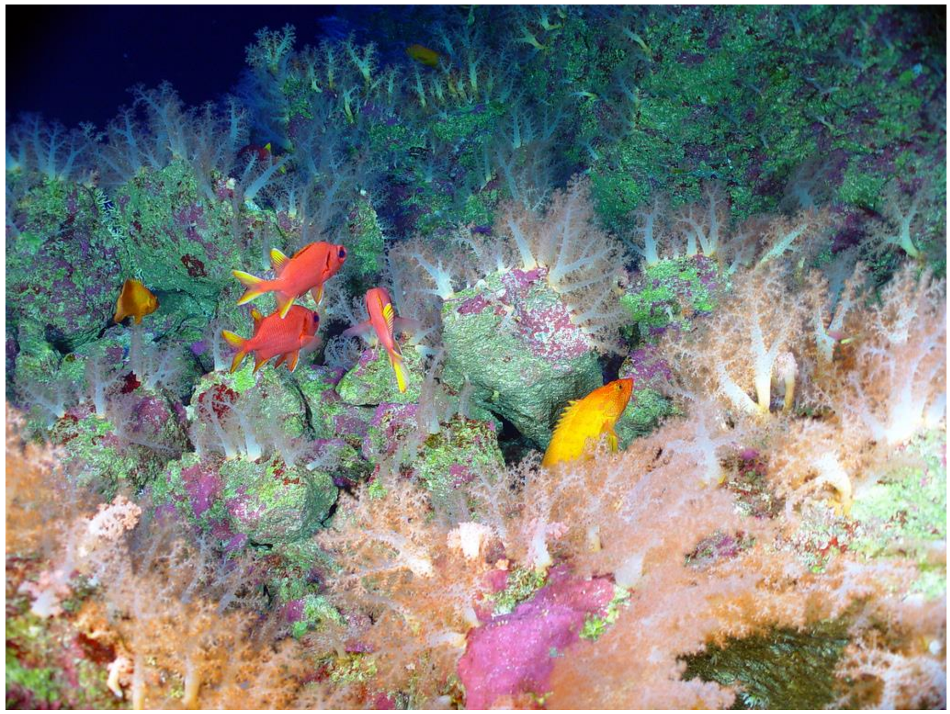
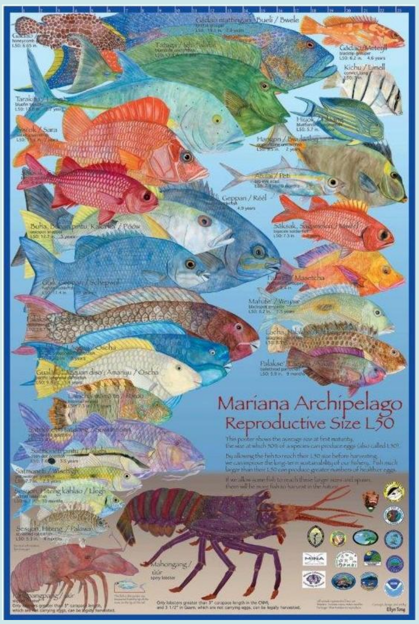
Marianas Trench Marine National Monument: Island Fish



Soft corals and tropical fish tableau from the summit of the East Diamante submarine volcano. Photo credit: Dr. Robert W. Embley—PMEL/NOAA



Reproductive size chart for important food species in the Marianas Archipelago. Photo credit: NOAA

Grade Level

- 7-12

Timeframe

- Two 45-minute periods or one 90-minute periods

Materials

- Tables/desks with space (1 x student/group)
- Calculator (1 x student/group)
- Computers with internet access and/or coral reef fish ID books for research (1 x student/group)

Activity Summary

This lesson makes use of fish survey data to highlight the relationship between human fishing pressure and changes on fish population structure in the Marianas Archipelago. In this lesson students will learn about the islands and coral reef ecosystems that make up large parts of the Marianas Trench Marine National Monument (MTMNM, Monument). They will begin by reading about the structure and unusual features of the Monument. Next they will make observations about the influence of geologic history and age on the availability of reef habitat. Once they have an understanding of the differences among islands, they will spend time researching trophic feeding relationships among fish and investigating patterns of fish distribution around the islands of the Marianas Archipelago. Finally they will draw conclusions about how human population pressures impact fish populations and make recommendations for balancing the needs of human populations with protecting fish resources in the Marianas Archipelago.

Learning Objectives

Students will:

1. Become familiar with the MTMNM and the nearby islands

Key Words

- Marianas Archipelago
- Consumers
- Planktivore
- Piscavore
- Reef health

Outline

ENGAGE – Anatomy of a monument
EXPLORE – Islands of the Mariana Archipelago
EXPLORE – Feeding frenzy
EXPLAIN – Islands and reef fish
ELABORATE – Humans and reef fish
EVALUATE – Summary

2. Practice data organization and graphing interpretation skills
3. Learn about different trophic groups of coral reef fish

Background Information

The Marianas Trench and Archipelago:

The Marinas Trench Marine National Monument (MTMNM) was created, in part, to help protect one of the most impressive examples of oceanic-oceanic plate convergence in the world. At the Trench the very old (up to ~170 Ma) dense Pacific Plate (Stern et al. 2003) subducts under the younger (~50 Ma) less dense Philippine Sea Plate (Fang et al. 2011) (Figure 1). Two types of volcanoes common to oceanic subduction zones are present in the MTMNM; serpentine mud volcanoes (the only modern, active examples in the world) and a line of stratovolcanoes that parallels the Trench. Both types of volcanoes are known as arc volcanoes and the volcanoes that break the ocean surface form the islands of the Marianas Archipelago. The three northernmost islands of the Archipelago, the Marianas Trench, and several volcanic features between the Marianas Arc and Trough were designated as the MTMNM by presidential proclamation in January 2009 (Figure 2).

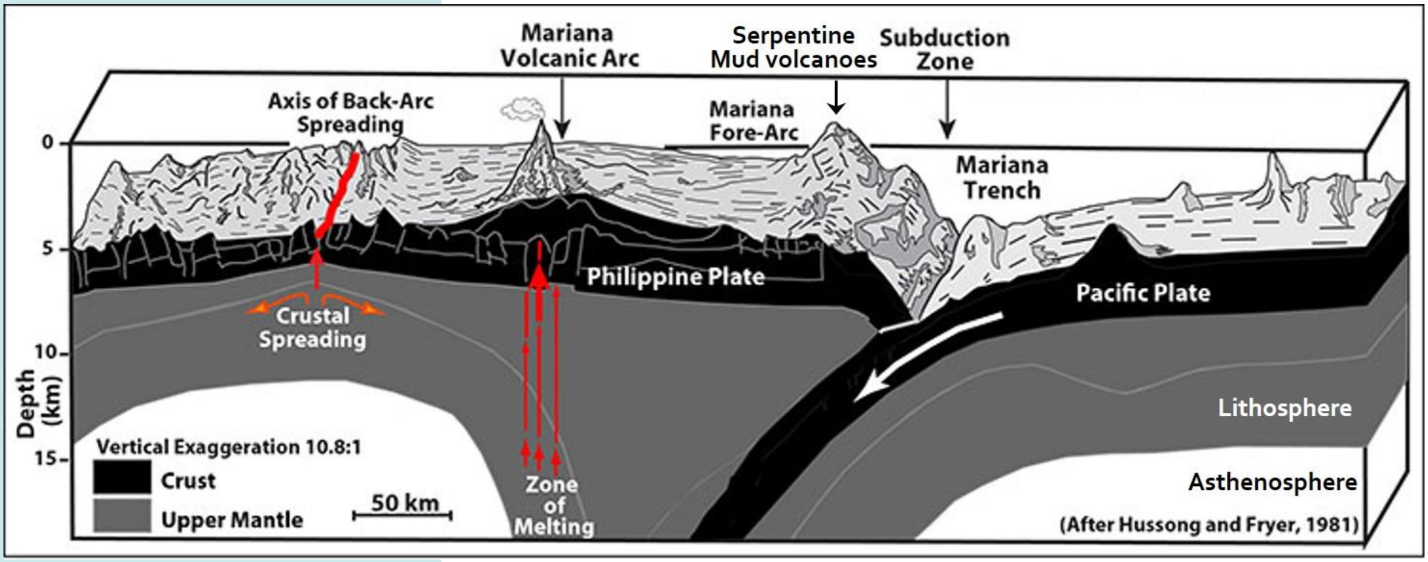


Figure 1: Overview of Marianas Trench Subduction System showing the Pacific Plate subducting into the Marianas Trench.

Vocabulary

BENTHIC- Pertaining to the seafloor or organisms that inhabit the seafloor.

PISCAVORE- A fish whose diet consists primarily of other fish. This category of fish includes the top predators in a coral reef ecosystem (Sharks, Jack, Eels, etc).

The Marianas Archipelago extends for 890 km and encompasses 15 islands and numerous offshore banks. The islands and reefs of the Marianas Archipelago can be divided into three geologic groups (Figure 2): (1) various offshore banks and submarine volcanoes located on the West Mariana Ridge; (2) the young, volcanic northern islands on the Mariana Arc, including, from south to north, Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Farallon de Pajaros; and (3) the old, southern islands located on the Mariana Arc, including Guam, Rota, Aguijan, Tinian, Saipan, and Farallon de Medinilla.

