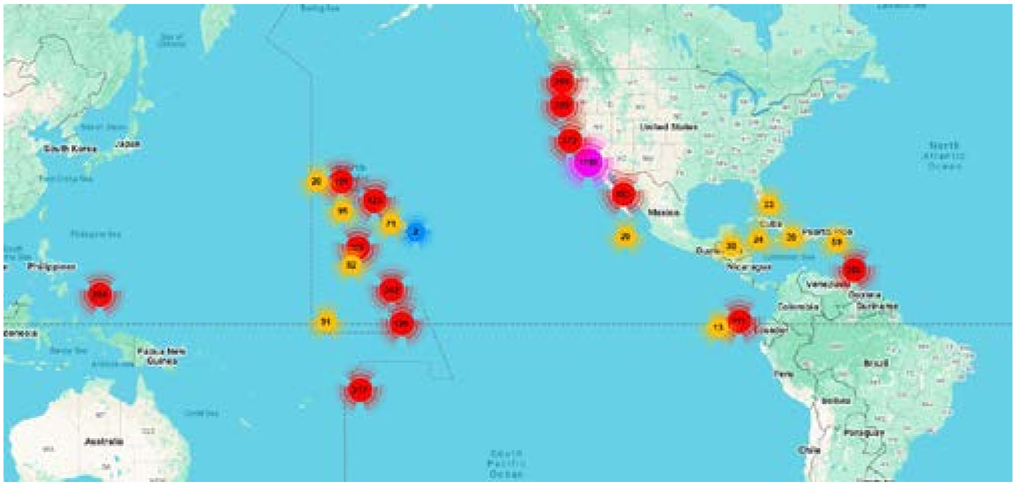


Figure 1. Map showing the geographic distributions of biological specimens collected by E/V *Nautilus* expeditions since 2013 that have been accessioned into the collections of the Museum of Comparative Zoology.

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 51 different E/V *Nautilus* expeditions have been accessioned at the museum (Figure 1), primarily in the Invertebrate Zoology Collections (85%), with some specimens also housed in the Malacology, Ichthyology, and Vertebrate Paleontology Collections. Biological specimens collected by the E/V *Nautilus* augment other museum collections quite well, as the majority of E/V *Nautilus* specimens represent unique taxa, geographic locations, and depths. E/V *Nautilus* specimens also complement various ongoing projects at the Museum of Comparative Zoology, including the National Science Foundation-funded project Documenting Marine Biodiversity through Digitization of Invertebrate Collections (DigIn).

In addition to permanently curating biological specimens from E/V *Nautilus* expeditions (Figure 2), the Museum of Comparative Zoology provides opportunities for qualified researchers from around the world to access them. For this purpose, specimen metadata, including *in situ* photos, lab photos, location data, and environmental data are catalogued in the museum-wide database MCZbase, where they can be accessed by anyone with an Internet

Figure 2. Biological specimens collected by E/V *Nautilus* are primarily achieved in the Invertebrate Zoology Collections of the Museum of Comparative Zoology.

Figure 3. Imaging stations like this one in the Department of Malacology and the Digital Imaging Facility of the Museum of Comparative Zoology provide several advanced imaging technologies to examine specimens on site, including digital microscopes, cameras, micro-computed tomography scanners, and X-ray imaging systems.

connection, as well as shared with other databases, such as Integrated Digitized Biocollections (iDigBio), the Global Biodiversity Information Facility (GBIF), and GenBank. Additionally, a named group page exists within MCZbase that links to metadata of all E/V *Nautilus* specimens housed at the Museum of Comparative Zoology. This page lists specimen records, including searchable links enabling the breakdown of E/V *Nautilus* specimens by taxa, geography, ocean regions, expedition numbers, images, and specimens cited in scientific publications.

