

THE DEEPEST OCEAN ON EARTH

A Scientific Case for Establishing the Mariana Trench Marine National Monument

Global Ocean Legacy
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Soft corals and tropical fish share a paradise of habitat on the summit of an underwater volcano 558 feet deep in the Mariana Island Arc, a 900-mile chain of volcanoes in the Pacific Ocean that includes the Northern Mariana Islands. These underwater volcanoes, some of which emerge as islands, rise almost 10,000 feet from the deep-sea floor just west of the Mariana Trench, the deepest point on Earth.







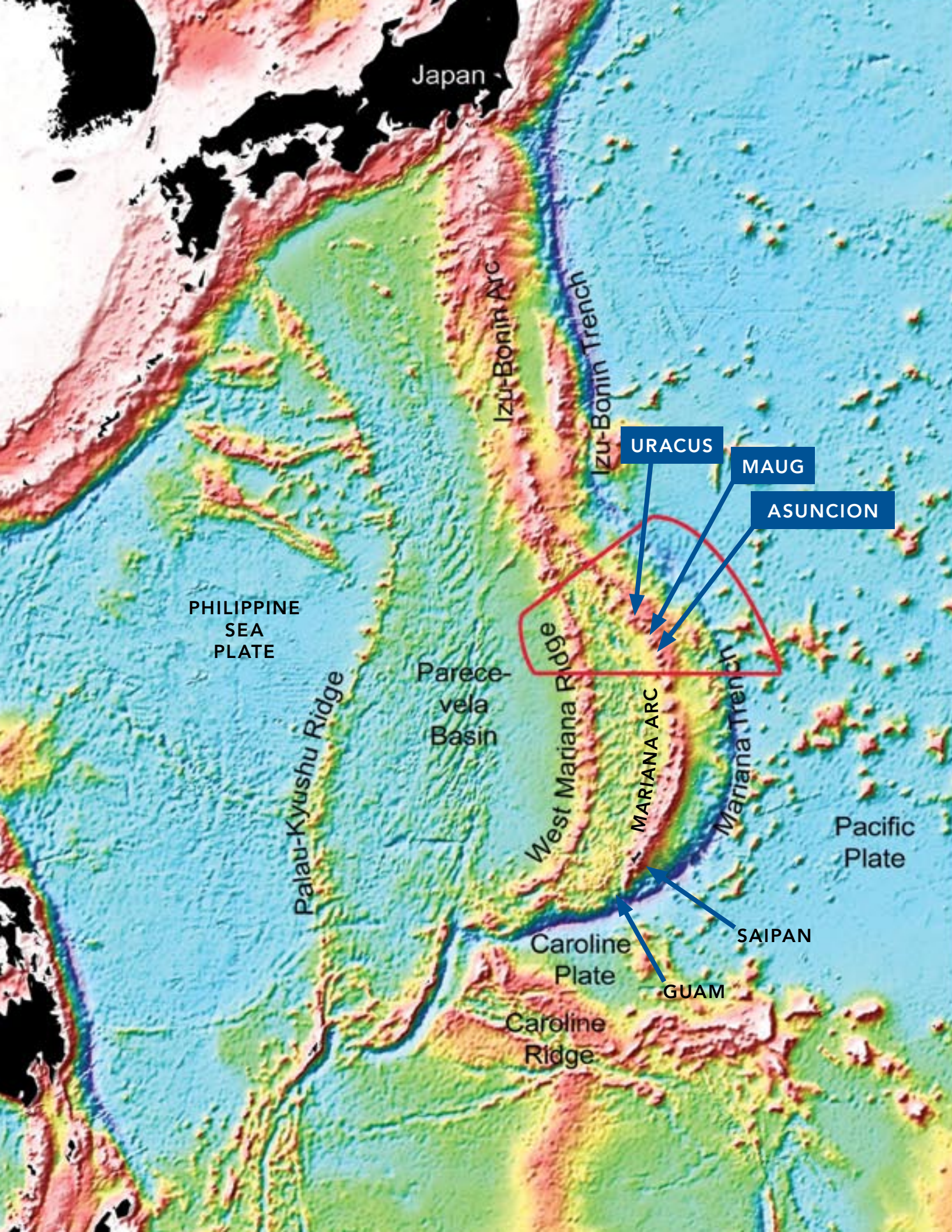
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Global Ocean Legacy is a project initiated by the Pew Environment Group of The Pew Charitable Trusts, in partnership with the Oak Foundation, the Robertson Foundation and the Sandler Family Supporting Foundation. Its goal over the next five years is to work with local citizens and governments to secure designation of three to five very large, world-class, no-take marine reserves that will provide ecosystem-scale benefits and help conserve our global marine heritage.

Written by consultant Elin Kelsey, Ph.D., for Global Ocean Legacy.

Opposite page: Humpback whale and calf.



EXECUTIVE SUMMARY

Where are the best places in the world to accomplish conservation at a truly oceanic scale? A key answer lies within the covers of this report—the proposed Mariana Trench Marine National Monument in the Commonwealth of the Northern Mariana Islands (CNMI).

The boundaries of the proposed monument are generous enough to protect an unprecedented cross section of the most volcanically active region on Earth—called the Ring of Fire. Its spectacular geology and rare ecology arise from the subduction of the world’s largest tectonic plate, the Pacific Plate, under the smaller, slower-moving Philippine Plate. Three uninhabited islands—Asuncion, Maug and Farallon de Pajaros (or Uracus, as it is more commonly called)—surrounded by the proposed monument are the exposed tops of a chain of volcanic mountains known as the Mariana Volcanic Arc. This wild, dangerous, tantalizing region is so remote that many of its wonders are yet to be quantified. This exceptional area has been the focus of seven separate scientific research expeditions since 2003.

The proposed monument includes the deepest ocean trench and the greatest diversity of seamount (underwater volcano) and hydrothermal vent life yet discovered. Here, the oldest species on Earth thrive amidst monstrous active mud volcanoes, and strange new species push life beyond all extremes. The world’s first discovery of hydrothermal vent fish was made in a boiling undersea lake of liquid sulfur on one of the

seamounts that dot the proposed monument area. The submerged caldera at Maug is one of only a handful of places on the planet where photosynthetic and chemosynthetic communities of life are known to exist together, fueling a microbial biodiversity hotspot of extraordinary complexity. This area provides a unique natural laboratory for studying ocean acidification and a potential coral refuge for climate change.

Sharks are more than an order of magnitude denser around the remote islands in the proposed monument than in the rest of the Mariana Archipelago, and one site in the western arc has one of the highest densities of sharks in the Pacific. Seamounts within the proposed monument area concentrate fish in a desert of deep ocean. Sharks and other apex predators drive smaller fish to the surface, creating the bait balls upon which many species of pelagic seabirds feed. Seabird populations in the CNMI are significant for Micronesia, and the islands of Maug and Uracus are major and important seabird breeding areas for the region. Seabirds, in turn, spike the nutrient load of coral communities, fertilizing the shores with energy from the sea. The proposed monument complements the protections already enforced by CNMI and presents a remarkable opportunity to protect every link in this complex and fragile chain—birds, seamounts, predatory fish and corals—as an integrated ecosystem.

Although not included within the proposed monument, the remote and uninhabited islands

Opposite page:
Proposed
115,000 square
mile Mariana
Trench Marine
National
Monument
outlined in red.



already protected by the CNMI also offer a last refuge for endangered endemic species such as the Mariana fruit bat. In February 2007, 19 species of whales and dolphins were sighted during the only systematic cetacean survey ever conducted in the Marianas, in an area just south of the proposed monument. Cetacean experts believe that some of the world's rarest beaked whale species reside in the waters around these islands. Perhaps the most striking example of the intimate link between volcanoes and wildlife is the Micronesian megapode—an endangered bird found only in the Northern Marianas and Palau. Heat from volcanic vents provides one of the remarkable strategies this bird uses to incubate its eggs.

At 115,000 square miles, the immense scope of the proposed monument, roughly the equivalent of a cross section of the Rocky Mountains from Nebraska to Utah, would be impossible to achieve on land. Such ecosystem-scale conservation demands great swaths of uninhabited regions found only in the remotest parts of the oceans. The proposed monument takes on even greater importance as populations, construction projects and associated impacts in the southern part of the archipelago increase. The U.S. State Department recently forged a treaty with Japan to move troops stationed at Okinawa to headquarters in Guam that will greatly increase local development. Proximity to rapidly growing populations and influences in Asia also pose an imminent risk to the health of this remarkable region.

Opposite page:

Uracus Island, the most northern volcano in the Mariana Archipelago, has been called the “Lighthouse of the Western Pacific” for its persistent eruptions. Measuring one square mile, covered with ash and lava flows, and rising from the deep-sea floor, Uracus is located 369 miles north of Saipan. Protected as a nature reserve under the CNMI Constitution and never inhabited, it is an important seabird nesting habitat.



SCIENTIFIC CASE

There is a place where birds warm their eggs with the heat from volcanoes and where thousands of crabs cluster around boiling pools of liquid sulfur. It is a place where the oldest species on Earth still thrive and strange new species push life beyond all known extremes. It is home to some of the greatest concentrations of sharks on the planet, the world's biggest hydrothermal vent system and the deepest ocean trench. "This is where the Challenger ROV (a remotely operated underwater vehicle) couldn't get to the bottom of the ocean," explains Dr. Verena Tunnicliffe.¹ "They couldn't get the line out that far."

To understand the complexity, and thus the uniqueness, of the Commonwealth of the Northern Mariana Islands (CNMI) and its surrounds, one first needs to embrace the fluidity of rocks. That's a tall order because for most of us, "rock solid" means just that—a rock is a thing we count on to stay put and not change shape. Dr. Patricia Fryer,² who has spent her life studying the deep sea geology of the Mariana Archipelago, knows rocks to "spew," "burp," "blanket," "fault," and "spread," creating one of the most geologically diverse places on the planet.

Few people have heard of this wild, dangerous, beautiful place. The 14 islands making up the CNMI lie atop a north-south volcanic mountain chain, three quarters of the way to the Philippines from Honolulu and 1,400 miles south of Japan. Guam, politically distinct from the CNMI, is the southernmost of the Mariana Islands.

To the east of this island arc, enormous underwater mud volcanoes dot the Mariana Forearc. Farther eastward, the seafloor descends into the deepest submarine canyon on the planet, the Mariana Trench. The geology to the west of the islands is no less spectacular. Stretching westward from the Mariana Volcanic Arc lies an actively spreading mid-ocean ridge system of the Mariana Trough, akin to the Mid-Atlantic Ridge. This backarc basin contains vast areas of low-productivity seafloor as well as the very deep Alice Springs hot vents. It is bordered to the far west by the extinct remnant arc volcanoes of the West Mariana Ridge.

Even by Pacific Ocean standards, this island chain is remote. Few people have ever set foot on the uninhabited islands that rise from volcanic bases in the northernmost part of the chain. Fewer still have ventured into the vast geological Shangri-la that beckons deep-sea researchers from across the globe. Yet this place is vulnerable. "The remoteness of the northern islands of the Mariana Archipelago will not protect them," says Dr. Rusty Brainard.³ "By boat, they are only a day away from Saipan. It would be easy to significantly exploit them."

Brainard knows of what he speaks. He and his crew conduct ecosystem observations for all 50 islands and atolls under the U.S. flag in the tropical and subtropical Pacific.⁴ (See Table 1 for a list of research expeditions.) They've discovered a pattern so clear and so worrying that it forms the basis of a number of papers Brainard's office prepared for the International Coral Reef Symposium in July 2008. "The pattern that emerges loud and clear is that wherever there are people, the amount of fish biomass decreases substantially."

The news that marine ecosystems, even the most remote marine ecosystems, are vulnerable to human activity is not new. What is becoming undeniable, however, is the scale of the problem. Dr. Benjamin Halpern and a prestigious group of co-authors published a major paper in the journal *Science*, in February 2008,⁵ showing that over 40 percent of the world's oceans are heavily affected by human activities. Few if any areas remain

Opposite page: One of the three islands of Maug, in the Mariana Archipelago.



“What Global Ocean Legacy has identified within this proposed marine reserve is a wonderful range of genetic, species and ecosystem diversity...”

The Maug islands surround the caldera of an ancient volcano.

untouched. Tunnicliffe agrees: “Some of the scariest stuff is what’s happening out in the middle of the ocean.”

The proposed monument’s vast range of geological habitats fuels impressive ecosystem, species, and genetic diversity

“What Global Ocean Legacy has identified within this proposed marine reserve is a wonderful range of genetic, species and ecosystem diversity,” Tunnicliffe says. “The boundaries encompass a vast range of large-scale geological habitats. It’s a much greater geological range than even Hawaii. As soon as you create that kind of habitat diversity, you start creating genetic diversity at both the macrofauna and microfauna levels.”