Vocabulary (continued)

PLANKTIVORE- A fish whose diet consists primarily of zooplankton (free floating, or slowly swimming, small organisms the live in surface ocean waters).

PRIMARY CONSUMER- An organism whose diet is consists primarily of material generated by photosynthesis. They are generally herbivores or detritivores.

SECONDARY CONSUMER - An organism that consumes other heterotrophs, often primary consumers, though sometimes other secondary consumers as well. For the purposes of this study this grouping includes omnivores that consume benthic invertebrates.

The territory of Guam includes the island of Guam and adjacent offshore banks and reefs, and the island of Guam is the largest island in the Marianas Archipelago with a land area of 544 km². All other islands and offshore banks are part of the Commonwealth of the Northern Mariana Islands (CNMI). Saipan is the largest island in the CNMI with a land area of 119 km², roughly similar to the combined area of 160 km² for the nine northern islands of the CNMI. Pagan and Agrihan (48 and 44 km²) are the largest of the northern islands, the majority of which have land areas < 10 km², very small relative to the southern islands. The combined human population of Guam and the CNMI in 2010 was estimated at 213,241 (U.S. Bureau of the Census 2011a, 2011b), with population centers largely focused on four of the six southern islands: Guam, with an estimated population of 159,358, as well as Rota, Tinian, and Saipan. The nine northern islands are sparsely inhabited with total populations on Agrihan, Pagan, and Anatahan fluctuating from 0 to 100 persons since World War II.

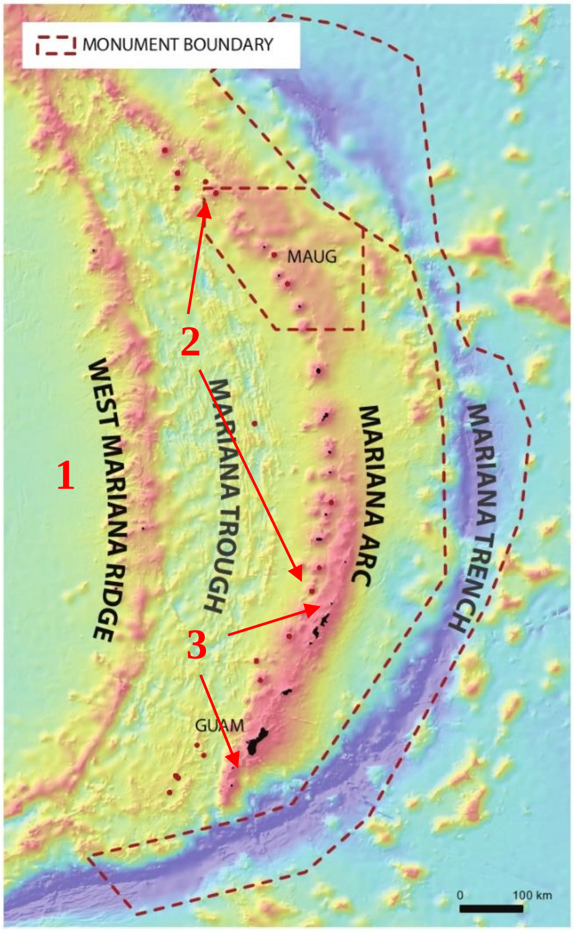


Figure 2: Geologic groups of the Marianas Archipelago

Differences in the geologic histories of these islands, which result in large differences in land area and slope, have been identified as a major factor shaping the coral reef ecosystems of the Marianas Archipelago (Burdick et al. 2008; Houk and Van Woesik 2010; Riegl et al. 2008). The six southern islands are, in general, significantly larger than the northern islands and have uplifted calcium carbonate terraces with mostly low slopes (0°–10°) both onshore and offshore, resulting in a substantial amount of total potential reef area. In contrast, the nine small, northern islands are active or dormant volcanoes with steep onshore and offshore slopes, narrow ridges, and few offshore terraces, resulting in total potential reef areas that are much smaller relative to the southern islands. Other factors likely influencing coral reef conditions include the anthropogenic stressors of coastal sedimentation and pollution, fishing pressure, and land use that in the populated, southern islands are associated with increasing population, tourism, and development. In the northern, largely uninhabited islands, the frequency, duration, and magnitude of active volcanism can severely affect coral reef ecosystems.

Pacific island human communities are economically and culturally dependent on their marine resources. Accurate and up-to-date characterizations of coral reef ecosystems are necessary to develop and evaluate effective strategies for resource management. The National Oceanic and Atmospheric Administration (NOAA) created the Coral Reef Ecosystem Division (CRED) in 2001 to carry out the mission of providing high-quality, scientific information about the status of coral reef ecosystems in the U.S. Pacific islands to the public, resource managers, and policymakers on local, regional, national, and international levels. For a significant majority of the islands, atolls, and banks in the Marianas Archipelago, virtually no ecological surveys, bathymetric or habitat maps, or *in situ* oceanographic observations existed prior to intense survey efforts begun by CRED in 2003. Little or no information was available about what to expect in terms of habitats, biogeographic structure, oceanographic conditions, or species composition, distribution, and abundance. In almost all regards, the initial survey in 2003 was an exploratory baseline assessment with the purpose of shaping a long-term monitoring program in the region.

Preparation

- Print out one card set (Island ID cards and fish graphs) per student or group (2-3 students). Island ID card and fish graph cards can be laminated for future use. Use a grease pencil and/or dry erase markers for labelling laminated fish graph cards.
- There are 13 individual fish graphs needed for these exercises. The handout has 12 of the graphs on one page and 12 copies of graph 13 on the second page. This is to minimize the amount of paper needed to print enough graphs for each group.
- Make sure there are sufficient computers with internet access for student research on fish. Alternatively, make sure there are sufficient coral reef fish identification guides for each of the student groups.

Learning Procedure

Engage: Part 1 – Anatomy of a Monument

Though many people know of the Marianas Trench, the area surrounding the Trench, is much less well known, though they make up some of the most unique habitats in the world. Have students read through the NOAA fact sheet to gain a better understanding of the structure and some of the unique features of the MTMNM. This activity would make a good homework assignment as preparation for a subsequent class.

Explore: Part 2 – Islands of the Marianas Archipelago

In this section students make observations about the shape and age of islands in order to better understand the amount of potentially available reef habitat for fish. The students will need space to spread out their Island ID cards for this exercise.

Explore Part 3 – Feeding Frenzy

The research on fish feeding habits would make a good homework assignment. Otherwise, giving each student group two to three fish to investigate and sharing data among groups will speed the research process.

Before students begin their research, be sure they understand the different types of feeding habits. Many species have flexibility in their feeding habits, so though this lesson tries to present species with fairly distinctive behaviors, students may encounter species with multiple feeding habits, depending on the sources they use for research. If that is the case, the primary feeding behavior is generally the one that will work for this exercise.

Explain: Part 4 – Islands and Reef Fish

When students are familiar with fish feeding habits and what types of fish exhibit those behaviors, they should label each of the fish graphs with the name of the island it represents. Fish biomass data found on each Island ID card corresponds to one specific graph in the fish graph dataset.

Fish Graph #	Island Name
1	FDP
2	Asuncion
3	Argihan
4	Pagan
5	Guguan
6	Sarigan
7	Saipan
8	Tinian
9	Maug
10	Aguijan

11	Alamagan
12	Rota
13	Guam

Once students have their fish graphs labelled, rearranging the graphs will allow them to evaluate different patterns in the data. The height of each bar graph indicates the total fish biomass per m^2 of available reef habitat, while each subsection of the graph corresponds to the amount of fish representing each feeding type. Have students answer the questions in corresponding section of their worksheet using the fish graphs.

Elaborate: Part 5 – Humans and Reef Fish

This section introduces students to the effect that humans have on reef health and fish biomass and distribution. Have the students use the reef health index, island ID cards, fish graphs, and answers from their previous work to answer the questions in the ***Part 5: Reef Fish and Humans*** section of their worksheet

Evaluate: Part 6 – Summary

In order to synthesize and summarize their learning, ask the students to produce a short essay highlighting at least three things they learned about the relationships between the islands and fish in the Marianas Archipelago and MTMNM. The second part of the essay asks them to think about and describe potential benefits and limitations of a Marine National Monument designation. In order to help the students develop their thoughts, it may be helpful to ask them to think about the different stakeholders in a Monument (fisherman, tourists, fish, reefs, governments, etc).

Extending the Lesson

Have students research major fish types caught for human consumption in the Marianas Archipelago and the methods used for catching those fish. How do those methods differ by fish type? From a management perspective, which fishing methods are preferable?

Connections to Other Subjects

- Geology
- Ecology
- Biology
- Technology
- Mathematics
- English/Language Arts

Related Links

Census of Marine Life
Pacific Islands Fisheries Science Center
NOAA Marine National Monument Program
NOAA Fisheries Pacific Islands Regional Office
Papahānaumokuākea Marine National Monument
R/V Oscar Elton Sette

For More Information

NOAA Fisheries Pacific Islands Regional Office
NOAA Marine National Monument Program
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Honolulu, HI 96818
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Acknowledgement

This lesson is one in a series exploring the geology, biology, oceanography, and ecology of the Pacific Marine National Monuments. It was developed for the NOAA Fisheries Pacific Islands Regional Office.

