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Integrating Field and Ashore Knowledge to Fill the Gaps of Habitat Mapping in Unexplored Edges of the Pacific Ocean

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Abstract: Seafloor mapping is crucial for sustainable Ocean management, but the distribution, drivers and origins of deep-sea biodiversity remain uncharted at global scales. The deep ocean is the largest and least-explored ecosystem on Earth, and the greatest source of unknown lifeforms. This contribution is firstly the story of a merge between exploration, science, education and technology for humankind cultural heritage advancement in one of the formally recognized protected areas of the Pacific Ocean. The data herein described are the outcome of a series of underwater surveys finalized during the 2023 Exploration Campaign onboard E/V Nautilus, led by the Ocean Exploration Trust within the Papahānaumokuākea Marine National Monument, which is the largest conservation area established in the U.S. and one of the largest marine protected areas of the world. Our findings provide an advanced approach to scientific research combining the traditional approach of marine sciences to the cultural and social dimension of local traditions, in order to empower the indigenous people in the underwater cultural heritage knowledge advancement process, aimed at deep-sea biodiversity detection and unexplored seafloor surveying. Beside the high potential for this human dimension inclusion, the indigenous voices allowed to integrate the mere scientific aspects commonly shared in every at-sea exploration, with the cultural values and practices respected from the local people who traditionally lived in sync with the Ocean for millennia. As a result, this approach allowed to enforce a trust relationship between the science world and some local representatives who joined the exploration onboard, providing an added value to the extant expertise.

Keywords: Habitat mapping; Underwater Cultural Heritage; Ocean Exploration; UN Decade Challenges; Marine biodiversity; UN Ocean Decade; Indigenous knowledge

1. Introduction

"We know more about the Moon and Mars surface than we do about the Ocean depths" is a common sentence when we speak about the deep-sea environments. Truly, the deep Ocean is the largest unexplored place on Earth—less than 5 percent of it has been explored so far. As of 2023, 24.9% of the global seafloor had been mapped with modern high-resolution technology (multibeam sonar systems), usually mounted to ships, that can reveal the seafloor in greater detail [1]. Mapping the seafloor is crucial for sustainable ocean management. It can be overwhelming thinking about mapping the entire seafloor whilst 2023 is approaching, but this task is crucial to improving human life [2;3]. The deep-sea habitats conditions are extreme to life but many species physiologically adapted to cope with this challenging conditions. The importance of a rigorous knowledge of ocean seafloor relies also on its implication for coastal resilience and oceanographic implications. The extensive exploration and the punctual knowledge of deep-sea environments is crucial also for the understanding of climate-change impact on the global carbon cycling pump mechanism [4]. The biodiversity investigated and the exploration outcomes highlighted in this contribution belongs to one of the less known areas of the Pacific Ocean and its role as biodiversity hotspot can be crucial even in the understanding of climate-related dynamics. To overcome the extant knowledge gaps the expedition onboard the E/V Nautilus were planned considering also the cultural aspect and the local

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ecological knowledge of indigenous people, whose local traditions are inextricably connected to the Ocean and its yet undisclosed lifeforms. This multiperspective approach [5] is deeply in line with the UN Decade of Ocean Sciences objectives, particularly the challenges: 2, 7, 8, 9 and 10 and the endeavors accomplished so far contributed to shed light on Ocean Literacy Principle n. 7 which deliberately states "the Ocean is largely unexplored". The main target of this expedition season was the largely unexplored northwestern section of the Papahānaumokuākea Marine National Monument and the Kingman and Palmyra Atoll area which fall within the U.S. Exclusive Economic Zone.

2. Materials and Methods

The outcome of this paper comes from a research experience joining the 2023 edition of the E/V Nautilus Ocean Exploration Trust campaigns in the Pacific Ocean as scientist ashore. The exploration rationale deeply focused on establishing a trust relationship with indigenous people. For this reason, some representatives of the indigenous local communities have been included in the cruise crew contributing to the toponyms' identification, ROV surveys and expedition routes planning. The cruise included high-resolution habitat mapping and has been finalized including some videoconference sessions to allow also the participation of more than a hundred of scientists even operating remotely. All the exploration sessions occurred regularly engaging the broader scientific community and public audiences via telepresence technology.