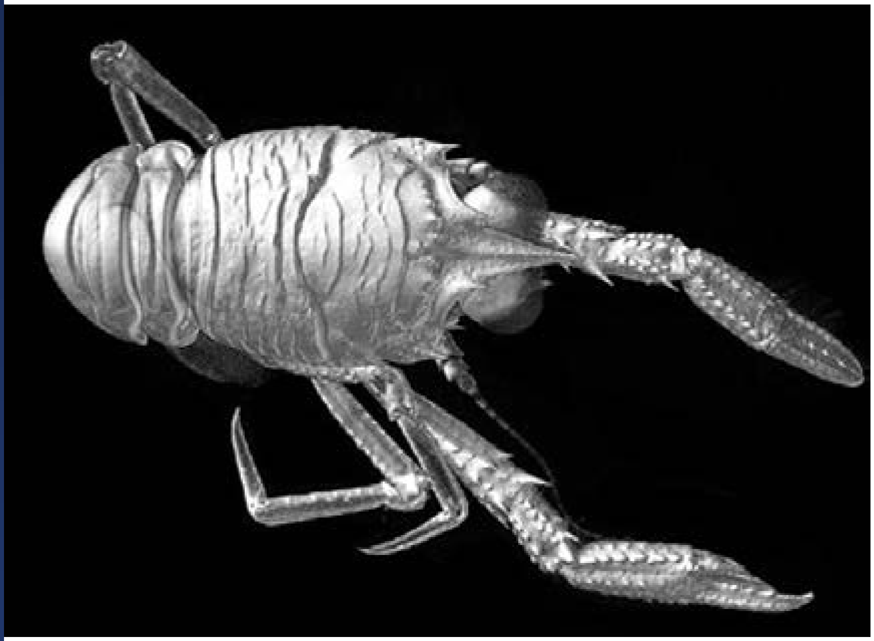


Figure 4. The new squat lobster species *Trapezionida hercules*, which was recently described using specimens collected by E/V *Nautilus* off Jarvis Island, and named in honor of ROV *Hercules* and its many contributions to science (image credit: Paula Rodriguez-Flores).

In addition to providing access to digital metadata, the Museum of Comparative Zoology also provides other opportunities for follow-on research and discovery. In most cases, archived specimens can be sent out on loan to qualified researchers around the world. Additionally, researchers are encouraged to visit the Museum of Comparative Zoology to examine specimens on site. Microscopes, micro-computed tomography scanners, and X-ray imaging systems are available at the Digital Imaging Facility of the museum (Figure 3). Furthermore, the museum provides travel grants to support research in animal systematics that can be completed via short museum visits. Typical expenses covered by this grant include travel costs, lodging and meals.

While recent studies of E/V *Nautilus* specimens archived at the Museum of Comparative have led to the description of many new species of squat lobsters (Figure 4), sea stars, and other invertebrates, these collections still provide an enormous opportunity for biodiversity research and discovery. To date, less than half of the invertebrate specimens collected by E/V *Nautilus* have been identified to the family level, with many new species to science likely awaiting to be found amongst the rich specimen collections housed at the museum.

15 YEARS OF E/V *NAUTILUS*
GEOLOGICAL SAMPLE COLLECTIONS

Katherine Kelley

Since 2010, E/V *Nautilus* and ROV *Hercules* have retrieved close to 2,000 samples of rocks and sediment from the Earth's ocean floor. Each sample is accompanied by a detailed set of associated data from the ROV-mounted video cameras, environmental sensors, and navigation systems that make these samples particularly valuable for scientific research. The Marine Geological Samples Laboratory at the University of Rhode Island serves as the official repository of geological specimens that have been collected by the E/V *Nautilus* program over its 15-year history. These collections provide a rich archive of the geologic history of many places around the world, including the Mediterranean, the Caribbean, the North America western coastal margin, the Gulf of California, the Galápagos Islands, the Revillagigedo Islands, the Central Pacific, and Palau (Figure 1).

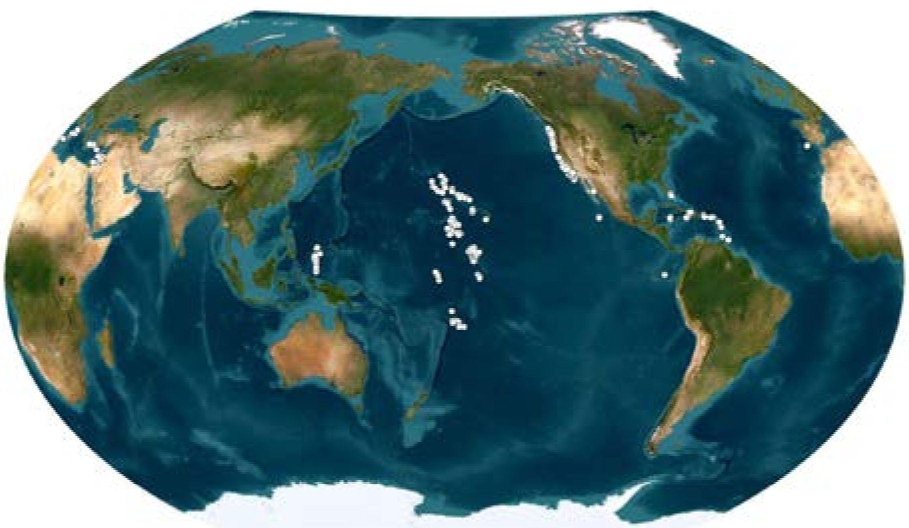


Figure 1. Map showing the locations of geological samples collected during E/V *Nautilus* expeditions in 2010–2024 that are archived at the Marine Geological Samples Laboratory at the University of Rhode Island.