This lesson was developed by Mary Engels of the University of Idaho and Laura Nelson of the University of Washington. This lesson is in the public domain and cannot be used for commercial purposes. Permission is hereby granted for the reproduction, without alteration, of this lesson on the condition its source is acknowledged. When reproducing this lesson, please cite NOAA's Fisheries Pacific Islands Regional Office as the source, and provide the following URL for further information: http://www.fpir.noaa.gov/MNM/mnm_index.html. If you have any further questions or need additional information, email pirohonolulu@noaa.gov.

All images are from NOAA unless otherwise cited.

Thank you to all the reviewers for their feedback and assistance.

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Sandin, Stuart A; & Williams, Ivor. (2010). Trophic Classifications of Reef Fishes from the Tropical U.S. Pacific (Version 1.0). Scripps Institution of Oceanography. UC San Diego: Scripps Institution of Oceanography. Retrieved from: http://escholarship.org/uc/item/5394f7m3

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Websites:

Presidential Proclamation
http://www.fpir.noaa.gov/Library/MNM/Proclamation%208335%20-%20Marianas%20Trench.pdf

Education Standards

Next Generation Science Standards	• **MS-ESS2-2.** – Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.] • **MS-LS2-4.** – Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.] • **HS-ESS2-1.** – Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] • **HS-ESS3-3.** – Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [Clarification Statement: Examples of factors that affect the management of natural resources include costs of resource extraction and waste management, per-capita consumption, and the development of new technologies. Examples of factors that affect human sustainability include agricultural efficiency, levels of conservation, and urban planning.] [Assessment Boundary: Assessment for computational simulations is limited to using provided multi-parameter programs or constructing simplified spreadsheet calculations.] • **HS-LS2-7.** – Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]
Ocean Literacy Principles	• **2C** – Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments. Most beach sand (tiny bits of animals, plants, rocks, and minerals) is eroded from land sources and carried to the coast by rivers; sand is also eroded from coastal sources by surf. Sand is redistributed seasonally by waves and coastal currents. • **2E** – Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast. • **5D** – Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land. • **5F** – Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life. • **6B** – The Ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security. • **6D** – Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), • and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean. • **6G** – Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Marianas Trench Marine National Monument

Located in the Mariana Archipelago east of the Philippines,the Marianas Trench Marine National Monument protects approximately 95,216 square miles of submerged lands and waters. This unique place on Earth includes three units: the Islands Unit, the waters and submerged lands of the three northernmost Mariana Islands; the Volcanic Unit, the submerged lands within 1 nautical mile of 21 designated volcanic sites; and the Trench Unit, the submerged lands extending from the northern limit of the Exclusive Economic Zone of the United States in the Commonwealth of the Northern Mariana Islands (CNMI) to the southern limit of the Exclusive Economic Zone of the United States in the Territory of Guam. No waters are included in the Volcanic and Trench Units, and CNMI maintains all authority for managing the three islands within the Islands Unit (Farallon de Pajaros or Uracas, Maug, and Asuncion) above the mean low water line.

Presidential Proclamation 8335 established the monument in January 2009 and assigned management responsibility to the Secretary of the Interior, in consultation with the Secretary of Commerce. The Interior Secretary placed the Mariana Trench and Volcanic Units within the National Wildlife Refuge System, and delegated his management responsibility to the Fish and Wildlife Service.

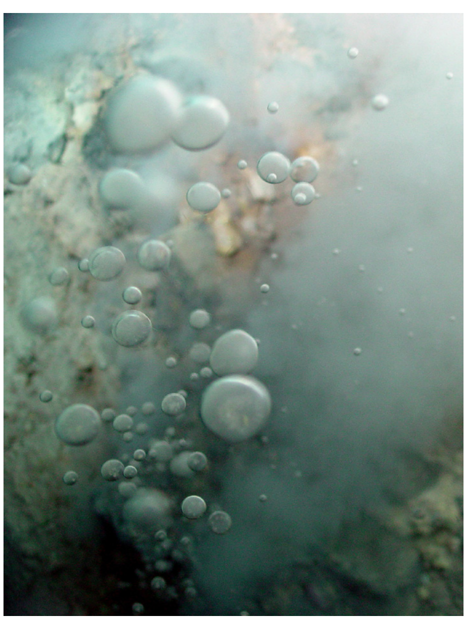
Soft corals and tropical fish at the summit of East Diamante volcano, nicknamed by scientists as the "Aquarium."

The Secretary of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), has primary management responsibility for fishery-related activities in the waters of the Islands Unit.

The Secretaries have established a Mariana Trench Monument Advisory Council to provide advice and recommendations on the development of management plans and management of the monument. The Council currently includes three officials of the CNMI government and one representative each from the Department of Defense and the U.S. Coast Guard.

Objects of Scientific Interest

The President established the monument under the authority of the Antiquities Act of 1906, which protects places of historic or scientific significance. Only recently have scientists visited the realm of the monument, observing previously unknown biological, chemical, and geological wonders of nature.



Champagne bubbles of carbon dioxide from the Champagne vent at NW Eifuku volcano.

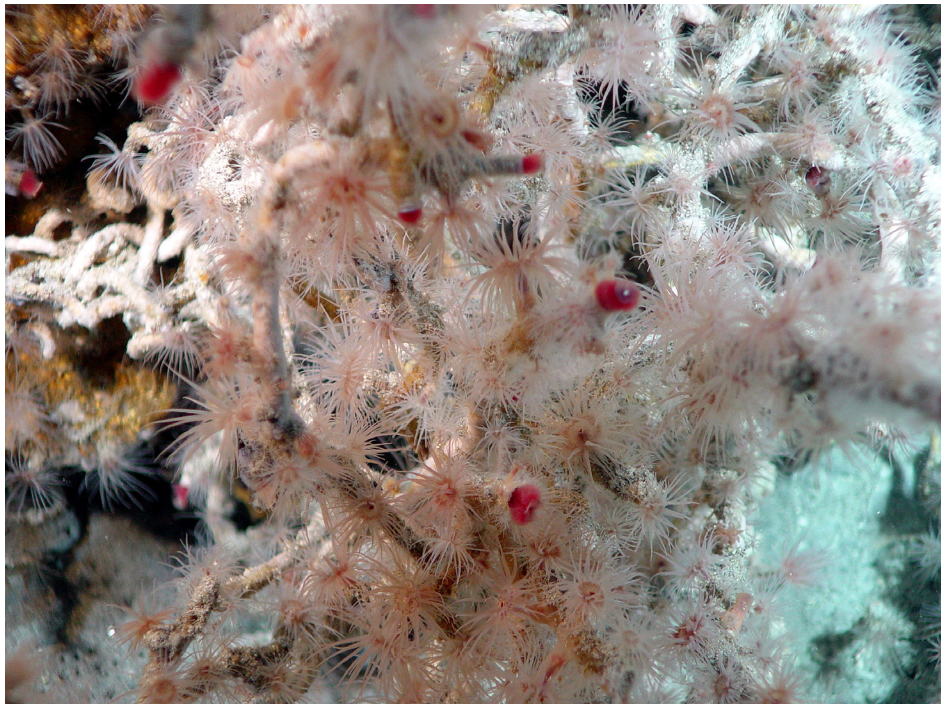
The Mariana Trench is the deepest place on Earth, deeper than the height of Mount Everest above sea level. It is five times longer than the Grand Canyon and includes some 50,532,102 acres that are virtually unknown to humans.

The Volcanic Unit – an arc of undersea mud volcanoes and thermal vents – supports unusual life forms in some of the harshest conditions imaginable. Here species survive in the midst of hydrothermal vents that produce highly acidic and boiling water.

The Champagne vent, found at the NW Eifuku volcano, produces almost pure liquid carbon dioxide, one of only two known sites in the world. A pool of liquid sulfur at the Daikoku submarine volcano is unique in all the world. The only other known location of molten sulfur is on Io, a moon of the planet of Jupiter.

In the Islands Unit, unique reef habitats support marine biological communities dependent on basalt rock foundations, unlike those throughout the remainder of the Pacific. These reefs and waters are among the most biologically diverse in the

Western Pacific and include the greatest diversity of seamount and hydrothermal vent life yet discovered. They also contain one of the most diverse collections of stony corals in the Western Pacific, including more than 300 species, higher than any other U.S. reef area.