In the most simplified terms, the farther west one goes across the Pacific, the greater the diversity of marine species. “All of the islands in the Marianas are higher in genetic richness than anywhere in Hawaii or Johnston or Jarvis,” agrees Brainard. “Parts of American Samoa, Kingman, and Palmyra are the only ones that exceed that. When it comes to diversity, it pretty much agrees with the biodiversity hotspot in the western Pacific. As you get farther and farther away from the more geographically isolated Hawaiian Archipelago, we see the same pattern—much lower diversity in Hawaii, higher in the Marianas and American Samoa.”

Tunnicliffe explains that the Mariana Arc is a geographical barrier for some marine species. “We see species on the east part of the arc, and some of the same species occurring on the



west part of the arc, but they may well be fairly genetically distinct because of the barrier between them. That's an interesting concept because the International Convention on Biological Diversity includes not only ecosystem and species diversity, but genetic diversity as well."

It's also generally assumed that endemism (species that are unique to a place) in the Northern Marianas is low. Yet the relatively recent ability to sample genetic diversity opens that assumption up to further questioning. "Endemism in the Marianas has been very under-surveyed," says Dr. Gustav Paulay.⁶ "When you look genetically, it may be higher than it appears." He mentions the fascinating Ogasawara, or Bonin, Islands in Japan that are higher up the same arc that forms the Marianas as an example of latitudinally induced endemism.⁷ "The Northern Marianas might not

be quite as rich in diversity as some of the other Pacific islands, but they may display an abundance of local or regional endemics," he says. "It's the potential mix of richness and endemism that makes them so compelling."⁸

The only volcanic archipelago in Micronesia

Dr. James Maragos⁹ has been studying coral reefs in the Pacific for nearly 40 years. He believes that protecting the waters around uninhabited islands is the most effective way to conserve coral reef diversity. A large map covered with red and yellow pushpins dominates one wall of his office. A closer look reveals a few green pins scattered among them. Each pin represents one of the 65 virtually uninhabited, pristine islands that remain in the

Masked booby family. Seabird populations in the CNMI are significant for Micronesia. Maug and Uracus islands support regionally important seabird colonies.

This illustration shows the effect of the Pacific plate (right side of diagram) colliding with the Philippine plate (left side of diagram). At certain depths, usually around 124 miles, there is melting of the subducted plate. The melting produces magmas that rise buoyantly to pond in the overlying mantle wedge and periodically erupt on Earth's surface as lavas, forming arc volcanoes.

Pacific. "Greens are the good ones—places like the northwest Hawaiian Islands that are now totally protected," he says. "Yellow are refuges and other protected areas that lack real protection on the ground."

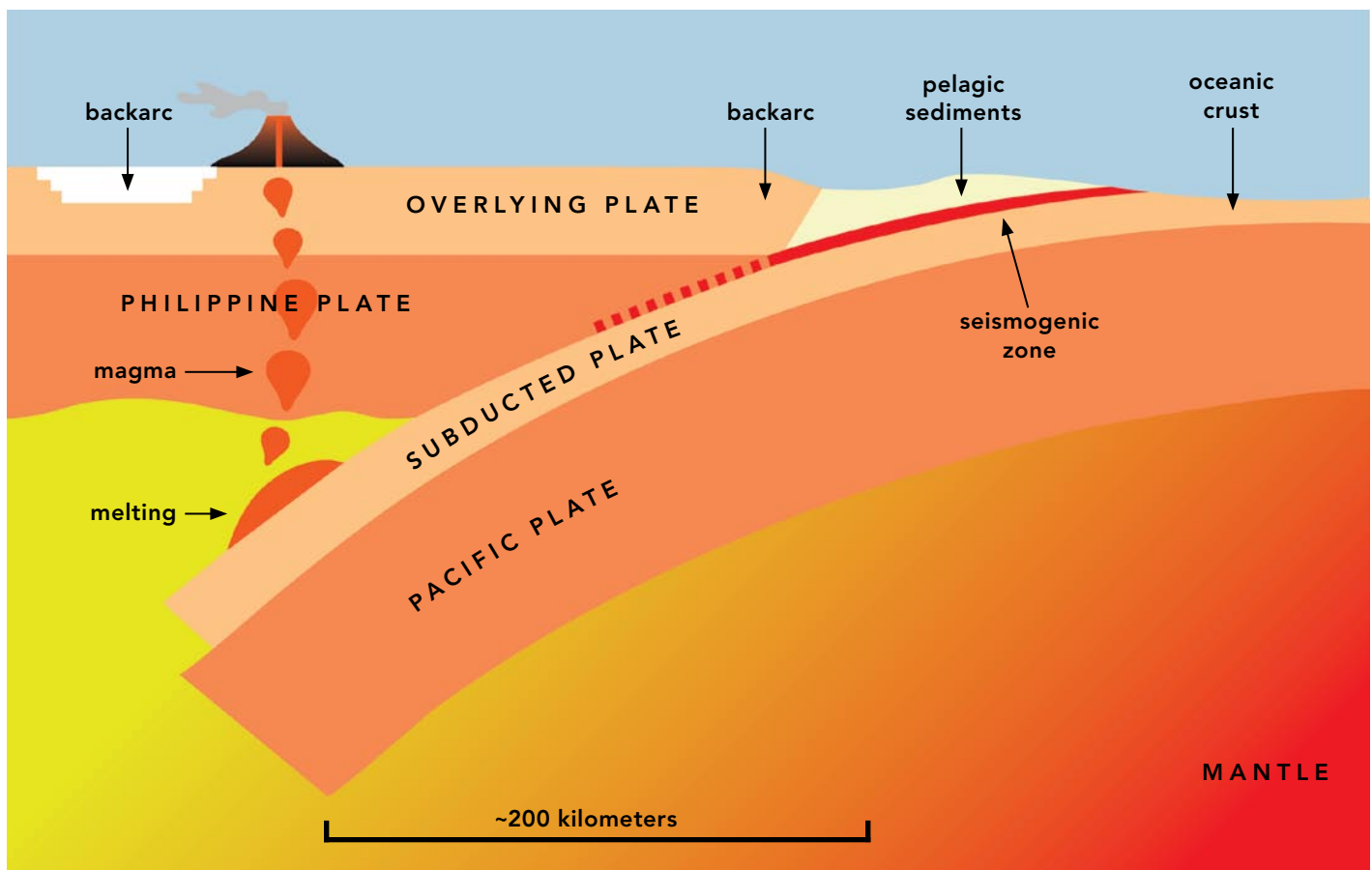
Maragos uses red pins to mark islands without any official conservation designation. The waters around the northern islands in the Mariana Archipelago fall within this category, and they top his list of places to try to protect. "They're unique," he explains. "Micronesia is its own biogeographic province, and the Mariana Islands are the only volcanic archipelago in Micronesia. All the rest are a mix of reef islands and atolls with a few volcanoes." Paulay puts it more directly: "Across the Pacific, if you've seen one reef, you've seen them all. Guam, Tahiti, the Hawaiian Islands—they're very similar. But the Northern Marianas are different. They're the only marine volcanic habitat in Micronesia. They support communities that require basalt. No one has ever studied this, but

there must be a dozen or more invertebrates that are endemic to these rare basalt communities."

Maragos also ranks the waters of the Marianas as his top priority for preservation because of their vulnerability. "They're closest to Asia," he says bluntly. "In the old days, remote areas like these were safe. Now it's a different world. We've got GPS and metal ships and a burgeoning population. Fishers are targeting these areas because it's easier to rip off giant clams and sharks and everything from uninhabited islands and reefs."

It's a sad truth that as one travels west in the Pacific, one experiences not only the greatest diversity but also the greatest threat from humans. Paulay speaks of poachers patrolling the Pacific islands in a rampant search for sharks and of the shock a colleague expressed after diving this year at the Caroline Atoll, one of the most remote islands on Earth, and seeing not a single shark.

MARIANA VOLCANIC ARC





Liquid carbon dioxide bubbles at the Champagne Vent more than a mile deep in the Mariana Island Arc. It is one of the few places in the world where this phenomenon occurs.



Grey reef sharks are a Species of Special Conservation Need for the CNMI. They are also on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. The waters of the proposed monument have high concentrations of sharks.

A haven for sharks and other apex predators

The proposed Mariana Trench Marine National Monument would stand out as a place where apex predators still exist in significant numbers. Sharks are more than an order of magnitude more dense around the remote northernmost islands than in the rest of the Mariana Archipelago¹⁰ One site, which lies on the western arc within the proposed monument, has the highest density of sharks in the region. “It’s comparable to anywhere we see in the Pacific in terms of numbers of sharks,” Brainard says. “That includes Jarvis Island, which has the highest biomass of anywhere, by far, that we survey, and Howland and Baker Islands, which are remote national wildlife refuges. This place has the same shark densities. We found that really surprising.”

It makes sense that these waters are rich in sharks and other apex predators because fish

concentrate at underwater volcanoes. “We know seamounts are sites of high productivity,” Tunnicliffe says. “We know that they tend to concentrate nutrients. But we’re really struggling to understand the processes that concentrate these animals.”

The waters around Asuncion, Maug and Uracus all show substantially higher fish biomass, according to Brainard—a finding in keeping with the pattern that biomass is higher in uninhabited areas. These islands have experienced little impact from the local fishing fleet. “They try to expand their longline fishery and their bottom-fish fishery every once in a while,” Gerry Davis says,¹¹ “but they rarely have the ability to reach those northern areas. That part of the world is geologically very irregular, so fishers lose a lot of gear. That’s typically why they don’t fish those areas. In terms of nearshore stocks and resources, I doubt if you could tell that they’ve ever been fished.”



The coastal slopes and seamounts that are part of the proposed monument serve as oases of life in a desert of deep, low-productivity ocean. “Anywhere deeper than 650 feet is dependent on marine organic rain,” explains Dr. James Barry.¹² “The farther away from the surface you

descend, the more it’s being used by the mid-water community and the less food (useful organic carbon) really makes it to the bottom. The ocean in the Marianas is very clear because there’s not much production.”

In March 2006, the United States Coast Guard seized this Taiwanese fishing vessel, Chuan Fa Sheng 128, for illegally fishing in the waters of the Northern Mariana Islands.

“In the old days, remote areas like these were safe. Now it’s a different world...”

The bumphead parrotfish is a Species of Special Conservation Need for the CNMI. It is also on the IUCN Red List of Threatened Species and is a U.S. National Marine Fisheries Service Species of Concern.

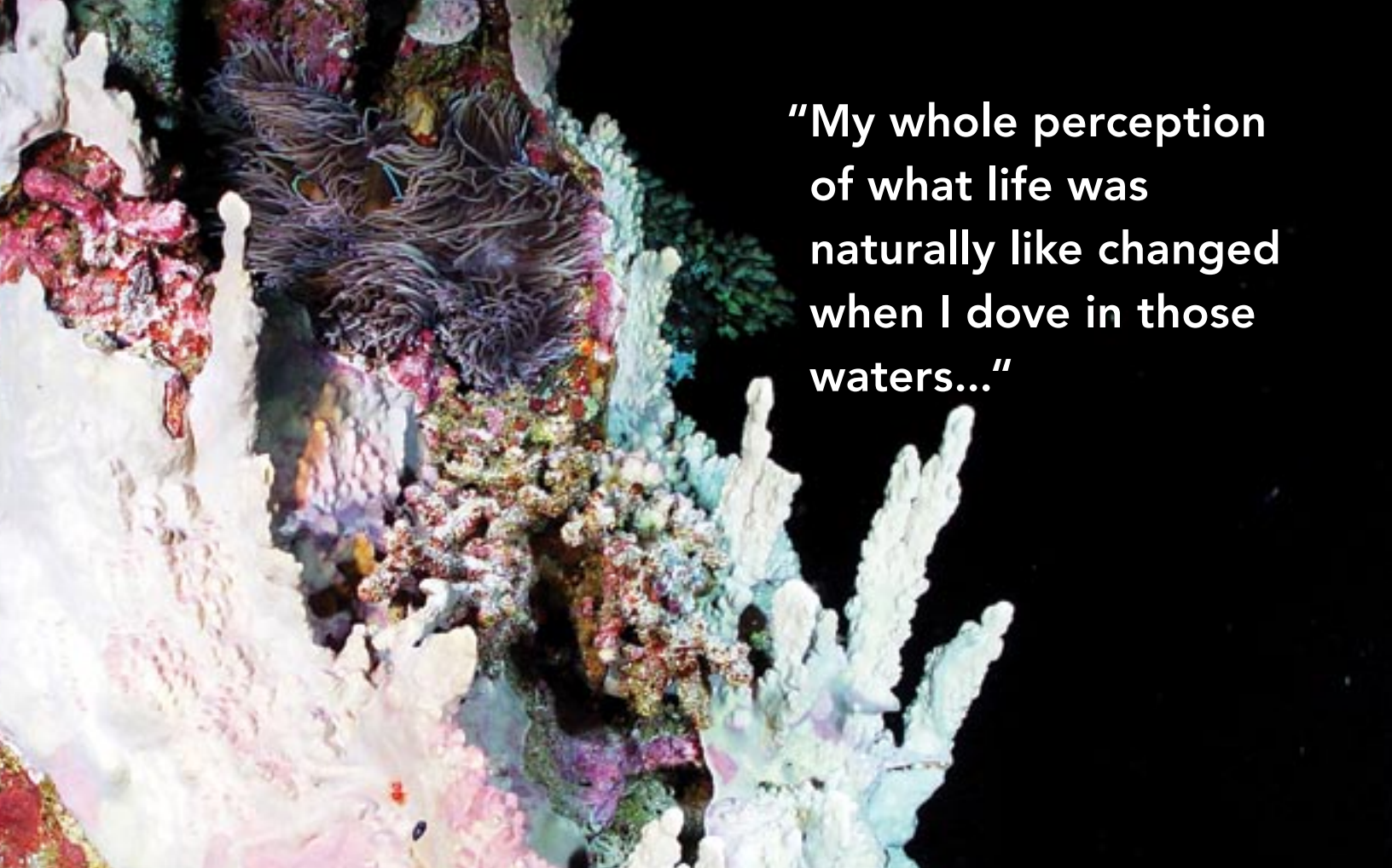


Submerged caldera provides an unparalleled opportunity to document a baseline for pristine volcanic coral communities