These collections include a wide diversity of geological samples, including rocks representing Earth's uppermost mantle and lower oceanic crust, basaltic lava erupted at spreading centers, sedimentary rocks capping ancient oceanic volcanoes, surface sediments from a variety of marine settings, mineral deposits from active spreading centers, and subduction zone volcanoes. These collections also house one of the largest collections of ferromanganese crusts, which are important critical mineral deposits found throughout the Central and Western Pacific. In total, the E/V *Nautilus* collections housed at Marine Geological Samples Laboratory include 1,942 geological specimens, each of which is precisely and richly documented, and available for further scientific investigation.

The Marine Geological Samples Laboratory archives these specimens following curatorial best practices (Figure 2), including assigning persistent unique identifiers linked to open access sample metadata that can be searched using various web interfaces, including the System for Earth and Extraterrestrial Sample Registration. Rocks are stored in dry, room temperature conditions, and push cores and other sediments are kept in a walk-in refrigerator to maintain moisture and slow decay. During the accessioning process, Marine Geological Samples Laboratory staff cut and photograph all rocks collected by E/V *Nautilus*, and are working on a new web interface to make these images publicly available.

Samples housed at the Marine Geological Samples Laboratory are openly and freely available upon request for scientific research and education (Figure 3). The Marine Geological Samples Laboratory welcomes in-person visitors to our facility at the University of Rhode Island Narragansett Bay Campus, where we have equipment for cutting and crushing rocks, picking minerals and microfossils, making smear slides, and other means of sample characterization and subsampling. Facility staff are also eager to assist remote requesters in finding suitable samples for study. Interested investigators and educators can search current listings of our E/V *Nautilus* collections and make sample requests directly through the Marine Geological Samples Laboratory website.

Our curatorial staff is eager to assist with any inquiries related to our E/V *Nautilus* collections, and we encourage prospective users to reach out to us with questions at: mgsl@etal.uri.edu.

Figure 2. Rock and core samples are stored at the Marine Geological Samples Laboratory using curatorial best practices (image credit: Alex DeCiccio).

Figure 3. Samples housed at the Marine Geological Samples Laboratory are openly available for scientific study, including to visiting researchers that want to make use of the facilities equipment for sample characterization and subsampling (image credit: Alex DeCiccio).

2024 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 2024 E/V *Nautilus* field season, a total of 49 science publications were published in 2024 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.

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WHAT IS NEXT

Allison Fundis, Daniel Wagner, and Robert D. Ballard

While E/V *Nautilus* expeditions in 2024 surveyed many deep-sea habitats and geological features, the majority of the Pacific Ocean, including vast areas under US jurisdiction, remains completely unexplored. E/V *Nautilus* expeditions in the coming years will continue filling the large knowledge gaps that remain across the Pacific via expeditions focused on seafloor mapping and ROV characterizations, operations that are similar in scope to those conducted in recent years. However, E/V *Nautilus* expeditions in 2025 will all be undertaken in geographies where the ship has not operated previously, including deep ocean areas around Guam, the Commonwealth of the Northern Mariana Islands, Wake Atoll, the Marshall Islands, and the Solomon Islands. As in previous years, the Ocean Exploration Trust will work closely with stakeholders in these places to ensure that future E/V *Nautilus* expeditions are planned and implemented in a way that incorporates local priorities, participation, and input.

In addition to basic exploration, our 2025 expeditions will continue to integrate emerging exploration technologies onto E/V *Nautilus* expeditions, particularly those from partner institutions of the NOAA Ocean Exploration Cooperative Institute. Building on the recent success of integrating uncrewed surface vehicle *DriX*, the *Deep Autonomous Profiler*, and eDNA multi-samplers into E/V *Nautilus* operations, expeditions in 2025 will continue to expand the application of these technologies in support of ocean exploration. Additionally, 2025 expeditions will also feature deployments of autonomous underwater vehicle *Orpheus* in combination with E/V *Nautilus* and its ROVs, and thereby seek to catalyze the force-multiplier of multi-vehicle exploration.