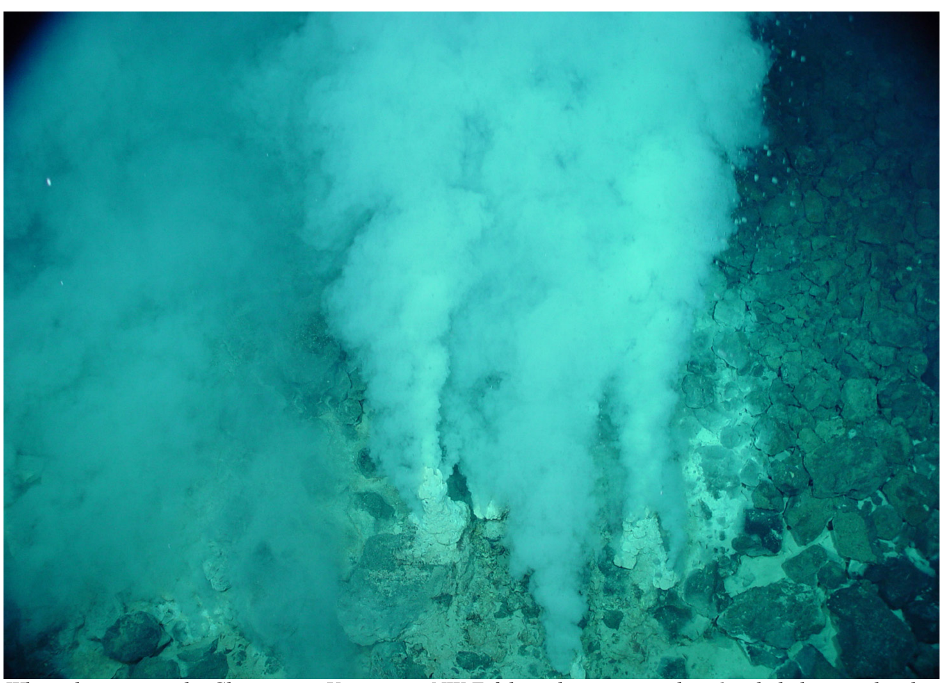


Tubeworms (Lamelli brachia) were found at both Kasuga-2 and Daikoku volcanoes.

The submerged caldera at Maug is one of only a few known places in the world where photosynthetic and chemosynthetic communities of life co-exist. The caldera is some 1.5 miles wide and 820 feet deep, an unusual depth for lagoons. The lava dome in the center of the crater rises to within 65 feet of the surface. Hydrothermal vents at about 475 feet in depth along the northeast side of the dome spew acidic water at scalding temperatures near the coral reef that quickly ascends to the sea surface. Thus, coral reefs and microbial mats are spared much of the impact of these plumes and are growing nearby, complete with thriving tropical fish. As ocean acidification increases across the Earth, this caldera offers scientists an opportunity to look into the future and ensure continuation of coral reef communities.

The coral reef ecosystems within the Islands Unit have high numbers of apex predators, larger than anywhere else along the Mariana Archipelago. One site has the highest density of sharks anywhere in the Pacific, even higher than those of the remote islands of the Central Pacific.

Similarly, these northern islands have the highest large fish biomass in the Mariana Islands. The rare bumphead parrotfish – the largest parrotfish species – thrives in these waters. The species has been depleted throughout much of its range and is included on the IUCN Red List of Threatened Species.



White chimneys at the Champagne Vent site at NW Eifuku volcano, more than 1 mile below sea level. Venting fluids were measured at 217°F (103°C); the surrounding water temperature was 36°F (2°C).

Looking to the Future

This vast and unique area is perhaps the most spectacular part of the Ring of Fire that encircles most of the Pacific Ocean. It has many secrets to yield and many potentially valuable lessons that can benefit the rest of the world. NOAA research expeditions will continue to lead comprehensive oceanographic and ecological surveys of coral reefs in the Islands Unit.

The Fish and Wildlife Service and NOAA are working with the CNMI government, Department of Defense, Department of State, U.S. Coast Guard, and others to develop a monument management plan.

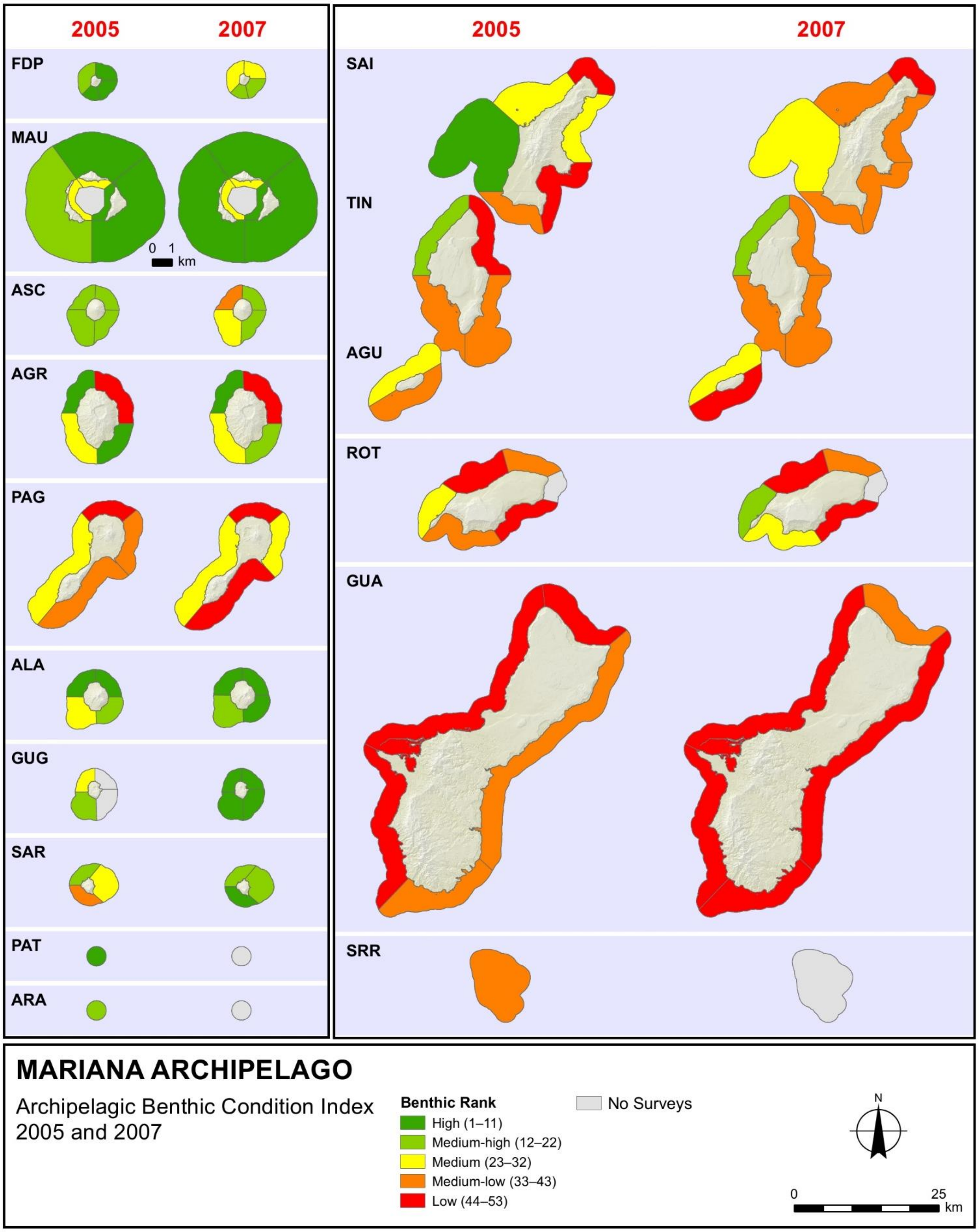
The plan will provide for public education programs, traditional access by indigenous persons, scientific exploration and research, consideration of recreational fishing if it will not detract from the monument, and programs for monitoring and enforcement. A draft plan will be made available for public review and comment.

All photos courtesy of NOAA, Submarine Ring of Fire 2004 Exploration and NOAA Vents Program.

Revised 5-24-2012

Marianas Trench Marine National Monument: Datasheets

Figure 1: Benthic Condition Index



Source: Brainard et. al 2012

Marianas Trench Marine National Monument: Island Fish Student Worksheet

Name____ Date__________________________________

Part 1: Anatomy of a Monument

The Marianas Trench Marine National Monument (MTMNM), jointly managed by National Oceanic and Atmospheric Administration (NOAA) and the US Fish and Wildlife Service (USFWS), is one of the most recently created US Marine National Monuments. For a more comprehensive overview of the history and features of the MTMNM, read through the fact sheet provided by NOAA and the USFWS and answer the following questions.

1. How big is the MTMNM?

2. If this monument were perfectly square, what would be the length of each side of the monument be? Be sure to show your work….

3. What are the names of the units that make up the MTMNM?

4. What is protected in the Island Unit that is not protected in the other units?

5. **When** and **how** was the Monument first established?

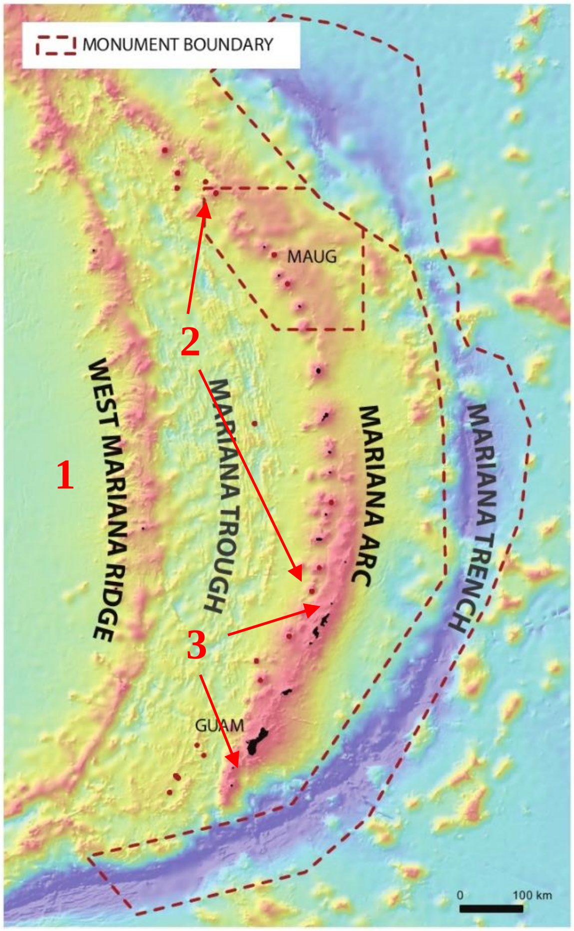
6. What makes the Trench Unit unique?