2.1. Study area

The Papahānaumokuākea Marine National Monument, herein indicated as PMNM, is the largest conservation area established in the United States Exclusive Economic Zone (EEZ) and one of the largest marine protected areas of the world, covering over 1.5 million square kilometers [6]. Its designation dates back to June 2006. The field data herein described belong to the NA153 and NA154 expeditions performed during the field season 2023, near Johnston Atoll to map many unnamed seamounts and seabed areas in the nearby. The images were obtained thanks to the ROV Hercules dives along the Hawaiian Ridge and around the Gardner Pinnacles area (Figure 1 a, b).

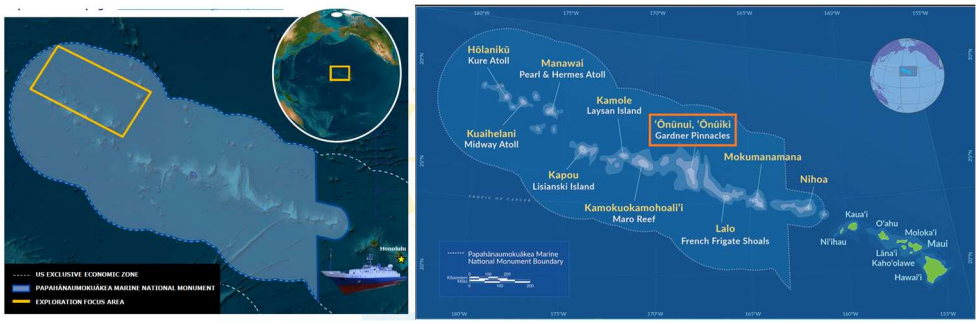

Figure 1. (a,b) Study area located within the U.S. Exclusive Economic Zone.

2.2. High resolution habitat mapping surveys

The expeditions season 2023 included some habitat mapping surveys to fill the gaps on some uncharted portions of the investigated area. Particularly the charting target were some seamounts to date identified with numbers which required to be charted more in detail (6 of the 8 investigated seamounts were unexplored before). Both acoustic sonars and ROVs were used to survey the northwesternmost and least explored portion of the Monument (Table 1).

The expedition completed 12 successful ROV dives for a total dive time of over 264 hours and over 218 hours of seafloor exploration. ROV dives focused on exploring deep environments relevant for their conservation value. These include: seamounts (Figure 2), ridges, and underwater cultural heritage sites associated with the Battle of Midway. Dives surveyed seafloor at depths ranging between 589-5,437 meters, which included the deepest dives ever conducted off E/V *Nautilus* [7].

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Table 1. Dive locations of the explored seabed portions during the Nautilus Expedition 2023.

Dive area	Expedition Name	Charting/Operational objectives	Maximum depth
Kingman Reef- Palmira Atoll	NA149	Filling data gaps north of the Kingman/Palmyra Unit of PRIMNM	2500 meters
Ocean Networks Canada Cabled Observatory Maintenance	NA151	ROV dives to support observatory maintenance Deploy sensors and equipment	2672 meters
Ancient Seamount Johnston Atoll	NA153	Deep sea geology and biology around the atoll Filling data gaps in seafloor mapping	3163 meters
Ala ʻAumoana Kai Uli in Papaha ¯naumokua ¯kea Marine National Monument	NA154	Gambia Shoal Unnamed Seamount* Seamount 17* Seamount 11*	5,437 meters
King George Seamount	NA154	Pink coral forest+	1423 meters

Legend: (*) Previously uncharted areas; (+) Significant cultural value of the area for locals.

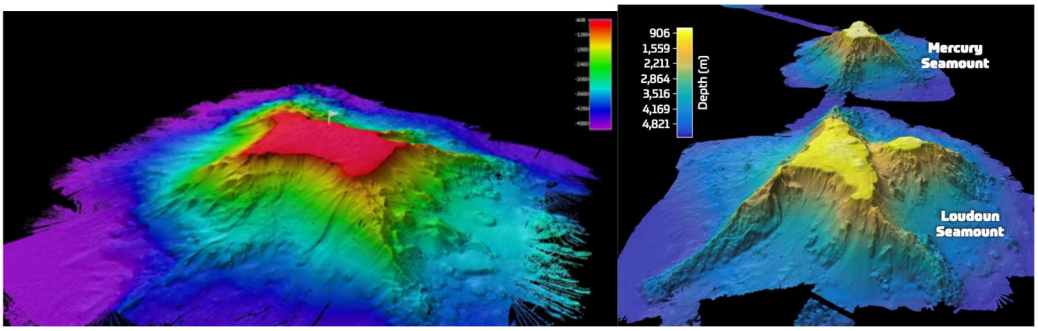

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Figure 2. King George and Loundon Seamounts explored during the 2023 Expedition (Image source: NOAA).