Davis's voice grows soft as he describes how remarkable it is to dive in the lagoon on Maug. Maug comprises three wall-like islands that form the rim of an ancient volcano. The submerged caldera spans one and a half miles and plunges to a depth of 800 feet. "I don't know of any other lagoons that go to that kind of depth," he says. "My whole perception of what life was naturally like changed when I dove in those waters. I saw fish species in that lagoon that are only ever found on coastal slopes. I saw big jacks, big groupers, sharks, and large schools of barracuda when I was standing chest deep on the reef flats. These big predators are usually the first to disappear on reefs and they tend to find refuge at depth. It became clear to me that I was seeing them in a natural habitat that doesn't exist in other places anymore."

It was not just where the fish were found but the size and unusual numbers of individuals that impressed Davis. "I saw densities of fish that I've never seen anywhere else in the Marianas," he explains. He struggles to find words to describe the deafening sound of dozens of enormous bumphead parrotfish crunching live coral in just three feet of water. The biggest of the parrotfish, the bumphead can reach the size of a small woman and live for 40 years.¹³ Because they sleep in large groups, come nightfall they are vulnerable to spearfishers and netters, and they have been decimated through much of their range. For this reason, the bumphead is now on the IUCN Red List of Threatened Species and is a U.S. National Marine Fisheries Species of Concern; it is also a Species of Special Conservation Need for the CNMI.¹⁴

Davis's experience on Maug is a clear case of "shifting baselines"—what Dr. Daniel Pauly, Director of the Fisheries Centre at the University of British Columbia, describes as the very human tendency to redefine what is "natural" according



“My whole perception of what life was naturally like changed when I dove in those waters...”

to one’s personal experience. Davis was well aware of the impacts of humans on the oceans, but only when he dove in the lagoon did he fully comprehend what we’ve lost. According to Dr. Eric Sala,¹⁵ a Pew fellow in marine conservation, and his colleagues, “Effective conservation requires rigorous baselines of pristine conditions to assess the impacts of human activities and to evaluate the efficacy of management. But most coral reefs are moderately to severely degraded by local human activities, such as fishing and pollution as well as global change; hence, it is difficult to separate local from global effects.”¹⁶

Maug Crater provides rare glimpses of what the ocean was like before humans started tinkering with it. Recounting what it’s like to dive at Maug, Dr. Peter Houk¹⁷ describes a reef so completely crowded with corals that they fight one another for space. Surveys of this pristine volcanic coral community would provide a much-needed baseline of how such ecosystems naturally function.

A unique case of hydrothermal venting into shallow coral reefs

“Maug is one of those really special places,” says Brainard. “It has a more mature coral reef ecosystem than we see in the rest the Northern Marianas.” But it is the geochemistry that is unique. When Brainard and his colleagues first visited the lagoon, in 2003, they discovered bubbles coming out of the shallow water areas inside the reef. Hydrothermal vents were spewing acidic (pH 6.0) water at nearly scalding temperatures (140°F) into the coral reef.

Dr. Robert Embley¹⁸ and his crew investigated this remarkable interface of photosynthetic and chemosynthetic ecosystems during the 2003 Ring of Fire expedition, and they used their ROV to trace its source when they returned in 2004. They found that the lagoon crater extends down 820 feet; however, the lava dome in the center of the crater—the most recent output from this volcano—rises to within 65 feet of the surface. The ROV dives revealed a line of diffuse vents

One of the central domes in the Maug underwater caldera is covered with many types of corals, sponges and algae. Near the top right is a beautiful lilac anemone; two clown fish hide within it.

along the northeast side of the dome at a depth of about 475 feet. “We’ve got hydrothermal fluid coming into the photic zone, and there are corals growing around and we’ve got microbial mats and tropical fish swimming through them,” says Tunncliffe, who participated in the expedition. “It’s amazing.”


“Maug is unique because of the venting,” says Brainard. “It has a different chemistry than any other place that we know of that actually reaches the surface in a shallow reef system. It’s the only place where, in a natural way, we could look at what is already happening in an acidifying ocean scenario. It’s a natural laboratory for looking at

what the world may be like in the not-too-distant future because of climate change.”

Brainard returned to Maug to collect samples in 2007 and has begun arranging with NOAA’s Pacific Marine Environmental Laboratory in Seattle to treat the lagoon as a potential study site for working on the long-term consequences of ocean acidification. “The reefs in the lagoon are in beautiful condition,” says Brainard. “The effects of the venting appear to be quite localized. It looks like right at the venting site the reefs are fairly degraded because of natural acidification. We see it as an opportunity to better understand what may be facing reefs in the coming decades.”

Located 329 miles north of Saipan, Maug’s three islands compose part of the rim of a volcano, now partially submerged. The collapsed volcano cone is a deep caldera that spans one and a half miles. These uninhabited islands, totalling .8 square mile, are protected by the CNMI Constitution as permanently uninhabited nature reserves.



The image shows an underwater hydrothermal vent site. Two prominent white, mineral-rich chimneys rise from a dark, rocky seafloor. The chimneys are covered in a porous, crystalline material. The surrounding water is dark and filled with numerous small, light-colored bubbles, likely liquid carbon dioxide. A red pin marker is visible on the left side of the image, pointing to the text.

“Maug is unique because
of the venting...”

Underwater chimneys vent a cloudy chemical soup at 217°F with the highest carbon dioxide concentration known for oceanic hydrothermal fluids. Bubbles of liquid carbon dioxide escape in never-seen-before abundance at this mile-deep site nicknamed Champagne.

Dense populations of a newly discovered species of tonguefish thrive around the hydrothermal vents at Daikoku and Nikko volcanoes. Scientific research shows they may be feeding directly on hydrothermal bacteria, another first find for a vent fish species. Both camouflaged tonguefish and crabs cover the seafloor. For a sense of scale, note that the two red dots in the center—lasers—are four inches apart.



Paper-thin shells on living mussels provide clues to deep-sea life in an acidifying ocean

Nearly a mile beneath the surface of the ocean, a very dense bed of mussels thrives at Champagne Vent, located on the summit of a seamount called NW Eifuku (21.485°N, 144.043°E).¹⁹ Here, carbon dioxide (CO₂) exists in a never-before-seen liquid form, looking like the liquid bubbles of a lava lamp. “It’s very acidic,” says Tunnicliffe. “Around pH 5.5. The shells of the mussels are paper thin.” Remarkably, the same species of mussels are found in the Tonga Arc in far less acidic waters and have more robust shells. “It’s a bit of a warning,” explains Tunnicliffe. “As you move toward a more acidic ocean, these shelled animals just completely dissolve if they don’t have sufficient protection from a shell. The thinner the shells become, the greater opportunity predators have to just rip through them.”

Even though there are huge numbers of mussels living around the hydrothermal vents at NW Eifuku, Tunnicliffe and her colleagues hardly ever found any dead shells. This was very unusual. She suspects that the high levels of CO₂ released from the volcano increase the acidity of the water; after a mussel dies, its shell quickly dissolves.

Potential to be a globally important refuge for corals threatened by climate change

Ironically, one of the best places on Earth to study the naturally occurring effects of an acidifying ocean may also prove to be an important refuge from human-caused ocean acidification. According to Barry, CO₂ emissions in the atmosphere are readily absorbed by seawater. The CO₂ then combines with water and consumes carbonate ions, leading to an increase in acidity. “The surface



of the ocean has experienced a 25 to 30 percent increase in acidity just in the last 50 years,” Barry explains. “The scale of the CO₂ story is amazing. Right now CO₂ is going into the ocean at a rate of a million metric tons an hour.”

By the end of this century, Barry says, pH levels even in the central area of the Pacific will be marginal in terms of supporting corals. Barry points to a map of projected changes in reef calcification.²⁰ “Though it still won’t be good, the best area for coral growth is right over the Mariana Trench. So if you want to look for an area of the ocean where you might see a refuge for corals due to the acidification problems that we anticipate through the next century, the area proposed for monument might be a good spot.”

Superimposed on the whole acidification issue is warming. The warming story is dire for corals. According to Dr. Peter Brewer,²¹ it is likely that by

2070 the optimal growth conditions for warm-water coral will simply no longer exist, and about 60 percent of the environment for cold-water coral will be gone.²²

It is not just the magnitude of the changes that has climate-change scientists gravely worried. It is also the rate at which we are changing things. “We are changing the ocean at a rate that is much higher than anything in the last many millions of years,” says Barry. “It may be 30 million years since the ocean has seen anything like this. This is not just this little human effect of a bit of climate change. This is a massive event in Earth’s history.”

A tremendous mussel biomass adorns the lava ridges at the crest of submarine NW Eifuku volcano north of Uracus. These seven-inch mussels are so densely massed that they obscure the bottom. The white galatheid crabs are 2.5 inches long.

Paulay also advocates the proposed monument area as a potential refuge from climate change. The Northern Marianas are part of a chain with a rich diversity of corals at the southern end. “The monument could be a safe place for corals to spread as the oceans get warmer,” he explains. “Most coral recruitment around islands is self-seeding, according to data from the last decade and a half. You need to protect islands in the same archipelago.”

The height of Maug, Asuncion and Uracus also favors this concept of coral refuges. The main impact of fluctuating climate on intertidal ecosystems will be through changes in sea level and temperature. Indeed, rising sea level associated with global warming increases the already existing problems of erosion and inundation in the U.S.-affiliated islands of the Pacific.²³ According to Dr. Lucius Eldredge,²⁴ “The islands in the proposed monument are high enough to avoid intertidal effects from climate change.”

“There’s lots of CO₂ and SO₂, which creates incredible potential for a lot more life.”