7. What are found in the Volcanic Unit that give this unit some of its most unusual features?

8. Describe one of the unique features found in the Volcanic Unit.

9. Give two reasons why protecting the Island Unit is important.

Part 2: Islands of the Mariana Archipelago



The Marianas Archipelago is 890 km long and encompasses 15 islands, located on the Marianas Arc, and numerous offshore banks. The territory of Guam includes the island of Guam and adjacent offshore banks and reefs. All other islands and offshore banks compose the Commonwealth of the Northern Mariana Islands (CNMI). The islands and reefs of the Marianas Archipelago can be divided into three geologic groups: (1) various offshore banks and submarine volcanoes located on the West Mariana Ridge; (2) the young, volcanic (active or dormant stratovolcanoes) northern islands on the Marianas Arc; and (3) the old, volcanic (extinct stratovolcanoes) southern islands located on the Marianas Arc. The three northernmost islands, Asuncion, Maug, and Farallon de Pajaros, the Marianas Trench, and several volcanic features between the Marianas Arc and Trough were designated as the Marianas Trench Marine National Monument by presidential proclamation in January 2009.

Lay out the island ID cards by latitude (only 13 of the 15 islands) and answer the following questions.

1. Looking at the island shapes and geographic locations, which islands are the young volcanic islands?

2. In general, describe the shape of the young volcanic islands. Which of these islands do not follow the pattern?

3. What is the average land area of these young volcanic islands?

4. What is the average reef area around these young volcanic islands?

5. Looking at the island shapes and geographic locations, which islands are the old volcanic islands?

6. In general, describe the shape of these old volcanic islands. How are the coastlines of the old volcanic islands different from the coastlines of the young volcanic islands?

7. What is the average land area of these old volcanic islands?

8. What is the average reef area around these old volcanic islands?

9. In the space below, draw a graph that represents the trend of island size and reef area with age.

10. Based on the relationships you describe above, which islands do you expect to have the most fish and why?

Part 3: Feeding Frenzy

The warm waters of the Marianas Archipelago are home to amazing and unique coral reef ecosystems upon which the human communities of these Pacific islands are economically and culturally dependent. Intense survey effort by the Coral Reef Ecosystem Division of NOAA over the last few years has for the first time provided data about the different types of fish found in and around these specular reef communities. These data help us understand not only the current fish resource distribution, but can help us develop management strategies to protect these resources into the future.

In order to compare fish data between different islands, scientists at NOAA grouped their fish survey data into four categories by feeding habits:

Primary Consumers: This group consists of fish that eat plants (herbivores) and fish that feed on decomposing plant and animal particles (detritivores).

Secondary Consumers: This group consists of fish that eat both plants and animals (omnivores) and fish that eat invertebrates which live on the seafloor (benthic invertivores).

Planktivores: This group consists of fish that consume primarily zooplankton (free floating or slowly-swimming small organisms that live in surface ocean waters).

Piscivores: This group consists of fish that consume other fish.

Below is a list of fish types found in the Marianas Islands. Spend some time researching the feeding habits of these fish types and to the best of your ability organize them into the appropriate categories below.

Fish Types:

Butterfly fish	Rabbitfish
Damsel fish	Tuna
Eels	Sharks
Groupers	Silversides
Herring	Snappers
Jacks	Squirrelfish
Manta ray	Surgeonfish
Mullet	Triggerfish
Parrotfish	Whaleshark
Pufferfish	

Primary Consumers:

Secondary Consumers:

Planktivores:

Piscivores:

Part 4: Island and Reef Fish

Now that you are familiar with how NOAA organizes their fish survey data, use the island ID card to determine which of the fish graphs belongs with each island. Write the name of the island on the graph card.

Organize the graphs from lowest total biomass to highest total biomass and answer the following questions:

1. Which islands have the lowest and highest biomass in each category?

Primary Consumers ____________________________ (low)__________________________(high)

Secondary Consumers____________________________ (low)__________________________(high)

Planktivores ____________________________ (low)__________________________(high)

Piscivores ____________________________ (low)__________________________(high)

2. **What type** of islands (young or old) and **where** are the islands that have higher total fish biomass?

3. **What type** of islands (young or old) and **where** are the islands that have lower total fish biomass?

4. What categories (Primary, Secondary, Planktivore, Piscivore) change the most across the islands?

5. What categories (Primary, Secondary, Planktivore, Piscivore) change the least across the islands?

Part 5: Reef Fish and Humans

1. In addition to surveying fish in the Marianas Archipelago, NOAA divers surveyed the health of the reefs around each of the islands. Two years of these **benthic** survey data are shown in Figure 1 of your handout. How might benthic health affect the fish patterns you see?

2. Why do you think the reef health and fish biomass might be so different along the island chain?

3. Which category (primary, secondary, planktivore, or piscivore) has the most fish that are important to humans as food?

4. Why do you think that these fish might be more desirable as food sources?

Organize the island ID cards and fish graphs by human population.

5. In the space below **describe** and **draw** the relationship between island size and human population (for those islands that actually have populations).

6. In the space below **describe** and **draw** the relationship between human population and total fish biomass (for those islands that actually have populations).

Part 6: Summary

Please write a short essay highlighting at least three major things you learned about the relationships between the islands and fish in the Marianas Archipelago and MTMNM. In addition, please discuss what benefits might be provided by the Marine National Monument designation, and what some of the limitations on this protection might be.

Marianas Trench Marine National Monument: Island Fish Student Worksheet (Answer Key)

Name____ Date__________________________________

Part 1: Anatomy of a Monument

The Marianas Trench Marine National Monument (MTMNM), jointly managed by National Oceanic and Atmospheric Administration (NOAA) and the US Fish and Wildlife Service (USFWS), is one of the most recently created US Marine National Monuments. For a more comprehensive overview of the history and features of the MTMNM, read through the fact sheet provided by NOAA and the USFWS and answer the following questions.

1. How big is the MTMNM?

   The Monument is 95,216 square miles.

2. If this Monument were perfectly square, what would be the length of each side of the monument be? Be sure to show your work….

   Each side would be $\sqrt{95{,}216\ miles^2} = \sim 308.6\ miles$.

3. What are the names of the units that make up the MTMNM?

   The Trench Unit, the Volcanic Unit, and the Island Unit

4. What is protected in the Island Unit that is not protected in the other units?

   In the Island Unit both the waters and the submerged lands are protected as part of the Monument. In the other two units, just the submerged lands are protected.

5. **When** and **how** was the Monument first established?

   The MTMNM was created by Presidential Proclamation 8335 in January of 2009.

6. What makes the Trench Unit unique?

   The Trench Unit encompasses large portions of the Marianas Trench, including some of the deepest places on Earth. In addition, much of the Trench Unit is virtually unexplored (unknown) by humans.

7. What are found in the Volcanic Unit that give this unit some of its most unusual features?
   Hydrothermal vents and mud volcanoes

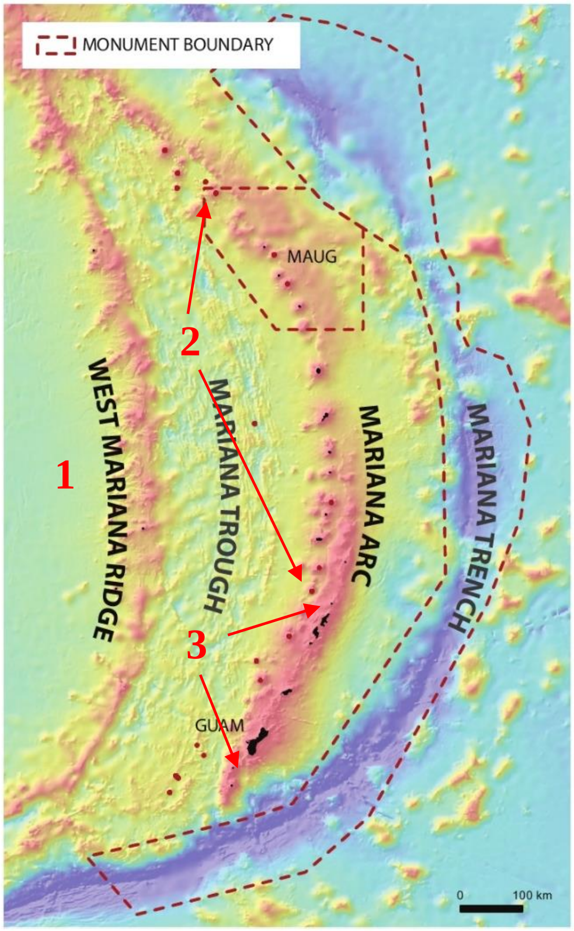
8. Describe one of the unique features found in the Volcanic Unit.

   Students should talk about either the Champagne Vent at Eifuku or the pool of molten sulfer found at the Daikoku volcano.