2.3. Native Hawaiian cultural protocol entering Papahānaumokuākea Monument

The NA154 leg of the 2023 Expedition focused on the most culturally valuable part of the exploration onboard the E/V Nautilus. Entering the Ala ʻAumoana Kai Uli expedition, the crew was asked to observe a peculiar protocol to observe the Native Hawaiian values, practices, cultural protocols and respectfully engage with this ʻĀina Akua, a sacred realm, and the biological, geological, and archaeological elements found here, which are considered all cultural resources by locals.

Table 2. Toponyms of explored areas during the NA154 expedition leg surveys.

TOPONYMS OF MAPPED AREAS	Ōiwi name	English name	Expedition leg
	ʻŌnūnui, ʻŌnūiki	Gardner Pinnacles	NA154
		King George Seamount	NA154
		Loudoun Seamount	NA154
		Seamount 17*	NA154
		Seamount 11*	NA154
		Gambia Shoal	NA154

3. Results

3.1. Benthic diversity detected during the expedition

The most relevant structure forming taxa characterizing the seafloor mapped during the expedition is the dominated by octocorals and sponges (Figure 1, 2,3).

Chrysogorgia and *Siphonogorgia* are the main genera observed among soft corals (Figure 3 a,b). Among the hard corals Isididae spp. (Figure 4) dominated the main benthic assemblages particulary in some unexplored seamounts detected during the NA154 expedition. Many colonies of the spiral corals belonging to the *Iridogorgia* genus were also observed (Figure 3 c-e).

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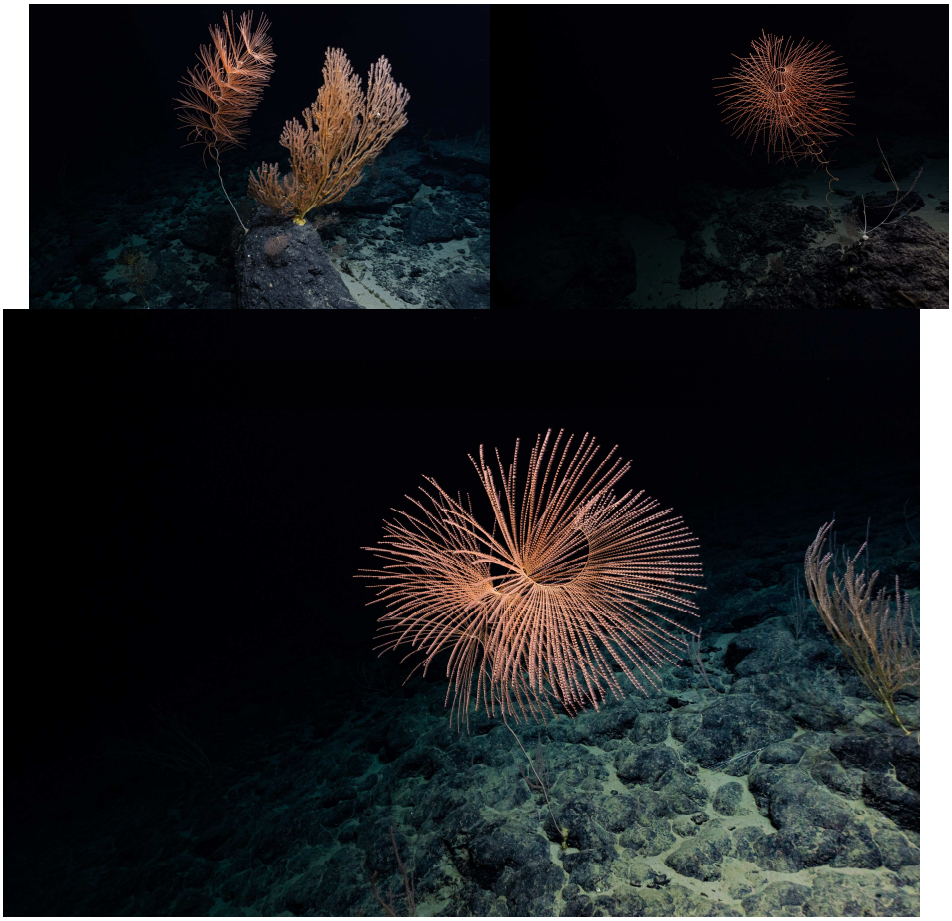