Greatest diversity of seamount and hydrothermal vent life yet discovered on Earth²⁵

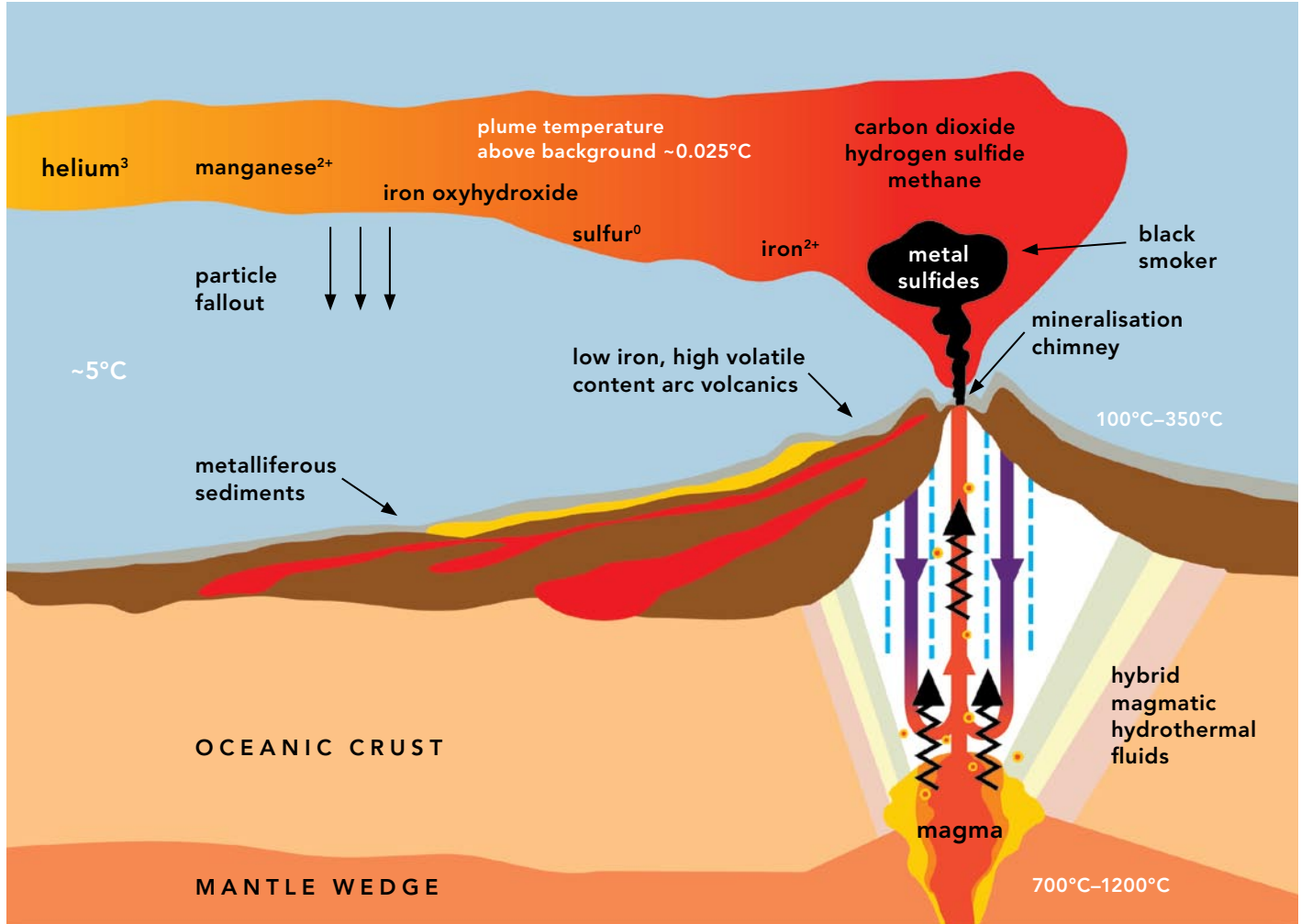
As terrestrial beings, most people tend to think of the Pacific in terms of islands, then shores, then surface waters, and finally, the deep. Embley, like many deep-sea researchers, pictures the world the other way around. His view of the Mariana Archipelago starts with the volcanic arc upon which it rests. There are more than 30 active volcanoes in the northern part of the Mariana Arc. Nine of these protrude above the ocean surface as islands. Asuncion, Maug and Uracus are simply the most northerly exposed portions of this vast underwater volcanic system. “These volcanoes put out a lot more gas than most submarine volcanoes because of the down-going slope of the crust,” Embley says. CO₂ and sulfur dioxide (SO₂) are abundant. “There’s lots of CO₂ and SO₂, which creates incredible potential for a lot more life.” Indeed, every time he dove on one of these volcanoes, he says, he found something new and different and fascinating.

“There is something very special about these arc-type hydrothermal vent systems,” says Dr. Craig Moyer.²⁶ “The chemistry is much more complex. It’s very much different from a divergent plate boundary. This is what’s called a convergent plate boundary, where you actually have one plate sliding underneath another. Because of that, it really increases the complexity of the geochemistry involved with the system. I’m entirely convinced that the biology is following suit, taking advantage of the different types of molecular fuel that are coming out because of the complex geochemistry.”

According to Tunnicliffe, every submarine volcano in the proposed monument area seems to be unique. “If you look at any one volcano, the diversity, whether it’s the vent fauna or the non-vent fauna, is pretty low,” she explains. “But at the next volcano, you’re seeing quite a different grouping of animals. So in the larger context of the proposed monument, your regional diversity goes up. Because I’ve worked on seafloor systems that span exactly this kind of distance in many

Cross section of a typical submarine volcano with an active hydrothermal system. As magma ascends, water and gases enter the deep hydrothermal system as pressure is released. Cold seawater (purple arrows) permeates the volcano and becomes heated by the hot rock near the magma body. Hybrid hydrothermal fluids (red arrows), derived from seawater and magmatic gas and fluid, buoyantly rise to the

summit while altering the volcanic rock (white=alteration). Fluids discharged at the seafloor rise from 30 to 1,000 feet or more before they spread laterally in the hydrothermal plume. The plume is dispersed by the local currents, carrying various dissolved and particulate chemical species derived from the magma and the volcanic rock.



other places in the ocean, I find myself very intrigued and surprised at how much diversity there is in this region from place to place.”

“The whole Mariana Arc is just an incredibly diverse region for hydrothermal vents,” says Moyer “even when you compare it on the same spatial scales as the Juan de Fuca Ridge or the East Pacific Rise or even the Mid-Atlantic Ridge. Of all the places where we have any kind of research base, any kind of literature base, we know that they don’t hold the same level of diversity that’s seen out on the Mariana Arc.”

One of only a handful of biodiversity hotspots in the world fuelled by both of the earth’s power systems

To appreciate how special the ecology of the proposed monument is, it would be helpful to take a moment to step outside and peer at the sun. Every animal we normally think of relies on the sun for energy. Through the complex process of photosynthesis, plants convert sunlight, water and carbon dioxide into sugars or carbohydrates, which are eaten by plant eaters who, in turn, are consumed by carnivores.



Hydrothermal vent species defy the norms of the photosynthetic world. Inside their bodies dwell symbiotic bacteria capable of obtaining energy directly from chemical-rich fluids generated by volcanic processes. Chemosynthesis, as this remarkably different form of productivity is called, is one of the major biological discoveries of the last several decades. Instead of photosynthetic plants, chemosynthetic microbes form the base of this food chain. Bacteria in the water around the vents use CO₂ in the presence of other dissolved gasses, such as methane or hydrogen sulfide, to fuel the manufacture of sugar. Even more amazing, the bacteria are found not only in the water but living symbiotically in the tissues of the numerous newly discovered worms, clams and mussels around the vents.

Maug Crater is one of only a handful of places on Earth where photosynthetic and chemosynthetic communities of life are known to come together. The result is an unparalleled site of maximum diversity in the microbial world. “They are so incredibly diverse,” says Moyer, “we’re actually calling them biodiversity hotspots.”

Too rare and too new to have been studied, these areas are nonetheless gaining a lot of attention. “We actually have trophic level interactions,” marvels Moyer. “Our hypothesis is that the chemosynthetic microorganisms are actually helping fuel the growth of the photosynthetic side of these communities. It’s not just the fact that there are lots of different species; it’s that we’re seeing lots of populations interacting with one another at the most abundant level.”

World’s first known hydrothermal vent fish thrive in a boiling lake of liquid sulfur at Daikoku seamount

To find a unique environment, one that blows all preconceptions of where life on our planet can exist, one need look no further than the Daikoku Seamount (21.324°N, 144.194°E).

In 2006, Embley and his colleagues made the first discovery of sulfur volcanism on Earth. He writes

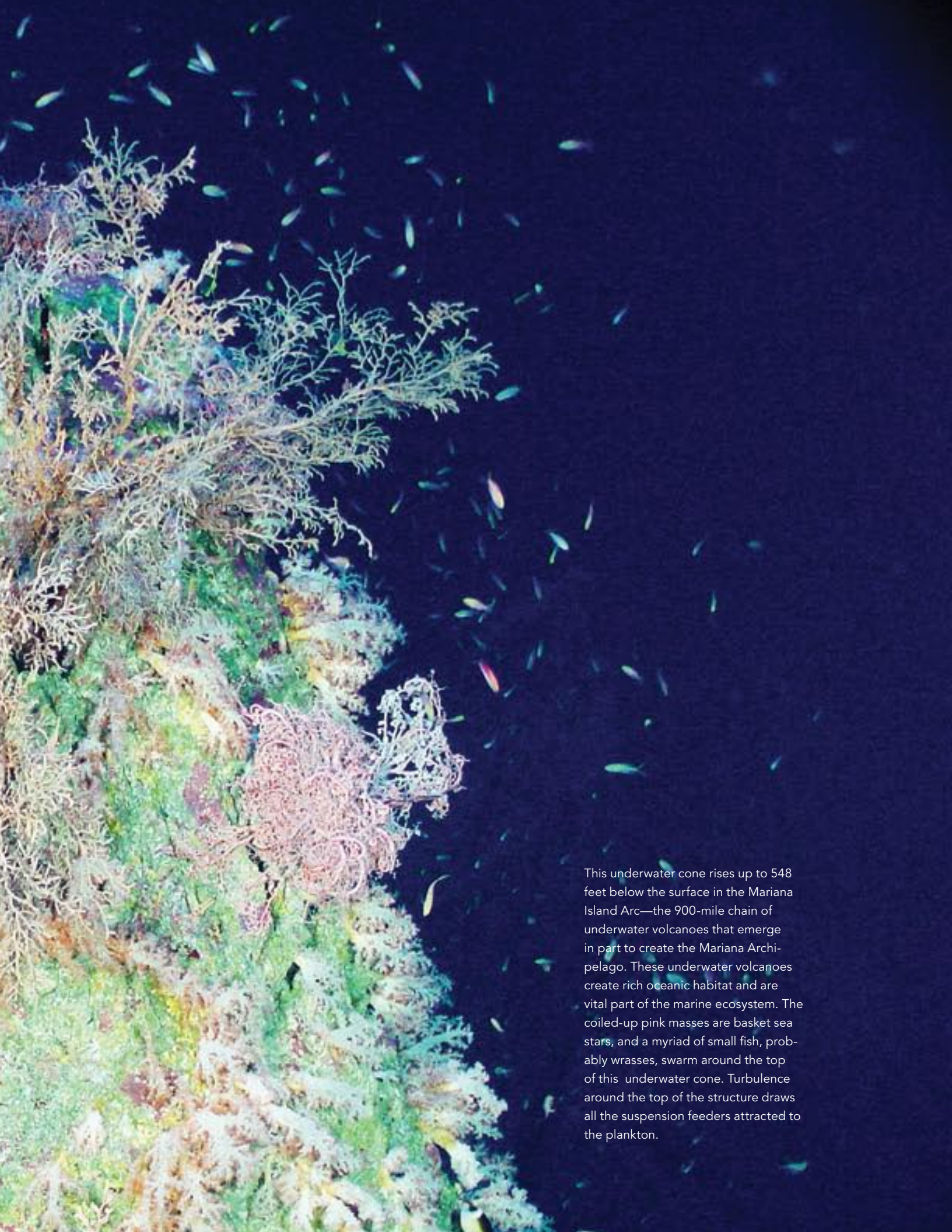
in the expedition log: “One of the most exciting discoveries of the 20th century was the discovery of active sulfur volcanism on Io, the innermost (major) moon of Jupiter. Last night we came across another extreme of sulfur volcanism in the Solar System, a convecting pool of liquid sulfur under more than 40 atmospheres of pressure!”²⁷

“These are just wonders,” says Tunnicliffe. “It’s mind-boggling. All around the boiling sulfur lake (or Sulfur Cauldron as it’s now named²⁸) are thousands and thousands of crabs and fish. They love it.” Unique environments harbor new species of animals, and Daikoku delivers in spades. Embley’s team has digital footage of a new species of flatfish²⁹—the first fish ever discovered to live at a hydrothermal vent—actually swimming out on the crusted-over surface of the molten sulfur cauldron.³⁰ These fish also cover the adjacent slopes of the volcano in hydrothermal areas. Vent ecosystems are known to support a wide range of invertebrates such as crabs, shrimp, mussels and worms. Elsewhere that fish have been observed at vents, they tend to make short feeding forays into the vent area before retreating to the surrounding non-vent waters. The discovery of vent-loving fish at Daikoku smashes the widely held assumption that fish are unable to withstand the harsh chemical environments associated with hydrothermal vents.

Moyer is eager to return to Daikoku to get microbiological samples from the microbial mats around the undulating Sulfur Cauldron. No one knows how these amazing fish are feeding, though it appears they may be digesting small worms from the sediments. More exciting still, these same fish have also been found on the un-sedimented bottom of a fossil sulfur lake on another seamount, Nikko. Moyer and his colleagues speculate that these fish may also be capable of feeding directly on hydrothermal bacteria—another first for a vent fish species. “Daikoku is on the top of our list,” Moyer says. “We suspect the animals around the sulfur lake are attracted by the chemosynthetic bacteria. It’s just one of those places that has an incredible story around it—what it is that life can do on our planet and what we can learn from it.”

Opposite page: Galatheid crabs and shrimp graze on bacterial filaments on the mussel shells at NW Eifuku submarine volcano, north of Uracus Island. The black “scars” on the shells are former anchor points of mussels who have cut their threads and moved on.