9. Give two reasons why protecting the Island Unit is important.

   Answers will vary, but answers might include protection of unique environments (e.g. photosynthetic and chemosynthetic communities at Maug), protection for areas that are little-studied (hydrothermal vent communities), and protection of biodiversity and fish stocks.

Part 2: Islands of the Mariana Archipelago



The Marianas Archipelago is 890 km long and encompasses 15 islands, located on the Marianas Arc, and numerous offshore banks. The territory of Guam includes the island of Guam and adjacent offshore banks and reefs. All other islands and offshore banks compose the Commonwealth of the Northern Mariana Islands (CNMI). The islands and reefs of the Marianas Archipelago can be divided into three geologic groups: (1) various offshore banks and submarine volcanoes located on the West Mariana Ridge; (2) the young, volcanic (active or dormant stratovolcanoes) northern islands on the Marianas Arc; and (3) the old, volcanic (extinct stratovolcanoes) southern islands located on the Marianas Arc. The three northernmost islands, Asuncion, Maug, and Farallon de Pajaros, the Marianas Trench, and several volcanic features between the Marianas Arc and Trough were designated as the Marianas Trench Marine National Monument by presidential proclamation in January 2009.

Lay out the island ID cards by latitude (only 13 of the 15 islands) and answer the following questions.

1. Looking at the island shapes and geographic locations, which islands are the young volcanic islands?

   Farallon De Pajaros, Maug, Asuncion, Argihan, Pagan, Alamagan, Guguan, Sarigan

2. In general, describe the shape of the young volcanic islands. Which of these islands do not follow the pattern?

   In general the young volcanic islands are circular or nearly circular. The exceptions are Pagan, which I shaped like a club, and Maug, which has a circular outline formed by three smaller islands surrounding a central lagoon.

3. What is the average land area of these young volcanic islands?

   Sum of island land area/number of islands = 15.6 km^2

4. What is the average reef area around these young volcanic islands?

   Sum of reef area/number of reef areas = 3.7 km^2

5. Looking at the island shapes and geographic locations, which islands are the old volcanic islands?

   Saipan, Tinian, Aguijan, Rota, Guam

6. In general, describe the shape of these old volcanic islands. How are the coastlines of the old volcanic islands different from the coastlines of the young volcanic islands?

   In general the older volcanic islands are oblong in shape and have relatively complex coastlines when compared to the younger volcanic islands.

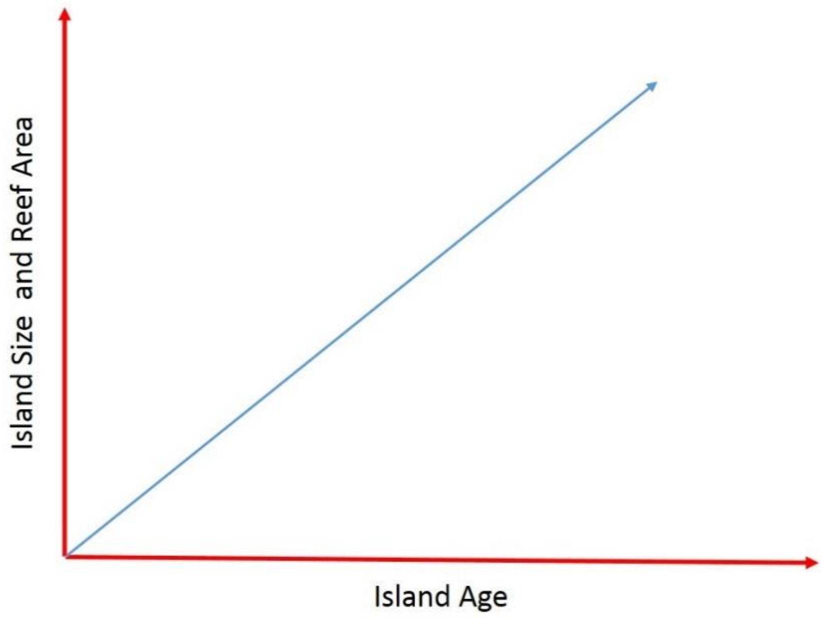
7. What is the average land area of these old volcanic islands?

   Sum of island land area/number of islands = 171.6 km^2

8. What is the average reef area around these old volcanic islands?

   Sum of reef area/number of reef areas = 35.5 km^2

9. In the space below, draw a graph that represents the trend of island size and reef area with age.



10. Based on the relationships you describe above, which islands do you expect to have the most fish and why?

    Answers will vary, but it would be reasonable to expect that there would be more fish around the islands that have more reef space. This is an excellent place to have a discussion about the difference between absolute amounts and relative amounts. For example, even though Guam has only 13.1 g/m^2 *of total fish biomass per unit area, the larger reef size (91.3 km*^{2}*) means there will be more total fish biomass overall at Guam than around Alamagan, which has a total fish biomass of 147.6 g/m*^{2} *but only 3.1 km*^{2} *of reef area*

Part 3: Feeding Frenzy

The warm waters of the Marianas Archipelago are home to amazing and unique coral reef ecosystems upon which the human communities of these Pacific islands are economically and culturally dependent. Intense survey effort by the Coral Reef Ecosystem Division of NOAA over the last few years has for the first time provided data about the different types of fish found in and around these specular reef communities. These data help us understand not only the current fish resource distribution, but can help us develop management strategies to protect these resources into the future.

In order to compare fish data between different islands, scientists at NOAA grouped their fish survey data into four categories by feeding habits:

Primary Consumers: This group consists of fish that eat plants (herbivores) and fish that feed on decomposing plant and animal particles (detritivores).

Secondary Consumers: This group consists of fish that eat both plants and animals (omnivores) and fish that eat invertebrates which live on the seafloor (benthic invertivores).

Planktivores: This group consists of fish that consume primarily zooplankton (free floating or slowly-swimming small organisms that live in surface ocean waters).

Piscivores: This group consists of fish that consume other fish.

Below is a list of fish types found in the Marianas Islands. Spend some time researching the feeding habits of these fish types and to the best of your ability organize them into the appropriate categories below.

Fish Types:

Butterfly fish	Rabbitfish
Damsel fish	Tuna
Eels	Sharks
Groupers	Silversides
Herring	Snappers
Jacks	Squirrelfish
Manta ray	Surgeonfish
Mullet	Triggerfish
Parrotfish	Whaleshark
Pufferfish	

Primary Consumers:

Mullet, Parrotfish, Rabbitfish, Surgeonfish

Secondary Consumers:

Butterflyfish, Triggerfish, Pufferfish

Planktivores:

Damselfish, Herring, Manta ray, Silversides, Soldierfish, Whaleshark

Piscivores:

Eels, Groupers, Jacks, Tuna, Sharks, Snappers

Part 4: Island and Reef Fish

Now that you are familiar with how NOAA organizes their fish survey data, use the island ID card to determine which of the fish graphs belongs with each island. Write the name of the island on the graph card.

Organize the graphs from lowest total biomass to highest total biomass and answer the following questions:

1. Which islands have the lowest and highest biomass in each category?

Primary Consumers ____________________________ (low)__________________________(high)

Tinian (S) *Guguan (N)*

Secondary Consumers____________________________ (low)__________________________(high)

Aguijan (S) *Alamagan (N)*

Planktivores ____________________________ (low)__________________________(high)

Tinian (S) *Guguan (N)*

Piscivores ____________________________ (low)__________________________(high)

Tinian (S) *Farallon De Pajaros (N)*

2. **What type** of islands (young or old) and **where** are the islands that have higher total fish biomass?

   The young, northern islands have, in general, higher fish biomass across all fish type categories.

3. **What type** of islands (young or old) and **where** are the islands that have lower total fish biomass?

   The old, southern islands have, in general, lower fish biomass across all fish type categories.

4. What categories (Primary, Secondary, Planktivore, Piscivore) change the most across the islands?

   Planktivores and Piscivores categories change the most across the islands.

5. What categories (Primary, Secondary, Planktivore, Piscivore) change the least across the islands?

   Primary and Secondary consumers change the least across the islands.

Part 5: Reef Fish and Humans

1. In addition to surveying fish in the Marianas Archipelago, NOAA divers surveyed the health of the reefs around each of the islands. Two years of these **benthic** survey data are shown in Figure 1 of your handout. How might benthic health affect the fish patterns you see?

   Again, answers will vary, but they should be able to see that the benthic health in general is better around all the young, northern islands. From this they should be able to make the leap that the health of the reef likely affects the amount and type of fish present at that reef.

2. Why do you think the reef health and fish biomass might be so different along the island chain?

   Answers will vary. For example, students may suggest that differences in latitude or island sizes could be controls on fish biomass and reef health.

3. Which category (primary, secondary, planktivore, or piscivore) has the most fish that are important to humans as food?

   The piscivore category has many fish that are important to humans as food. However, be aware that in the Marianas (and most of the Pacific), several herbivores are also highly targeted by fisherman for human consumption as well.