Figure 3. (a-e). Hard and soft coral assemblages, with some *Iridogorgia* spiral coral colonies observed during the Gambia Shoal exploration.

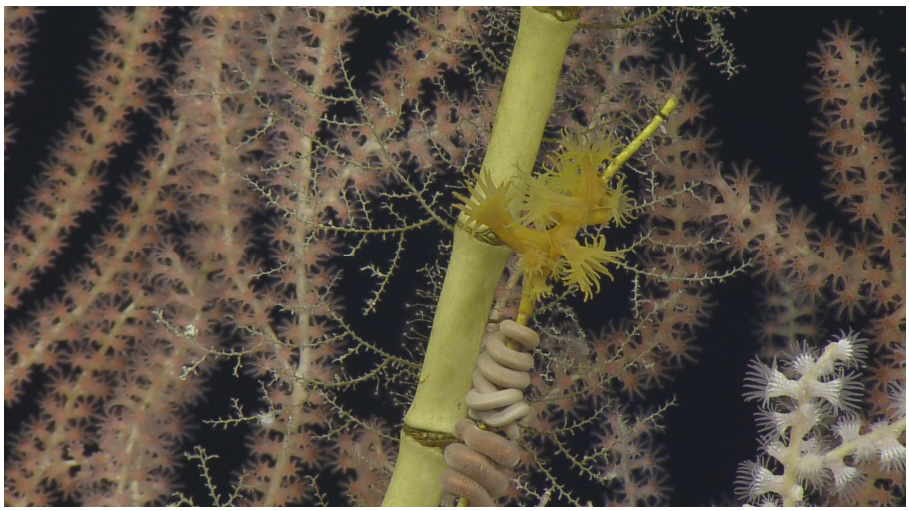

Figure 4. Detail on a *Isididae* coral colony, also known as "bamboo coral" detected in an unnamed seamount explored for the first time during the NA154 expedition.

Many glass sponges showing peculiar adaptations to the environmental conditions were observed [8–10]. Among the Hexactinellid sponges detected some pedunculate euplectellid specimens belonging to the subfamily Bolosominae, bearing the main choanosomal spicules of diactins (Figure 6-7) resembling similar biodiversity patterns on other comparable seabed regions of the Pacific Ocean previously explored [11].

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The most representative groups of vagile fauna detected were: decapods crustaceans soft corals symbiont crabs (*Neolithodes* sp.), squat lobsters, picnogonidae, jellyfishes (*Solmaris* spp.), abyssal fishes (*Caunachops* sp., toothy goosefishes) and echinoderms mainly represented by sea stars, soft-bottoms sea urchins and crinoids (Figure 5 a-g).