This underwater cone rises up to 548 feet below the surface in the Mariana Island Arc—the 900-mile chain of underwater volcanoes that emerge in part to create the Mariana Archipelago. These underwater volcanoes create rich oceanic habitat and are vital part of the marine ecosystem. The coiled-up pink masses are basket sea stars, and a myriad of small fish, probably wrasses, swarm around the top of this underwater cone. Turbulence around the top of the structure draws all the suspension feeders attracted to the plankton.



This convecting pond of molten liquid sulfur discovered at Daikoku submarine volcano astonished scientists. It is about 15 feet long and 10 feet wide with a temperature of 369°F and is under more than 40 atmospheres of pressure.

The single biggest hydrothermal vent community on Earth—a possible U.S./Japanese marine reserve

Nikko Seamount (23° 05.00' N 142° 19.00' E) lies in Japanese waters just beyond the boundary of the proposed monument. It features the world's biggest single hydrothermal vent system and a range of other unique geological features. Embley feels it is so significant that it would be wise to explore the potential of including Nikko within the proposed monument, in the form of a binational U.S./Japanese marine reserve. Indeed, Japanese scientists have conducted significant studies within the CNMI.³¹

"Nikko Seamount is one of the most fascinating in this whole system," agrees Tunnicliffe. "I've worked on a lot of hydrothermal systems in the Pacific, in the Atlantic, around the world, as has Embley. I think Nikko is the biggest extent of hydrothermal vent communities that exists." The rimmed crater on Nikko spans a couple of kilometers. Hot-vent animals are usually found

clustered where the water comes out of the seafloor. But on Nikko, the crater appears to trap waters from the volcano. "It is *full* of life," Tunnicliffe says. "It must have truly billions of crabs in that crater. There are fish and tubeworms and mussels everywhere. And all of these animals are related to the chemosynthetic production."

Embley describes a sulfur lake even larger than the one found on Daikoku, this one home to flatfish twice as large.³² "There are sulfur chimneys and ornamental sulfur phalanges that are so beautiful; they are like nothing we'd ever seen before." He felt so astounded, so privileged to be the first person to see these formations, that he could not bring himself to sample them. "I was in awe. I felt that these should be a national park some day," he says. Yet they would be all too easy to destroy. As Tunnicliffe puts it: "It would just take a few trawlers to go through there, and it would all be wiped out."



The Mariana Arc, and in particular Maug Crater, is one of the few places on the earth where photosynthetic and chemosynthetic communities of life are known to exist together. These rare biodiversity hotspots are fuelled by both of the earth's power systems: photosynthesis (sun) and chemosynthesis (chemical). Microbial mats, which are chemosynthetic, cover red algae and coral, which are photosynthetic. Hydrothermal vent and coral reef communities overlap here at depths around 600 feet in this photo from the Mariana Island Arc.



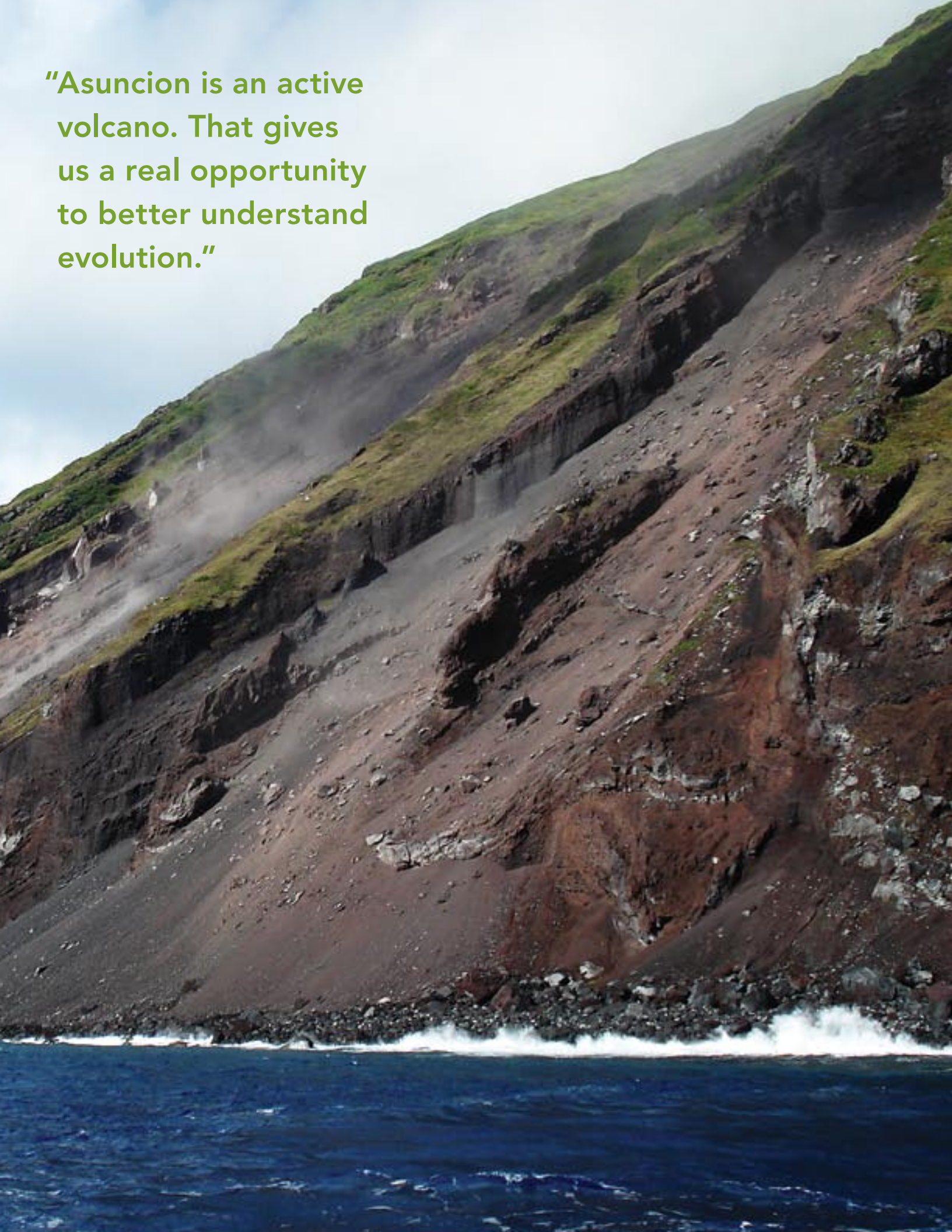
The only place in the world with monstrous active mud volcanoes

If one were to travel out to the forearc, the region between the earth's deepest ocean trench, the Mariana Trench, and the active volcanic arc, one would be in for yet another astonishing discovery—enormous mud volcanoes. The largest is 31 miles across and many are more than a mile high. Much smaller mud volcanoes occur on many convergent plate margins, according to Fryer, but usually they are formed from sediments burping out from depth. What makes the mud volcanoes of the proposed monument unique is that they're spewing ground-up rock derived from the Earth's mantle.³³ The mantle rock reacts with fluids and changes its mineralogy to become serpentinite, an asbestos material. This muddy paste erupts on the seafloor to form these giant mud volcanoes. "Mud volcanoes allow you to see what's down really deep beneath," Fryer says. "Not only are they bringing up the mantle of the overriding plate, but they're also bringing up little bits of the down-going plate."

Another compelling feature of mud volcanoes is the opportunity they present to help scientists better understand how earthquakes form. "The whole reason we got started on these mud volcanoes is that we wanted to understand the pressure-temperature conditions at depth," says Dr. Geoffrey Wheat.³⁴ "These are conduits that are bringing up the minerals, bringing up the fluids from the subducting plate to the seafloor. You don't have the astronomical expense of trying to drill down 20 kilometers to get to it. Through experimentation and lab work, you can figure out the pressure-temperature conditions that are critical for the seismogenic models."

"I was in awe. I felt that these should be a national park some day..."

"Asuncion is an active volcano. That gives us a real opportunity to better understand evolution."



Mud volcanoes shed light on how life began billions of years ago and where it can exist today

“One of the other interesting things about mud volcanoes,” says Fryer, “is that the serpentinization reaction itself releases hydrogen. Hydrogen is cotton candy to microbes.” Hydrogen is what fuels some of the microbial populations that exist on seamounts. And those in turn are feeding the mussels and other animals found 6,000 feet down at the seafloor. “We know that this process has taken place on the ocean floor in a variety of places, but this is the only place in the world where it is currently ongoing,” Fryer explains. “It provides not only a unique scientific laboratory but also a unique biological environment.”

Moyer thinks that these kinds of systems were much more abundant billions of years ago and that they might actually be reservoirs for some of the oldest forms of life. “We’ve seen some of the older lineages in the hydrothermal systems,” he says, “but it’s out on the forearc, in the mud volcanoes, where we find the really old types. We call those archaea.” As Wheat puts it, “These microbes are some of the oldest on the DNA tree. It’s the kind of scenario where life on Earth could have started. You have the hydrogen, the carbon, and a lot of the precursors for life.”

Moreover, microbes recently discovered in mud volcanoes are stretching researchers’ ideas of where life can exist. “We discovered microbes living in a pH of 12.5,” says Wheat. “They are reducing sulfate to hydrogen sulfide. This is the first time life has been discovered at a pH higher than 11. Theoretically, life isn’t supposed to exist at that level.”

A rare opportunity to study how new ecosystems begin

The Northern Marianas are unique in being geologically young. The shallow reef areas within the proposed monument are essentially being reborn on a regular basis. Eruptions occur frequently, and they have widespread impacts on the near shore reefs. “In many cases they just completely bury the reefs,” explains Brainard. “They essentially cause the ecosystem to start over. That happens every few years, every few decades, or every few centuries; in other reef systems millions of years have passed since the last major event.”

The proposed monument turns out to be a remarkable place to study colonization and other evolutionary patterns at a microscopic level, too. Hydrothermal vent systems come and go more quickly in the Marianas than in any other place yet studied, according to Moyer. Whereas vents on the East Pacific Rise or the Juan de Fuca Ridge are decadal in scale, some of the vent systems in the Marianas last just a few years. “It’s a real boom-and-bust life,” he explains.

What happens when a lava flow comes through and kills everything? How quickly can species colonize? “Islands are still forming in the proposed monument area,” says Davis. “Asuncion is an active volcano. That gives us an opportunity to better understand evolution.” Maug, Asuncion and Uracus, he explains, have assemblages of spiders. “Spiders are usually among the first animals to colonize places because they can fly long distances with webs. You can see a similar strategy in the marine environment. Some species, like moray eels, have extremely long larval cycles, so they can tolerate the expanse of time to get to places and colonize them. The older forms make it first. They have figured out the dispersion success issue.”

The waters around Asuncion are a great place to see this phenomenon. “The population of primitive Beryciform fish is through the roof,” he explains. “It’s a function of both the dispersion strategy and the fact that those fish are much

Opposite page: Asuncion Island rises from the Pacific as a steep, almost perfectly symmetrical cone, and is an active volcano that last erupted in 1906. Located 304 miles north of Saipan, the 2.8 square mile island is protected as an uninhabited nature preserve under the CNMI Constitution.

more attuned to non-coral habitats. Modern fish usually depend more heavily on coral reefs.” Squirrel fish and other species within the order Beryciformes are considered “primitive” because they date back at least as far as the late Cretaceous period, a time when dinosaurs were abundant. Despite their impressive lineages, the strategies that make more primitive fishes likely to be early colonizers can also make them more vulnerable. “Modern fish tend to out-compete them,” explains Davis. “If you look at primitive fish, they tend to be heavily armoured and they’ve generally shifted to deeper depths because they couldn’t compete with the more advanced forms of the fish in the shallower depths.”

Davis is well aware that he is over-simplifying a complex story. Indeed, it’s the complexity of coral communities that makes them so difficult to manage. “That’s the valuable thing about uninhabited systems like this one,” he says. “You can eliminate, almost entirely, the people part of the equation. It gives you a tremendous opportunity to understand how these communities evolve and function, from a natural perspective.”

Population increases in the southern islands elevates the conservation importance of the proposed monument

Learning how coral communities naturally function in the region has become even more pressing since 2003. That’s the year Michael Molina³⁵ and his colleagues reviewed the effectiveness of compensatory mitigation for coral reefs in the U.S. Pacific islands. They discovered that half of the direct coral reef loss caused by U.S.-funded or U.S.-permitted projects had not been restored. The review served as a springboard for more effective solutions, and today it is not simply coral reefs but the ecological function of coral reefs that must be replaced when a construction project is being planned.

Of course, Molina is highly supportive of the requirement to replace the ecological function of a coral reef. He is also quick to point out the

impossibility of the task. “A coral reef is something that is so complex and so slow growing—how do you fix it? We don’t know how or what to do to replace a system like a coral reef.”