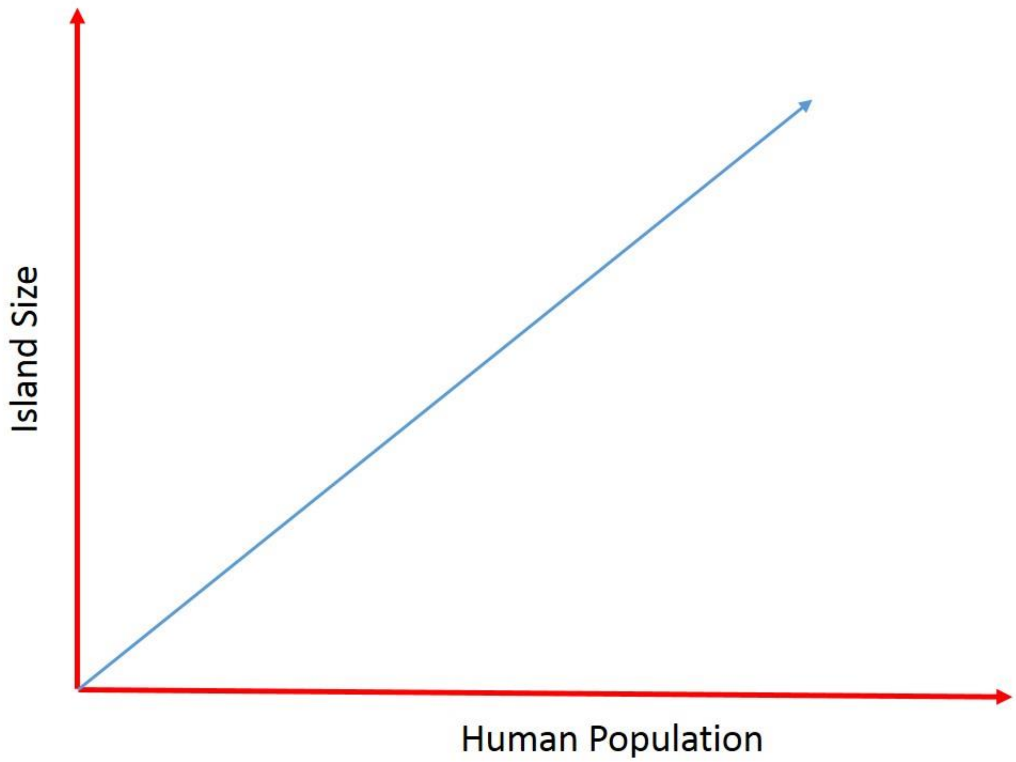
4. Why do you think that these fish might be more desirable as food sources?

   These fish tend to be large and therefore yield lots of food for the amount of energy expended to catch them. In addition some of these fish exhibit schooling behavior making them relatively easy to catch in large numbers. For these reasons, in addition to other, these fish tend to be the primary targets of human fishermen. Also, some of these fish tend to stay in the same region or near the same reef, making their target locations easy for fishermen to find.

Organize the island ID cards and fish graphs by human population.

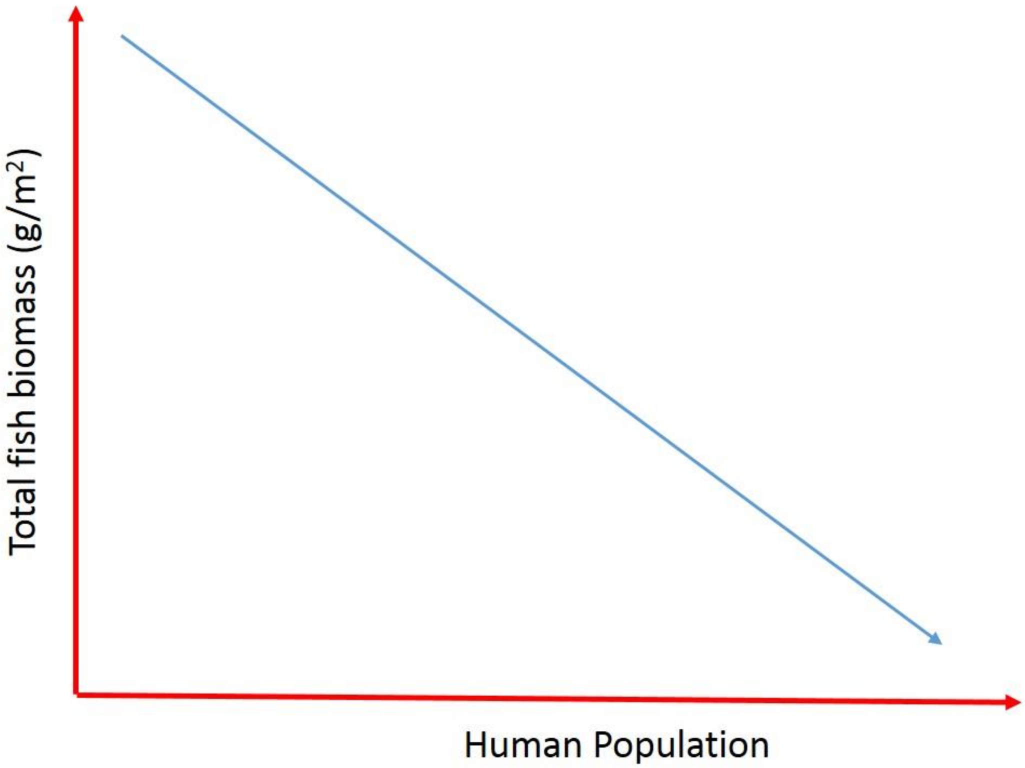
1. In the space below **describe** and **draw** the relationship between island size and human population (for those islands that actually have populations).

   There is a positive correlation between island size and human population density on the islands.



2. In the space below **describe** and **draw** the relationship between human population and total fish biomass (for those islands that actually have populations).

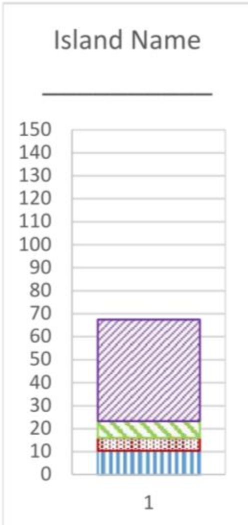
As human populations increase in the Marianas Archipelago, the fish biomass decreases. This inversely correlated relationship likely results from increases in fishing pressure, increasing pollution, changes in land use, etc, associated with increasing human populations.

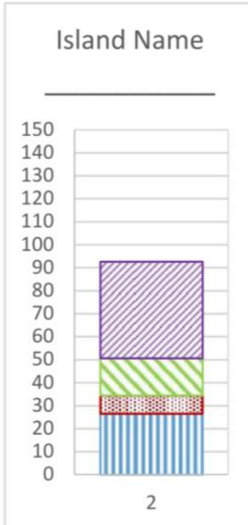

Total fish biomass (g/m2)
Human Population

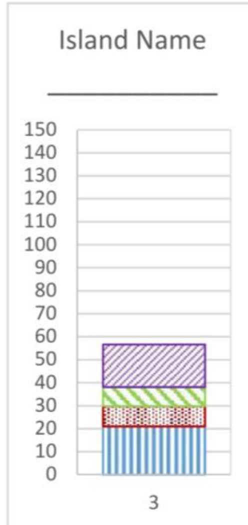
Part 6: Summary

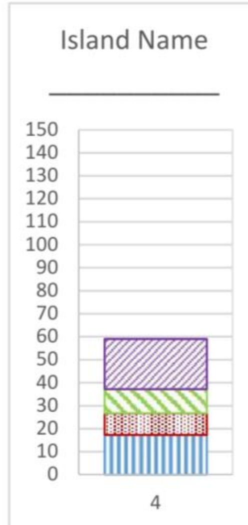
Please write a short essay highlighting at least three major things you learned about the relationships between the islands and fish in the Marianas Archipelago and MTMNM. In addition, please discuss what benefits might be provided by the Marine National Monument designation, and what some of the limitations on this protection might be.

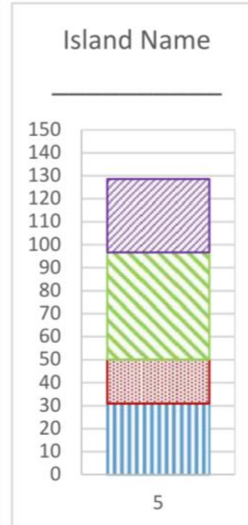
Marianas Trench Marine National Monument: Fish Graphs