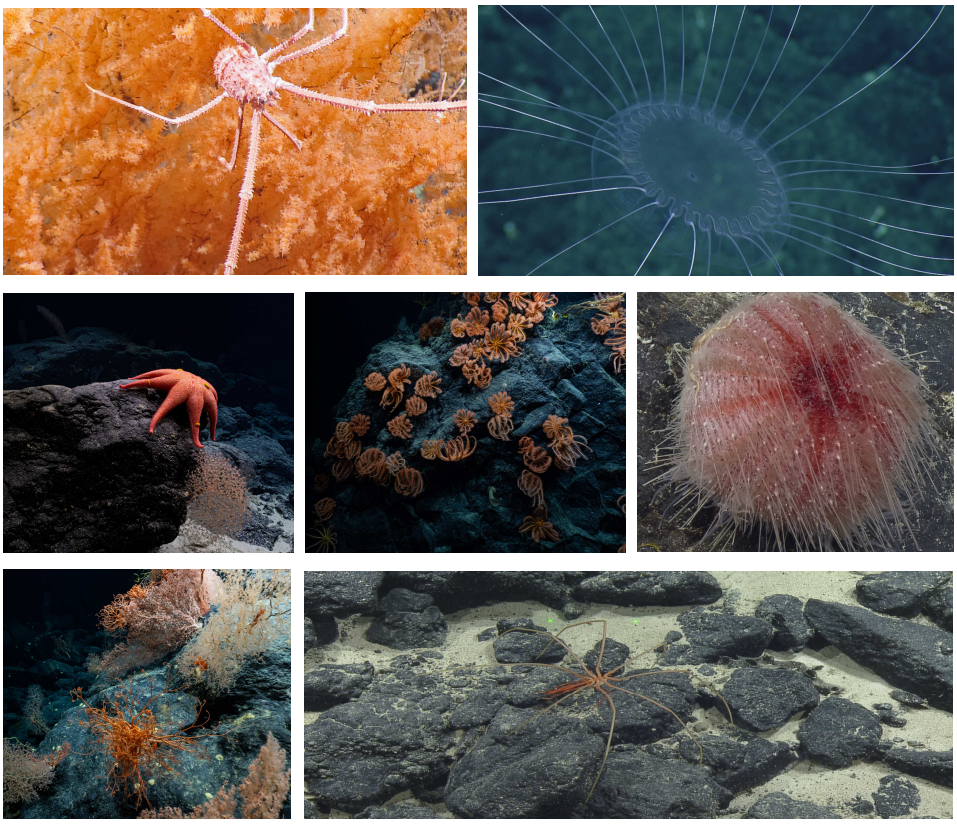

Figure 5. (a-g). Images of the most characteristic benthic organisms detected during the ROV dives.

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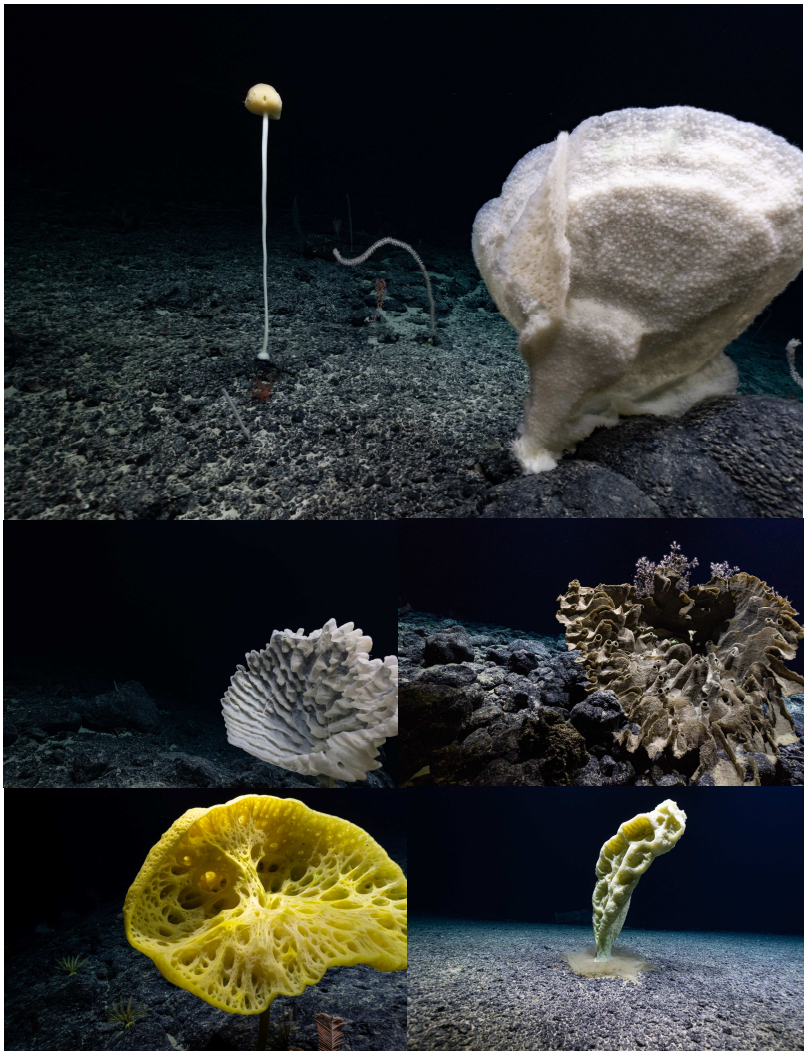

Figure 6. Glass sponges Bolosoma sp., Rossellidae sp. detected during the ROV surveys.