Yet Molina is now charged with doing just that for the largest modern-day construction project to hit the southern islands of the archipelago. The U.S. State Department recently forged a realignment of forces treaty with Japan to move troops stationed at Okinawa to headquarters in Guam. The proposed monument takes on even greater importance as populations, construction projects and associated impacts in the southern part of the archipelago increase.

This is particularly evident with respect to the threat of invasive species, an issue that has hit hard in Guam, the largest and most populated island in the Mariana chain. The accidental introduction of the brown tree snake shortly after World War II led directly to the extinction in the wild of nine species of native Guamanian birds.³⁶ Six other bird species are now considered rare or endangered and five native lizard species have become extinct locally.³⁷ Since Guam is a major transportation hub in the Pacific, increased boat and air traffic associated



with the troop relocation pose a worrisome threat to wildlife throughout the CNMI. Dr. Earl Campbell³⁸ chooses a stronger word to describe the environmental implications: nightmare. “From an invasive species perspective, from a brown tree snake perspective, there isn’t a higher risk thing they could be doing,” he says. “There is a concern about putting an entire avifauna at risk.”

An intimate connection between bird and volcano: the endangered Micronesian megapode

One might expect a bird living on active volcanic islands to lead a somewhat precarious existence. Yet for the Micronesian megapode, an endangered bird found only in the Northern Marianas and Palau, the heat from volcanoes turns out to nurture new life. “Megapodes are fascinating,” says Dr. René Dekker.³⁹ “They are the only birds that don’t incubate their eggs by means of body heat.” Instead, these “incubator birds” rely on some very green-sounding forms of energy—solar heating, compost heating or, amazingly, the heat from volcanic vents. The female will lay a single large egg in a warm area,

such as a thermal vent from volcanic activity, in dark-colored volcanic sand. Because suitable sites are few and far between, eggs tend to get grouped together. When the young birds hatch they are fully able to fend for themselves and receive no parental care. Megapodes are quite heavy-bodied birds and forage on the forest floor, where they search for insects, seeds and fruit. Although they can fly, they primarily walk. It is thus all too easy for introduced predators, such as monitor lizards and feral dogs, cats and pigs, to find and prey upon Megapodes and their eggs.

Since the Micronesian megapode was listed as endangered both federally and locally, it has been illegal to hunt them or take their eggs. But poaching still occurs. And the introduction of pigs and goats to many of the northern islands has destroyed valuable nesting habitat.⁴⁰

Micronesian megapodes have been found on Asuncion, Maug and Uracus. These uninhabited islands are not part of the proposed monument, yet their status as CNMI wildlife sanctuaries and the fact that Maug is managed as a bird reserve is highly complementary. The islands are remote and free of ungulates, which boosts their potential

The endangered Micronesian megapode lives on the Mariana Archipelago.

“Megapodes are fascinating. They are the only birds that don’t incubate their eggs by means of body heat.”



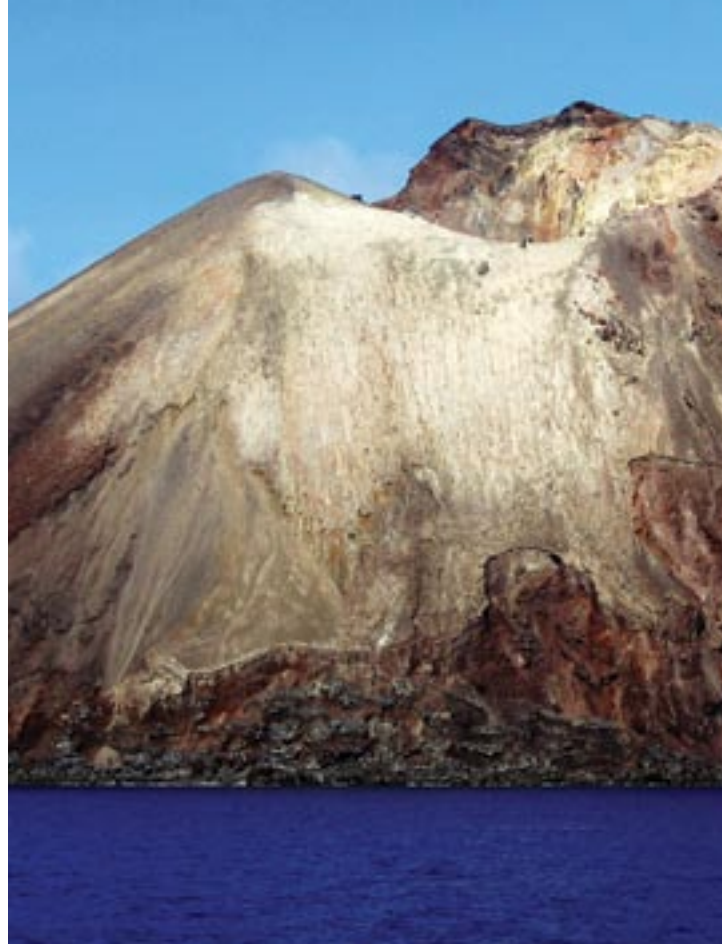
to serve as relocation sites for Micronesian megapodes as well as other heavily impacted forest birds. In 1997, the Northern Mariana population was estimated at 1,440 to 1,975 birds.⁴¹ According to Dr. Fred Amidon,⁴² surveys of these islands are planned for 2009. The intention is to gather data for the environmental review processes associated with the troop relocation and to explore possible bird relocation sites.

Regionally important seabird breeding area

Uracus Island, also known as Farallon de Pajaros, which means “birds’ rock” in Spanish, provides important bird habitat and is protected as an uninhabited nature reserve by the CNMI Constitution.

The connections between seabirds and volcanoes may not be as obvious as they are for Mariana megapodes, but they are no less remarkable. The underwater volcanoes that dot the proposed monument area concentrate fish in a desert of Pacific Ocean.⁴³ They attract large predatory fish, such as sharks, tuna and jacks, that in turn drive smaller fish to the surface. It is here that the beautiful but comically named noddies and boobies perform their astonishing aerial dives. They plunge from the sky to seize fish from the bait balls formed by the larger fish below. Without the seamounts and the large predatory fish, there would be no noddies and boobies. And, according to Paulay, without the seabirds and their impressive quantities of guano, or “poop,” the proposed monument might not have as rich coral communities. Seabirds spike the nutrient load of these invertebrate communities, fertilizing the shores with energy from the sea.

The need for seabird protection has never been higher. Entanglements in fishing nets and lines and human encroachment into nesting habitat are taking a severe toll on seabird populations. Added to that, a highly influential 2003 Nature study found that 90 percent of the top predatory fishes have vanished from the world’s oceans.⁴⁴ Unable to fish as effectively without the aid of the large fishes, and faced with dwindling numbers of food fish, the populations of plunge-diving boobies and noddies have suffered sharp declines. Brown boobies—one of the species found nesting in colonies on the three CNMI



islands surrounded by the proposed monument—are at only 1 to 10 percent of their historic world population.

Seabird populations in the CNMI are significant for Micronesia.⁴⁵ “The islands of Maug and Uracus are major and important seabird breeding areas for the region,” says Amidon, listing the masked and brown boobies, black and brown noddies, and white and sooty terns that nest on them.⁴⁶ The proposed monument complements the protections already enforced by CNMI and presents a remarkable opportunity to protect every link in this complex and fragile chain—birds, seamounts, predatory fish and corals—as an integrated ecosystem.

A last refuge for Mariana fruit bats

“Fruit bats like to be where people are not,” says Dr. Anne Brooke,⁴⁷ explaining why 85 percent of the Mariana fruit bat population is found on the nine northernmost islands in the chain. “The uninhabited islands of Maug and Asuncion represent one of the few areas in the archipelago



where fruit bats can avoid human predation,” says Amidon. But making any kind of statistical statement about the largest native mammal in the Marianas is difficult. The population of Mariana fruit bats (also called flying foxes) has not been surveyed for the past 25 years. The 1983 population statistics are thus the most recent: 400 fruit bats on Asuncion and fewer than 25 on Maug.

With a three-foot wingspan and a weight of a pound or more, this flying fox is found only in the Mariana Islands.⁴⁸ Over the last few decades its numbers have plummeted, especially in the populated southern islands. Archeological evidence shows that the indigenous Chamorros have eaten fruit bats for over a thousand years. They probably captured them with sling stones, primitive traps and various types of nets. But following World War II, consumption of fruit bats dramatically increased as a result of easy access to firearms and an increased emphasis on a cash rather than subsistence economy. One species, the little Mariana fruit bat, was driven to extinction.⁴⁹ The other, the Mariana fruit bat, was federally listed as Threatened throughout its entire range of Guam and the Northern Mariana

Islands on January 6, 2005. (Previously, it was federally listed as Endangered only on the island of Guam).⁵⁰ Although hunting fruit bats is illegal, poaching continues to be a major cause of bat mortality.⁵¹ According to Brooke, the remote, uninhabited islands surrounded by the waters of the proposed monument provide a last refuge from human predation.

Surveys for both listed species—Mariana fruit bats and Micronesian megapodes—are planned for 2009 by the CNMI in conjunction with the federal government of the United States. The intention is to gather data for the environmental review processes associated with the troop relocation and to explore possible fruit bat relocation sites.

White tern, also known as the fairy tern.



Many more species of whales and dolphins than meets the eye

In 2005, Julie Rivers⁵² looked through the scientific literature for publications of systematic surveys of whales or dolphins in the Northern Marianas. Not a single paper existed. Indeed, according to the CNMI Comprehensive Wildlife Conservation Strategy, only one species of cetacean, the spinner dolphin, is considered a Species of Special Conservation Need in the CMNI.⁵³

One could take from this that cetaceans (whales and dolphins) are not key players in the proposed monument area. But that would be a serious mistake. When the U.S. Navy commissioned the first-ever systematic cetacean survey conducted in the Marianas, in February 2007, researchers found 19 species of whales and dolphins. “The Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) report is not being released to the public at this time,” says Rivers, although a copy of the cruise report, which outlines species sighted but not density calculations, is available. (The area surveyed is just below the southern limits of the proposed monument.)

The MISTCS sighting data is not the only evidence pointing to the proposed monument as an important area for a large number of whales

and dolphins. A 2006 report by the Whale and Dolphin Conservation Society, lists nine known species and six unconfirmed species of cetaceans for the Northern Marianas.⁵⁴

For Dr. John Hildebrand⁵⁵ the Navy survey serves as a tantalizing snapshot: “For large whales, if you did the same survey six months later, it could be a totally different story.” He is eager to set up an acoustic survey that could operate for six months or a year. “It is such a huge hole in the map of the Pacific,” he exclaims. “Terra incognita!”

Brainard and his colleagues have started deploying ecological acoustic recorders that continually listen to the marine environment in other parts of the Pacific. Their primary purpose is to listen for the encroachment of vessels that are not supposed to be there. “We are also using them to monitor bio-acoustic energy as an indicator of ecosystem health,” he says. “One of the other uses is to listen for the presence and absence of cetaceans.” None of these systems is operating in the Northern Marianas. “Maybe if a monument was established it would provide additional resources for that area to help get those systems established for both encroachment and cetaceans,” he says.

Dr. Robin Baird,⁵⁶ believes that some of the world’s rarest beaked whale species, such as



Blainville's beaked whales, Cuvier's beaked whales, Longman's beaked whales,⁵⁷ and Ginkgo-toothed beak whales, are resident to the waters around these islands. "But there are probably no sightings," he says. That's the magic of beaked whales. These deep divers are among the most elusive of cetaceans and are rarely spotted at the surface. Cuvier's beaked whales dive to more than 3,000 feet on average to hunt for the deep-sea squid that makes up most of their diet. The deepest dive recorded reached over a mile deep and lasted for 85 minutes.⁵⁸

"Prior to our work, there really wasn't anything known about beaked whale populations in Hawaiian waters either," says Baird. "What we know now is that there are small but resident populations of at least two species of beaked whales in Hawaiian waters." The discovery of resident populations of beaked whales is a critical one. It means that beaked whales in the Northern Marianas are likely to be island-associated populations rather than just animals moving through from open-ocean populations.

"We're finding that type of residency with species of dolphins that are otherwise considered open-ocean dolphins, like rough-toothed dolphins," says Baird. "They are resident to the islands. And false killer whales are resident to the islands. Pilot whales are resident to the islands. These are

all species that are otherwise considered open-ocean dwellers. Even though they are feeding, in the case of pilot whales and beaked whales, at depths of 2,300 feet or more, whatever their prey is doing is also showing the same kind of increase in productivity around the islands. Extrapolating to what's probably going on around the Marianas, I think that's a pretty likely scenario there as well. Given the distances between the Mariana islands, it is quite possible that there are populations associated with the whole island chain as well as populations associated with specific islands."

Baird emphasizes the importance of individual identifications over sighting surveys. "Because we don't see them very often it is easy to dismiss these rare, deep-diving whales as unimportant or to assume they are just moving through."