In addition to the above-mentioned efforts aimed at advancing the goals of the NOAA Ocean Exploration Cooperative Institute, our 2025 field season will include dedicated surveys to support projects funded by the Bureau of Ocean Energy Management. Building on the success of expeditions conducted in partnership with the Bureau of Ocean Energy Management, the US Geological Survey and NOAA in 2023–2024, E/V *Nautilus* will conduct an expedition in 2025 to Guam and the Commonwealth of the Northern Mariana Islands that will advance interagency priorities, including all goals of the US National Strategy for Ocean Mapping Exploration, and Characterization.

As in previous years, partnerships will remain the centerpiece of our exploration efforts in 2025 and beyond. Building on its ongoing collaborations with NOAA Ocean Exploration, NOAA Ocean Exploration Cooperative Institute, Office of Naval Research, Bureau of Ocean Energy Management, National Geographic Society, and many others, the Ocean Exploration Trust will seek to continue exploring across the Pacific Ocean, and meaningfully connect this work to audiences across the globe, particularly those from the geographies where E/V *Nautilus* will operate.

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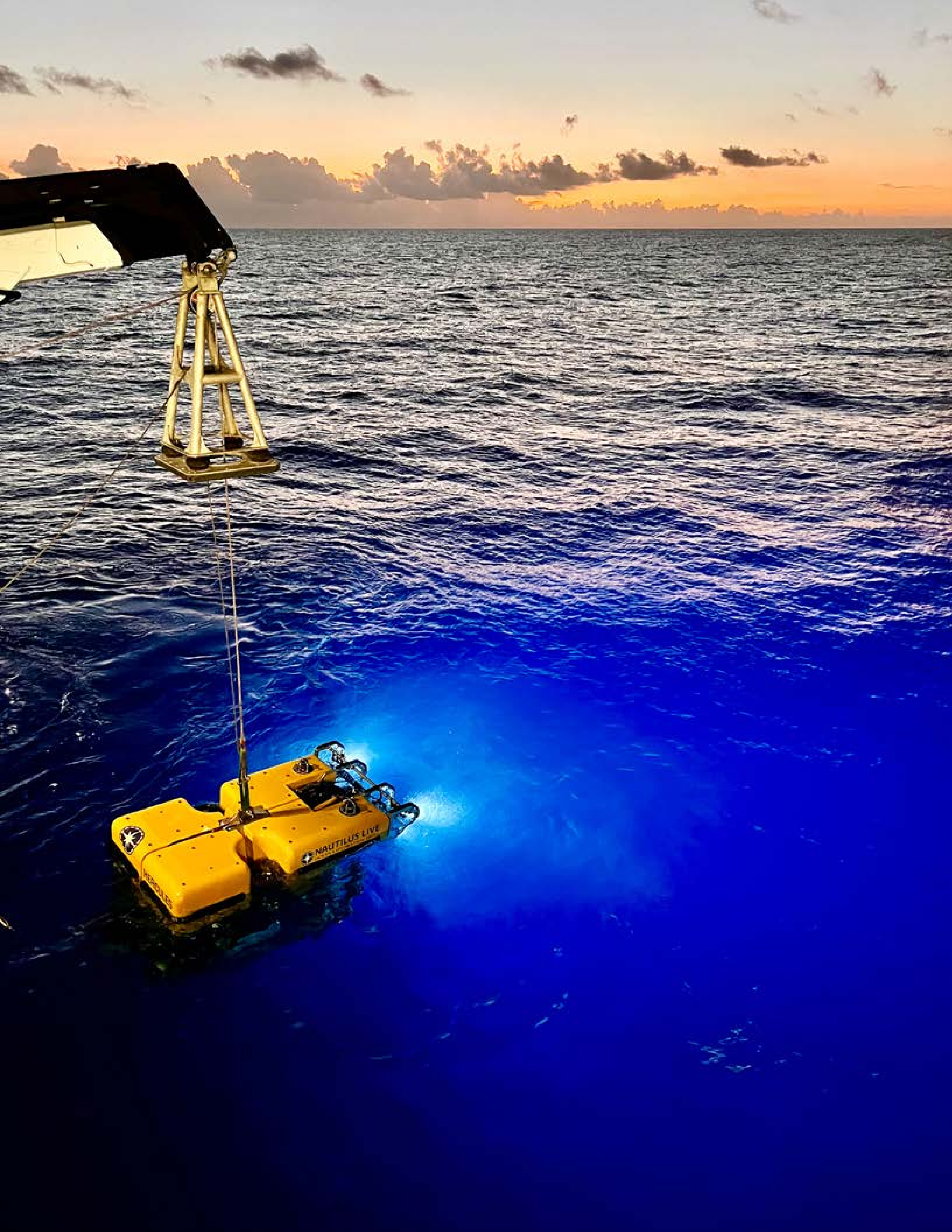
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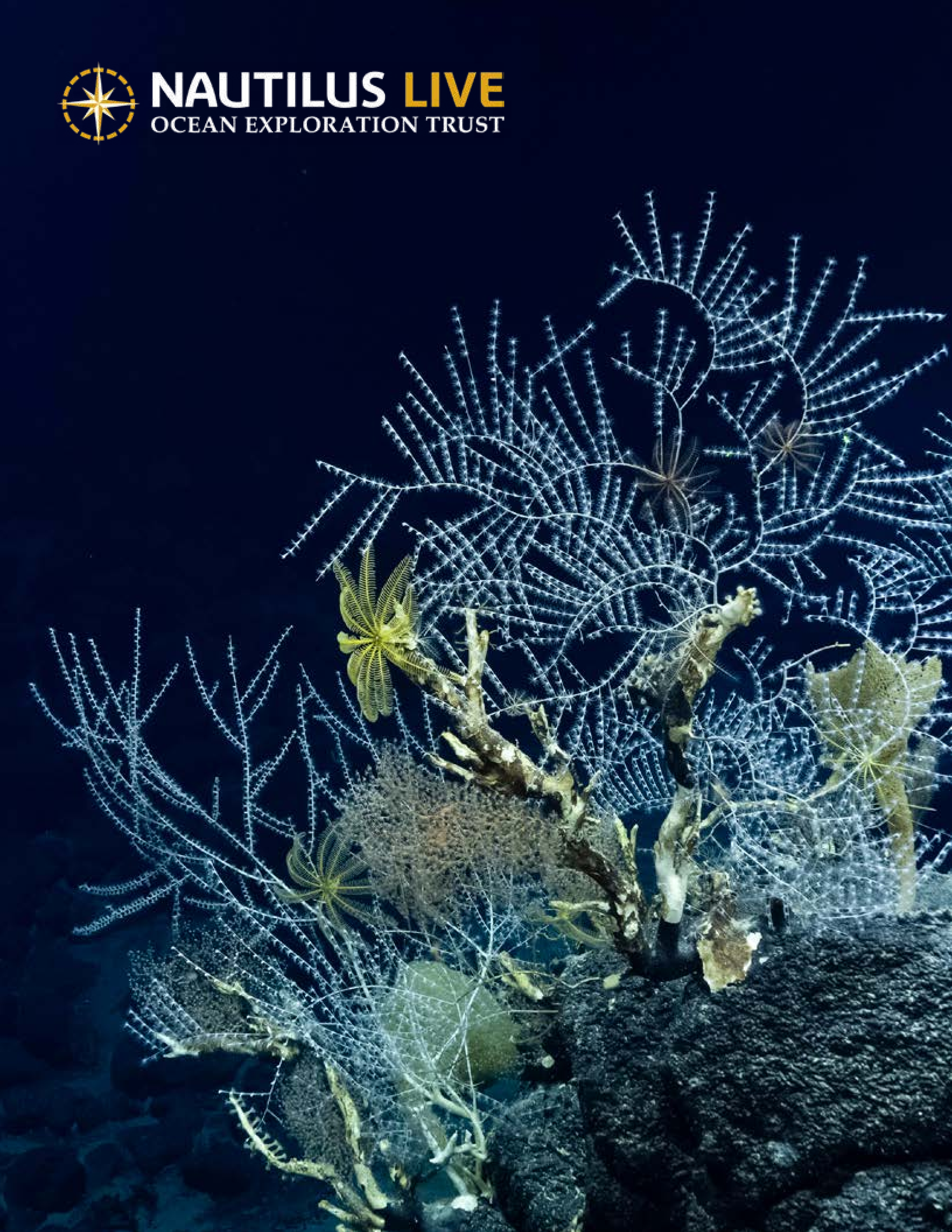
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