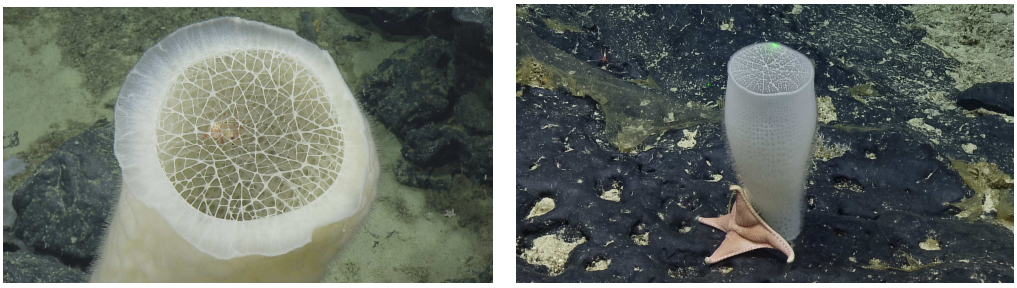

Figure 7. A glass sponge (family *Euplectellidae*) entrapping a small shrimp detected in the yet unnamed Seamount n.17 during NA154 expedition.

3.2. The social value of local community engagement within the field expedition

The engagement of indigenous people beside giving insightful advices during the expedition, has been an unprecedented occasion to turn a language almost extinct into a cutting-edge source of knowledge, to fill the extant gaps into the deep-ocean exploration ad to enforce a trust relationship between the scientific world representatives and the locals holding cultural values on the area. This goal was accomplished through:

- Onboard engagement of indigenous representatives
- Teleconference shared presence

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- Pre-expedition documentation and route planning

Honoring the native indigenous knowledge is the main added value of the activities performed during this field expedition. Collaboration is at the basis of trust and the engagement of local people in seafloor exploration within the PMNM boundaries, beside adding values to the seafloor mapping itself, contributed also to the enforcement of the social dimension of scientific research and mapping endeavors aimed at filling the main deep-sea exploration gaps in the explored areas. The biodiversity patterns observed included many taxa holding a high ecological value. The strong relationship between the indigenous people and the Ocean is confirmed by the wide variety of terms specifically indicating marine organisms and the plethora of sacred figures belonging to the local traditions which have a strong relationship with the Ocean itself (Tables 3 and 4).

Table 3. This is a table summarizing some of general terms commonly used by locals to indicate the main taxonomic groups, expressed both in the native Ōiwi idiom and the corresponding term in English.

ORGANISMS NAMES	English general term	Ōiwi term
	Coral	Ko'a
	Sponge	Hu'akai
	Octopus	He'e
	Sea star	Pe'a
	Fish	I'a
	Crab	Pāpa'i
	Gulper eel (*)	Puhi Wahanui

(*Scientific name: *Eurypharynx pelecanoides*)

Table 4. This is a table summarizing the general terms to indicate some relevant cultural references and the names of the main divinities and their cultural role in the native Ōiwi tradition.

DIVINITIES NAMES	Ōiwi term	Role description according to the local traditions
	Papahānaumoku	Mother figure personified by the Earth
	Wākea	Father figure personified in the expansive sky
	Kūpuna	General term to indicate the Ōiwi ancestors

The importance on relying on generational knowledge even in the field of deep-sea charting gaps filling is confirmed by the surprising event occurred in a deep portion of the PNMN where once deployed the Hercules ROV an endless field of precious pink corals unveiled to the investigators eyes. The deep-corals field is located around the Pō island, a sacred realm of gods and ancestral spirits, was supposed to be according to the local traditions (Figure 8 a-f).