In addition to providing conservation protection for these rare species of cetaceans, the proposed monument could protect larger baleen and toothed whales (see Table 2 for a list of CNMI species and their status). This is an especially timely issue given the proximity of the proposed monument to Japan and the recent controversial plans to lift the worldwide ban on whaling in order to allow Japan to carry out a limited hunt in waters close to its shores.⁵⁹

The world's rarest beaked whales, such as Cuvier's beaked whale (left) and Blainville beaked whale (right), are believed to be resident in the waters around the northern islands.



“This region takes evolutionary adaptation to the extremes. It’s extremely deep. It’s extremely food poor. And it’s a uniquely extreme combination of geology, biology and ecology.”

The proposed Mariana Trench Marine National Monument in the CNMI is home to a tantalizing range of interconnected marine environments, including the Mariana Trench, the Mount Everest of the deep sea. As James Barry puts it: “This region takes evolutionary adaptation to the extremes. It’s extremely deep. It’s extremely food poor. And it’s a uniquely extreme combination of geology, biology and ecology.”

Currently, the remote, isolated location of the region has provided a natural oasis from human impacts. Here, seabirds, marine mammals, marine invertebrates, sharks and some of the world’s largest reef fishes thrive amidst a vast expanse of ocean desert. Deep beneath the surface, recent discoveries of an astonishing array of chemosynthetic communities challenge all understanding about where and how life can exist on Earth.

The immense scope of such a reserve, roughly the equivalent of a cross section of the Rocky Mountains from Nebraska to Utah, would be

impossible to achieve on land. Such ecosystem-scale conservation demands great swaths of uninhabited regions found only in the remotest parts of the oceans. Proximity to rapidly growing populations and influences in Asia and the southern CNMI pose an imminent risk to the health of this remarkable region.

The proposed Mariana Trench Marine National Monument in the waters around the CNMI would offer an exceedingly rare chance to preserve an entire slice of the planet—from shallow water reefs to the deepest depths of the ocean—*before* it has been heavily damaged by humans.

Opposite page:
Sooty tern.

Table 1. U.S.-funded scientific research expeditions to the CNMI proposed monument site

Project/Expedition Name	Dates	Lead Investigator	Platform	Project Emphasis
NOAA Ocean Explorer: Submarine Ring of Fire-2003	February 9 to March 5, 2003	Dr. Robert Embley and Dr. Edward Baker	R/V Thomas G. Thompson	Initial survey of the Mariana submarine volcanoes
NOAA Ocean Explorer: Submarine Ring of Fire-2004	March 27 to April 18, 2004	Dr. Robert Embley	R/V Thomas G. Thompson	Hot spring sites along the Mariana Arc
NOAA Ocean Explorer: Submarine Ring of Fire-2006	April 18 to May 13, 2006	Dr. Robert Embley	R/V Melville with the Jason II remotely operated vehicle	Mariana Arc volcanoes
2003 NOAA/NMFS Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP)	August 19 to September 30, 2003	Dr. Robert Schroeder	Oscar Elton Sette	Coral reef ecosystem research in CNMI, including Asuncion, Maug, Supply Reef, Uracas
2005 NOAA/NMFS MARAMP	August 16 to October 1, 2005	Dr. Robert Schroeder	Oscar Elton Sette	Coral reef ecosystem research in CNMI, including Asuncion, Maug, Supply Reef, Uracas
2007 NOAA/NMFS MARAMP	May 25 to June 9, 2007	Dr. Robert Schroeder	H'iialakai	Coral reef ecosystem research in CNMI, including Asuncion, Maug, Supply Reef, Uracas
NSF/University of Hawaii/ University of Alaska	March 23 to May 4, 2003	Dr. Patricia Fryer, Dr. Michael Motti and Dr. Geoffrey Wheat	R/V Thomas G. Thompson	Mariana forearc



NOAA Research Vessel Healy at Uracus Island.

Table 2. CNMI species and conservation status

Common Name	Genus/species	IUCN Red List Status	Asuncion	Maug	Urucus	Comments
Micronesian megapode	<i>Megapodius laperouse</i>	Endangered	<25 (1992)	<150 (1992)	rare	Endemic to the CNMI. Survey planned for 2009. Rare or extirpated in the southern islands. Species of Special Conservation Need for the CNMI
Mariana fruit bat or Mariana flying fox	<i>Pteropus mariannus</i>	Threatened throughout entire range of CNMI and Guam	400 (1983)	<25 (1983)		Endemic to the CNMI. Survey planned for 2009. Previously listed as Endangered only on the island of Guam. ⁶⁰ Species of Special Conservation Need for the CNMI
Napoleon wrasse	<i>Cheilinus undulatus</i>	Endangered				Among the largest of all reef fishes. Threatened by unsustainable fishing pressures. If CNMI fishers begin to participate in the export market for live reef fish, the pressure on this species will likely increase dramatically. Species of Special Conservation Need for the CNMI
Bumphead parrotfish	<i>Bolbometopon muricatum</i>	Vulnerable				A keystone species. Unsustainable fishing efforts have lowered their numbers to the point that fast-growing, grazing-resistant coral species are changing reef compositions and habitats. Species of Special Conservation Need for the CNMI
Grey reef shark	<i>Carcharhinus amblyrhynchos</i>	Near Threatened				Species of Special Conservation Need for the CNMI. First US conviction for shark finning was in Guam US Department of Commerce 2004. If not closely monitored, finning may become a problem in the CNMI. The local practice for some bottom fishers to “remove” sharks from an area prior to bottom fishing may be cause for alarm.
Giant clam	<i>Tridacna maxima</i> & <i>Tridacna squamosa</i>	Threatened				Threatened due to overharvesting. Species of Special Conservation Need for the CNMI

Coconut crab	<i>Bigus latro</i>	Rare [CNMI and U.S. Fish and Wildlife (FWS) Species of Concern]	Present	Present	World's largest land invertebrate. Rare due to overharvesting. Larger and more abundant on uninhabited, remote islands in the monument. Species of Special Conservation Need for the CNMI
Hawksbill turtle	<i>Eretmochelys imbricata</i>	Endangered			CITES Appendix 1 Species of Special Conservation Need for the CNMI
Sooty tern	<i>Sterna fuscata</i>	Least Concern	Present	Nesting colonies	Migratory Bird Treaty Act
Grey-backed tern	<i>Onychoprion lunatus</i>			Nesting colonies	Migratory Bird Treaty Act
White tern	<i>Gygis alba</i>	Least Concern	Present	Nesting colonies	Migratory Bird Treaty Act
Masked booby	<i>Sula dactylatra</i>	Least Concern		Nesting colonies	Migratory Bird Treaty Act Species of Special Conservation Need for the CNMI
Brown booby	<i>Sula leucogaster</i>	Least Concern	Nesting colonies	Nesting colonies	Migratory Bird Treaty Act
Red-footed booby	<i>Sula sula</i>	Least Concern	Present	Present	Migratory Bird Treaty Act
Brown noddy	<i>Anous stolidus</i>	Least Concern	Present	Nesting colonies	Migratory Bird Treaty Act
Black noddy	<i>Anous minutus</i>	Least Concern		Nesting colonies	Migratory Bird Treaty Act
White-tailed tropicbird	<i>Phaethon lepturus</i>		Present	Present	Migratory Bird Treaty Act
Red-tailed tropicbird	<i>Phaethon rubricauda</i>	Least Concern	Present	Present	Migratory Bird Treaty Act
Micronesian starling	<i>Aplonis opaca</i>	Least Concern (CNMI and FWS Species of Concern)	Present	Present	
Micronesian honeyeater	<i>Myzomela rubrata</i>	(CNMI and FWS Species of Concern)	Present	Present	Guam listed
Collared kingfisher	<i>Halcyon chloris</i>	(CNMI and FWS Species of Concern)	Present	Present	
White-throated ground dove	<i>Gallicolumba xanthonura</i>	Near Threatened (CNMI and FWS Species of Concern)	Present		Endemic to the Mariana Islands and Yap. Guam listed Species of Special Conservation Need for the CNMI
Pacific reef heron	<i>Ardea sacra</i>		Present		Migratory Bird Treaty Act

Table 2. CNMI species and conservation status

Common Name	Genus/species	IUCN Red List Status	Asuncion	Maug	Uracus	Comments
Oceanic gecko	<i>Gehyraocceanica</i>		Present			Guam listed
Snake-eyed skink	<i>Cryptoblepharus poecilopleurus</i>		Present	Present		Guam listed
Slevin's skink	<i>Emoiaslevini</i>		Present			Guam listed Species of Special Conservation Need for the CNMI
Mupunyao	<i>Aglaia mariannensis</i>	Vulnerable	Present			Endemic tree
Melon-headed whale	<i>Peponocephala electra</i>					Local status unknown
Spinner dolphin	<i>StenellaLonirostris</i>	Threatened				Species of Special Conservation Need for the CNMI
Striped dolphin	<i>Stenellacoeruleoalba</i>	Lower Risk: conservation dependent (out of date)				Local status unknown
Pantropicalspotted dolphin	<i>Stenellaattenuata</i>	Lower Risk: conservation dependent (out of date)				Local status unknown
Risso's dolphin	<i>Grampus griseus</i>	Data Deficient (out of date)				Local status unknown
Killer whale	<i>Orcinus orca</i>	Lower Risk: conservation dependent (out of date)				Local status unknown
Rough-toothed dolphin	<i>Steno bredanensis</i>	Data Deficient (out of date)				Local status unknown
Common bottlenose dolphin	<i>Tursiops truncatus</i>	Data Deficient (out of date)				Local status unknown
Pygmy sperm whale	<i>Kogia breviceps</i>	Lower Risk (out of date)				Local status unknown
Dwarf sperm whale	<i>Kogia sima</i>	Lower Risk (out of date)				Local status unknown

Long-finned pilot whale	<i>Globicephalamelas</i>	Lower Risk (out of date)	Local status unknown
Short-finned pilot whale	<i>Globicephalamacro-rhynchus</i>	Lower Risk: conservation dependent (out of date)	Local status unknown
False killer whale	<i>Pseudorca crassidens</i>	Lower Risk (out of date)	Local status unknown
Bryde's whale	<i>Balaenoptera edeni</i>	Data Deficient (out of date)	Local status unknown
Seiwhale	<i>Balaenoptera borealis</i>	Endangered (out of date)	Local status unknown
Pygmy killer whale	<i>Feresa attenuata</i>	Data Deficient (out of date)	Local status unknown
Sperm whale	<i>Physeter macrocephalus</i>	Vulnerable (out of date)	Local status unknown
Blue whale	<i>Balaenoptera musculus</i>	Endangered (out of date)	Local status unknown
Humpback whale	<i>Megaptera novaeangliae</i>	Vulnerable (out of date)	Local status unknown
Blainville's beaked whale	<i>Mesoplodon densirostris</i>	Data Deficient (out of date)	Local status unknown
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	Data Deficient (out of date)	Mass strandings associated with naval mid-frequency SONAR Local status unknown
Longman's beaked whale	<i>Indopacetus pacificus</i>	Data Deficient (out of date)	Local status unknown

- ¹ Verena Tunnicliffe, Ph.D., is project director of the Victoria Experimental Network Under the Sea and Canada Research Chair in Deep Oceans at the University of Victoria.
- ² Patricia Fryer, Ph.D., is a professor at the Hawai'i Institute of Geophysics and Planetology, University of Hawaii.
- ³ Rusty Brainard, Ph.D., has been an oceanographer with the National Oceanic and Atmospheric Administration (NOAA) for over 25 years. He serves as co-principal investigator of the Census of Coral Reef Ecosystems project of the International Census of Marine Life and is chief of the Coral Reef Ecosystem Division of NOAA's Pacific Islands Fisheries Science Center in Honolulu.
- ⁴ All NOAA coral reef ecosystem cruise reports are available on the NOAA Pacific Islands Fisheries Science Center Web site. The most relevant one for this project is the Hi'alakai Cruise 07-03 report at www.pifsc.noaa.gov/library/hiialakai.php.
- ⁵ Halpern, B.S., et al., "A Global Map of Human Impact on Marine Ecosystems," *Science* 319(5865) 2008: 948-952.
- ⁶ Gustav Paulay, Ph.D., is the curator of invertebrates and mollusks at the Florida Museum of Natural History, University of Florida.
- ⁷ As a point of comparison, Paulay says that the Kermadecs are further south and largely or entirely lack reef corals but have higher endemism, as the subtropical endemics are present in force.
- ⁸ Paulay, G., "The Marine Biodiversity of Guam and the Marianas," *Micronesica*, vol. 35-36 (Mangilao, Guam: University of Guam Press, 2003).
- ⁹ James Maragos, Ph.D., is senior coral reef biologist with the U.S. Fish and Wildlife Service, division of Remote/Pacific Islands National Wildlife Refuges.
- ¹⁰ Schroeder, R.E., et al., "Status of Fishery Target Species on Coral Reefs of the Marianas Archipelago," presented at the 10th International Coral Reef Symposium, Naha, Okinawa, June-July, 2004.
- ¹¹ Gerry Davis is the assistant regional administrator for the Habitat Division in the Pacific Islands Regional Office of NOAA's National Marine Fisheries Service (NMFS).
- ¹² James Barry, Ph.D., is senior scientist at the Monterey Bay Aquarium Research Institute. A benthic ecologist, he has studied the effects of climate change and carbon dioxide in the ocean for over 15 years. Among other projects, Barry's lab is currently investigating the tolerance of deep-sea marine invertebrates and microbes to changes in carbon dioxide and ocean acidity.
- ¹³ Choat, J.H., and Robertson, D.R., "Age-based Studies on Coral Reef Fishes," in P.F. Sale, ed., *Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem* (San Diego: Academic Press, 2002).
- ¹⁴ For information about these designations, see, respectively, cms.iucn.org/about/work/programmes/species/red_list/about_the_red_list/index.cfm; www.nmfs.noaa.gov/pr/glossary.htm#s; and www.wildlifeactionplans.org/pdfs/action_plans/cnmi_action_plan.pdf (p.19). For conservation status of other species in the proposed monument area, see Table 2.