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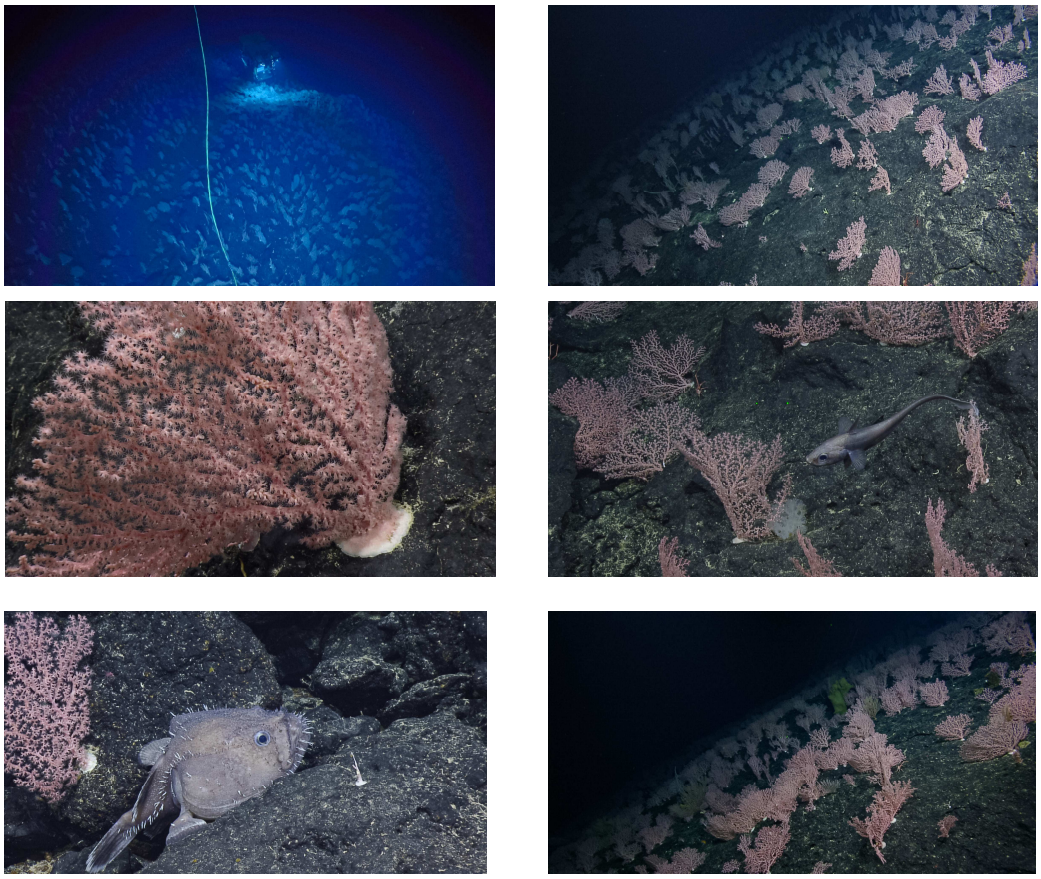

Figure 8. (a-f). The extensive precious coral field sacred to the local people detected around the King George Seamount along the Lili'uokalani Ridge following the indication of the indigenous engaged as field facilitators and sharing their traditional knowledge.

3.3. Human impacts detected along the ROV route

Despite the remoteness of the explored area some hints of human-driven impacts were detected during the ROV dives and charting sessions (Figure 9 a-d). The most peculiar and visible debris detected in the deep portion of the PMNM were:

- fishing nets residuals (Unnamed Seamount 11; Unnamed Seamount 17)
- metal cans and land-sourced debris (Gambia Shoal)

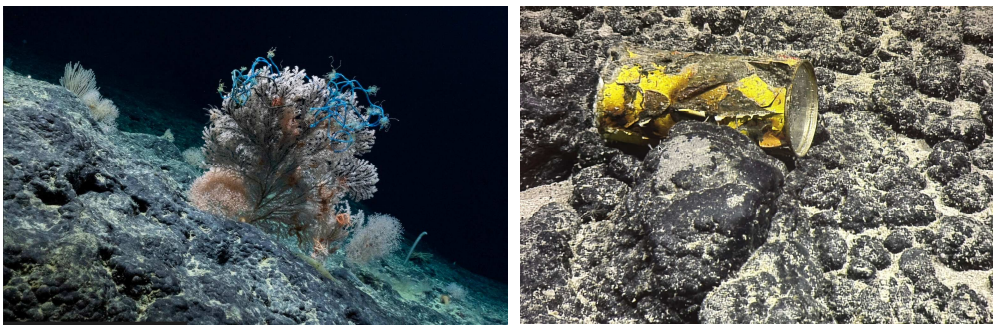

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Figure 9. (a-d). Some exemplificative pictures showing some human-driven impacts, mainly associated with lost fishing gears and land-sourced debris, detected during the exploration surveys of the NA154 expedition.

4. Discussion

Despite the advancements in technological tools and exploration endeavors many aspects of the deep-sea environments still being underknown. In the near future to fill the gaps in the most marginalized areas of the world what is important is establishing a trust relationship with local people, fostering at the same time the intangible and natural heritage preservation [12]. This is what extensively happened during the Nautilus Expedition season 2023, where the local communities held a pivotal role in each stage of the field mission accomplishment. The generational knowledge and the traditional aspects of the local cultures are essential to drive the resilience of indigenous people, even facing with the upcoming challenges in facing the climate change issues and the biodiversity loss consequences, even in the deepest portion of the ocean which is expected to significantly warm up in the upcoming years [13,14]. According to the Deep Ocean Observing Strategy (DOOS) community-driven initiatives facilitating collaboration across disciplines and fields, is essential to foster an intergenerational and multicultural dialogues connecting scientific advancements to societal needs which will need a coordinated effort [15].

Species richness normally decreases with depth in the ocean reflecting wider geographic ranges of deep sea than coastal species [16]. Deepsea biodiversity show maximum richness at higher latitudes (30-50°) with diversity patterns usually reflecting the energy availability (Woolley et al.,). Also, deep-sea patterns depend on energy availability, this is why many benthic species such as the sponges or corals observed during the E/V Nautilus expedition in the deep-sea environment adapted some alternative metabolic strategies to come with the oligotrophic conditions of the deep-sea environments where they live. Differently to many corals and sponges detected in shallow waters here the organisms are all predators due to the absence of photosynthetic symbionts in their tissues. Among the other physiological and functional adaptation observed there is the mild or totally absent pigmentation of body cells (as in some cephalopods detected during ROV surveys), bigger and more specialized eyes, less bones in organisms' skeletons and larger body sizes (as observed in many massive sponges or in some hermit crabs detected on the explored seafloor).

5. Conclusions

The outcome of this paper is a proof of a successful integration between exploration, educational goals fulfillment, scientific approach and cutting-edge technology use on field. This expedition marked a significant step ahead in deep-sea knowledge even toward the 2030 target goal for the attainment of an exhaustive ocean seafloor habitat mapping. The field activities performed so far allowed contributing to gathering data urgently needed to address local management and science needs of extant Natural Monuments as Papahānaumokuākea [17] and likely candidates for new National Sanctuaries designations such as Kingman Reef and Palmyra Atoll, including a better understanding of the deep-sea natural and cultural resources, biogeographic patterns of species distributions, and seamount geological history. Whilst the expedition main focus was to explore the geology and biology of unexplored seamounts, the operating area included also several historically-

significant shipwrecks associated with the Battle of Midway. By the way, for ethical reasons and in sense of respect for the victims engaged in this historically sounding event which dates back to the Second World War [18–20] a special code of conduct was observed by every expedition participant and since its sharing goes beyond the aim of this paper these images won't be showed in this occasion. The upcoming steps of deep-sea exploration hopefully will be addressed with the same attention for ethical aspects besides the scientific aims. The most sounding lesson learned from this experience with such an inspiring culture belonging to people who lived for millennia in harmony with the Ocean is their shared generational knowledge which allowed them to adapt and be resilient in the long term. Besides building trust with locals.

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Conflicts of Interest: The authors declare no conflicts of interest. The Ocean Exploration Trust and NOAA colleagues contributed to the data collection and positively evaluated the suggestion to publish the results and the expedition outcomes for outreach and dissemination purposes.

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