- ¹⁵ Enric Sala, Ph.D., is an adjunct professor at Scripps Institution of Oceanography. He is also a 2005 Aldo Leopold Leadership Fellow, a 2006 Pew Fellow in Marine Conservation, and a 2007 National Geographic Emerging Explorer.
- ¹⁶ Sandin S.A., et al., "Baselines and Degradation of Coral Reefs in the Northern Line Islands." PLoS ONE 3(2) 2008. www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0001548.
- ¹⁷ Peter Houk, Ph.D., is a coral reef biologist with the CNMI Division of Environmental Quality in Saipan. He served on the benthic rapid ecological assessment team of the 2005 Marianas Archipelago Reef Assessment and Monitoring Program (MARAMP) expedition.
- ¹⁸ Robert Embley, Ph.D., is a marine geologist with the NOAA Vent Program, Pacific Marine Environmental Laboratory in Newport, Oregon. He has served as chief scientist or co-chief scientist on 37 expeditions, including eight submersible and five ROV campaigns.
- ¹⁹ Most of the unique geological, ecological, and biological features of the proposed monument are hidden beneath the surface. The National Science Foundation maintains a Web site for all seamounts: www.earthref.org/SBN/.
- ²⁰ From "Global Climate Change and the Ocean," which Barry presented at the American Association for the Advancement in Science annual meeting in Boston, Massachusetts, February 2008.
- ²¹ Peter Brewer, Ph.D., is an ocean chemist and senior scientist at the Monterey Bay Aquarium Research Institute
- ²² <http://arstechnica.com/journals/science.ars/2008/02/15/aaas-that-other-carbon-problemocean-acidification>.
- ²³ Carter, L.M., et al., "Potential Consequences of Climate Variability and Change for the US-Affiliated Islands of the Pacific and Caribbean," in U.S. National Assessment, Climate Change and Impacts on the United States: The Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program, 2001. www.usgcrp.gov/usgcrp/Library/nationalassessment/11Islands.pdf.
- ²⁴ Lucius Eldredge, Ph.D., is an invertebrate zoologist and Pacific coral reef expert based at the Bernice P. Bishop Museum. See Eldredge, L.G., "Marianas Active Arc: A Bibliography," Technical Report 82, University of Guam Marine Laboratory, 1983.
- ²⁵ When asked how the waters around the Marianas compared to the Kermadecs with respect to diversity, Tunnicliffe cautioned that both areas have barely been studied. "Our larger take is that we are dealing with the same kind of thing in the variety of habitats, the isolated distributions of things and ecosystems that are coming up into the photic zones," she says. "In both the Marianas and the Kermadecs you have a back arc spreading system right next to a volcanic arc system. So there are a lot of similarities in how they work because you have a similar geological construct behind it. I think there is more variety up in the Marianas. It may be partly because of the diversity of habitats."
- ²⁶ Craig Moyer, Ph.D., is a microbiologist at Western Washington University and a member of the NOAA Submarine Ring of Fire expeditions.
- ²⁷ www.oceanexplorer.noaa.gov/explorations/06fire/logs/may4/may4.html.
- ²⁸ William Chadwick, Ph.D., a geologist at Oregon State University, participated in the 2004 and 2006 NOAA Submarine Ring of Fire expeditions. He describes the sulfur cauldron as follows: "At Daikoku Volcano on the northern part of the Mariana Arc chain, researchers found a pool of liquid sulfur at a depth of 1,365 feet with a 'crust' moving in a wavelike motion from continuous flow of gas from below. Liquid sulfur and clouds of gases rich in hydrogen sulfide and other sulfur gases, could be linked to an unusually high density of chemosynthetic organisms found on Mariana submarine volcanoes."

- ²⁹ First observed on the 2004 Submarine Ring of Fire expedition, the fish has since been determined to be a new species of tonguefish, a type of flatfish, in the genus *Symphurus*.
- ³⁰ www.oceanexplorer.noaa.gov/explorations/06fire/logs/may11/may11.html.
- ³¹ For example, see Ohba, T., et al., "Biological Expedition to the Northern Mariana Islands, Micronesia," in A. Asakura and T. Furuki, eds., *Natural History Research, Special Issue Number 1* (Chiba, Japan: Natural History Museum and Institute, 1994).
- ³² The Nikko flatfish are about twice as large as the flatfish from either Kasuga-2 or Daikoku. Current molecular work (using the Barcode of Life Data System) will determine the relationships among these populations—and verify that they are the same species. The observed size differences might reflect differences in food availability between the three seamounts, as Nikko Seamount appeared far more productive. However, the smaller fish may represent recent colonization events. See www.oceanexplorer.noaa.gov/explorations/06fire/background/biology/biology.html.
- ³³ Wheat, C.G., et al., "Borehole Observations of Fluid Flow from South Chamorro Seamount, an Active Serpentinite Mud Volcano in the Mariana Forearc," *Earth and Planetary Science Letters* 267 (2008): 401–409.
- ³⁴ Geoffrey Wheat, Ph.D., is a geological oceanographer in the University of Alaska's School of Fisheries and Ocean Sciences. He is also an adjunct researcher at the Monterey Bay Aquarium Research Institute.
- ³⁵ Michael Molina is a coral reef biologist with the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office. He is also the environmental review coordinator for the U.S. Coral Reef Task Force.
- ³⁶ Fritts, T.H., and Leasman-Tanner, D., "The Brown Treesnake on Guam: How the Arrival of One Invasive Species Damaged the Ecology, Commerce, Electrical Systems, and Human Health on Guam: A Comprehensive Information Source," 2001. www.fort.usgs.gov/resources/education/bts/bts_home.asp
- ³⁷ Jaffe, M., *And No Birds Sing: The Story of an Ecological Disaster in a Tropical Paradise*. (New York: Simon & Schuster, 1994); Wiles, G.J., et al., "Impacts of the Brown Tree Snake: Patterns of Decline and Species Persistence in Guam's Avifauna," *Conservation Biology* 17 (5) 2003: 1350–1360.
- ³⁸ Earl Campbell, Ph.D., is the invasive species division coordinator for the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office.
- ³⁹ René Dekker, Ph.D., is chair of the Megapode Specialist Group of the International Union for the Conservation of Nature and Natural Resources.
- ⁴⁰ Berger, G.M., Gourley, J., and Schroer, G., "Comprehensive Wildlife Conservation Strategy for the Commonwealth of the Northern Mariana Islands" (Saipan: Commonwealth of the Northern Mariana Islands, Department of Lands and Natural Resources, Division of Fish and Wildlife, 2005).
- ⁴¹ BirdLife International, Species Factsheet: *Megapodius Laperouse*, 2007. www.birdlife.org.
- ⁴² Fred Amidon, Ph.D., is a wildlife biologist for the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office.
- ⁴³ Rogers, A.D., "The Biology, Ecology and Vulnerability of Seamount Communities," International Union for Conservation of Nature and Natural Resources, 2004. www.iucn.org/THEMES/MARINE/pdf/AlexRogers-CBDCOP7-Seamounts-Complete1.pdf.
- ⁴⁴ Myers, R.A. and Worm, B., "Rapid Worldwide Depletion of Predatory Fish Communities," *Nature* 423 (2003): 280–283.

- ⁴⁵ Regional Seabird Conservation Plan, Pacific Region (Portland, Oregon: U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, Pacific Region, 2005), 29.
- ⁴⁶ Reichel, J.D., "Status and Conservation of Seabirds in the Mariana Islands," in J.P. Croxall, ed., *Seabird Status and Conservation: A Supplement*. Technical Publication No. 11 (Cambridge, United Kingdom: International Council for Bird Preservation, 1991), 248–262; Reichel, J.D., "Seabird Surveys and Inventories," *Division of Fish and Wildlife Progress Report 1982–1987* (Saipan: CNMI Division of Fish and Wildlife, 1987), 77–105; Rice, C.G., "Seabird Surveys," *Division of Fish and Wildlife Progress Report 1987–1992* (Saipan: CNMI Division of Fish and Wildlife, 1992), 185–197; Stinson, D.W., "Status and Conservation of Birds in the Mariana Islands, Micronesia," *Natural History Review* 3(2) 1995: 211–218.
- ⁴⁷ Anne Brooke, Ph.D., is a fruit bat expert and a wildlife biologist, with U.S. Fish and Wildlife Service, Guam National Wildlife Refuge.
- ⁴⁸ Lemke, T.O., "History of Fruit Bat Use, Research and Protection in the Northern Mariana Islands," in D.E. Wilson and G.L. Graham, eds., *Pacific Island Flying Foxes: Proceeding of an International Convention Conference Held on February 1–2, 1990* (U.S. Fish and Wildlife Service, U.S. Department of the Interior, 1992).
- ⁴⁹ Lemke, T.O., "Marianas Fruit Bats Near Extinction," *BATS* 3 (1) 1986: 1–2.
- ⁵⁰ www.fws.gov/news/NewsReleases/R1/498D91AB-9221-C06E-9C0E042BFAAF87F4.html.
- ⁵¹ Berger, G.M., Gourley, J., and Schroer, G., "Comprehensive Wildlife Conservation Strategy for the Commonwealth of the Northern Mariana Islands" (Saipan: Commonwealth of the Northern Mariana Islands, Department of Lands and Natural Resources, Division of Fish and Wildlife, 2005).
- ⁵² Julie Rivers is a cetacean expert with the Pacific Division, Naval Facilities Engineering Command.
- ⁵³ Berger, Gourley, and Schroer, p. 25.
- ⁵⁴ Miller, C., "Current State of Knowledge of Cetacean Threats, Diversity and Habitats in the Pacific Islands Region: A Report by the Whale and Dolphin Conservation Society for the First Meeting of the Signatories to the Memorandum of Understanding for the Conservation of Cetaceans and Their Habitats in the Pacific Islands Region." *Whale and Dolphin Conservation Society International*, 2006. www.sprep.org/SPREPCMS2007/pdfs/Inf_05_Pacific_Cetaceans.pdf.
- ⁵⁵ John Hildebrand, Ph.D., is a cetacean acoustic expert and professor of oceanography at the Scripps Institution of Oceanography.
- ⁵⁶ Robin Baird, Ph.D., is a cetacean expert specializing in beaked whales at Cascadia Research.
- ⁵⁷ This species is very poorly described; until quite recently it was known only from two skulls. <http://seamap.env.duke.edu/species/tsn/180502>.
- ⁵⁸ Tyack, P.L., et al., "Extreme Diving of Beaked Whales." *Journal of Experimental Biology* 209 (2006): 4238–4253.
- ⁵⁹ www.independent.co.uk/environment/nature/secret-plan-to-let-japanresume-whaling-793486.html.
- ⁶⁰ www.fws.gov/news/NewsReleases/R1/498D91AB-9221-C06E-9C0E042BFAAF87F4.html.

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Photos and Illustrations

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A species occurring on the Mariana Islands, the coconut crab is the largest land-living arthropod in the world and is known for its ability to crack coconuts with its strong pincers.

Champagne Vent is a remarkable hydrothermal site discovered by scientists in 2004 near the proposed Mariana Trench Marine National Monument. Underwater chimneys vent cloudy white fluid measured at 217°F and supercharged with dissolved gases into the surrounding seawater of 36°F. More than a mile below sea level at the summit of NW Eifuku volcano, this vent has the highest carbon dioxide concentration recorded for oceanic hydrothermal fluids. Scientists named this vent "Champagne" for the bubbles of liquid carbon dioxide exiting the sea floor around the chimneys in never-seen-before abundance. It is one of the few places in the world where this phenomenon occurs.



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