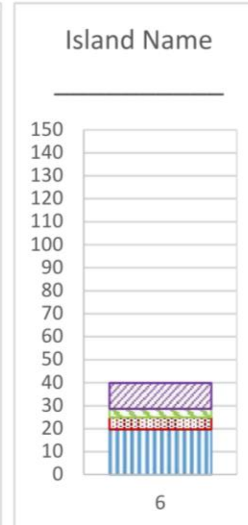


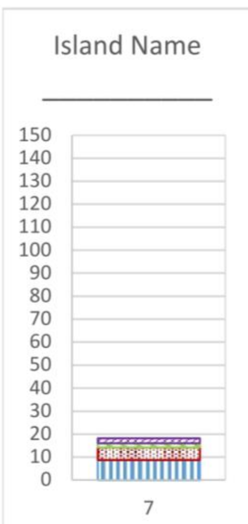


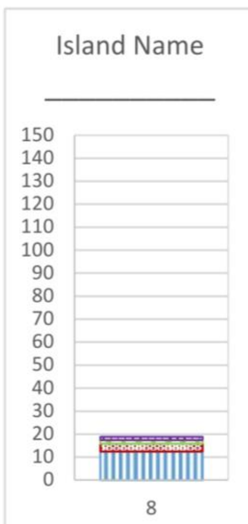


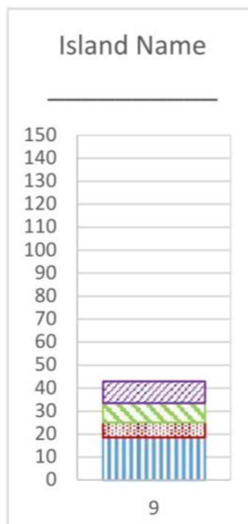


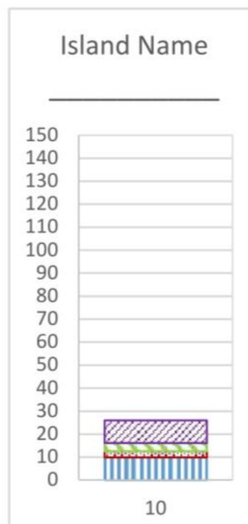


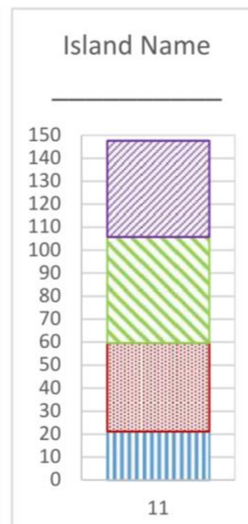


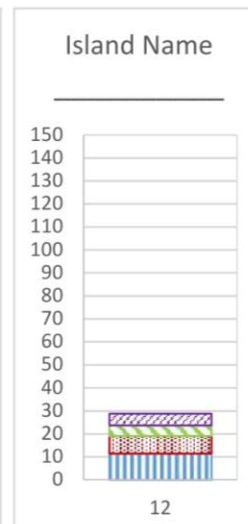


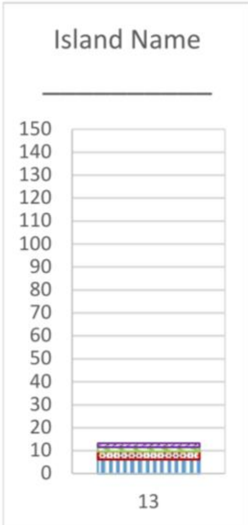








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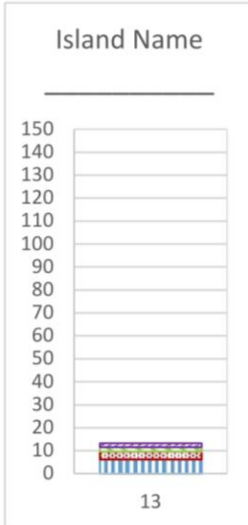
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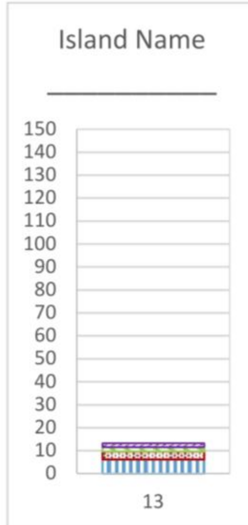
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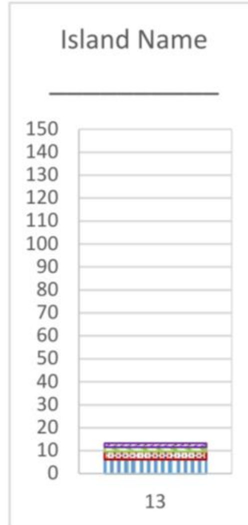
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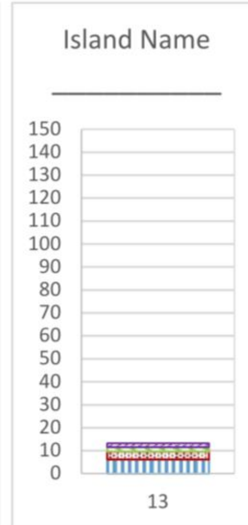
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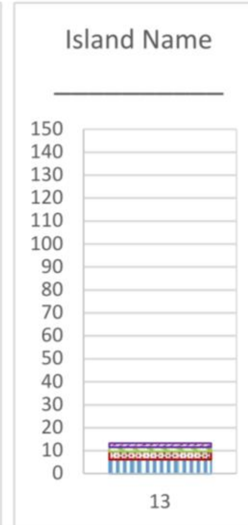
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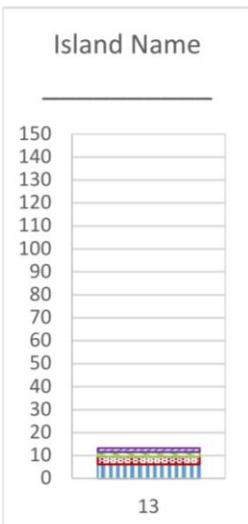
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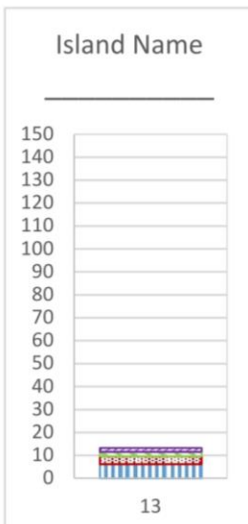
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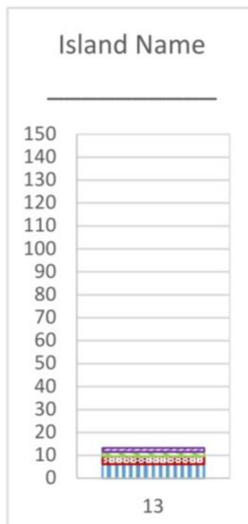
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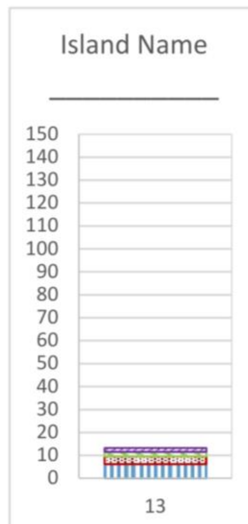
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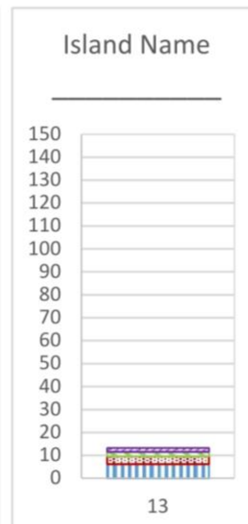
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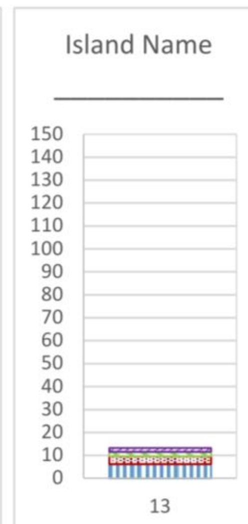
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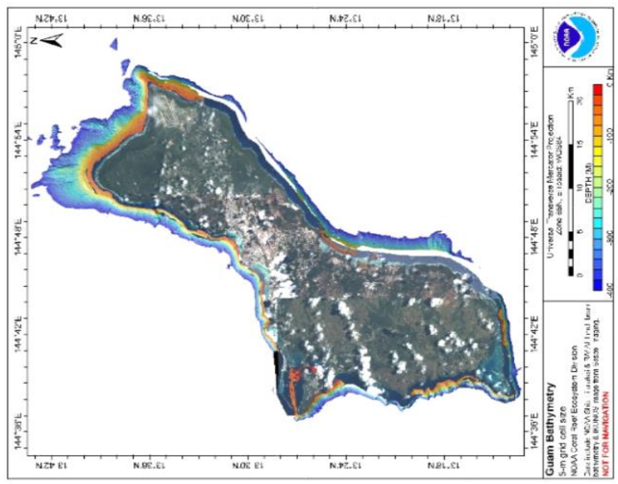
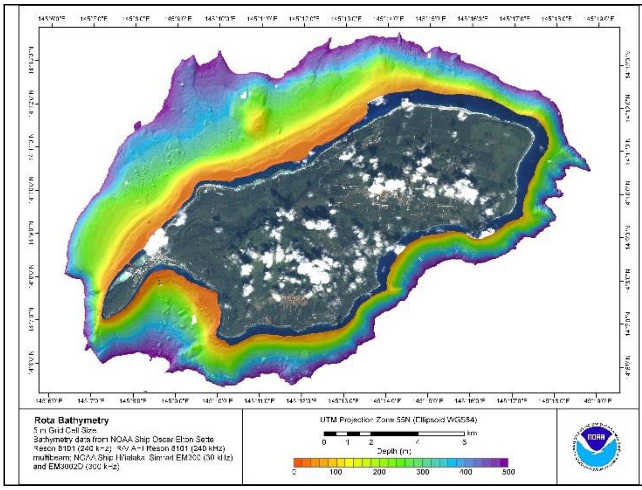
Marianas Trench Marine National Monument: ID Cards



Guam

Latitude x Longitude: 13.46°N x 144.79°E
Population: 154,805
Land Area: 549 km²
Reef Area: 91.3 km^2
Fish Biomass (g/m^2): 13.1

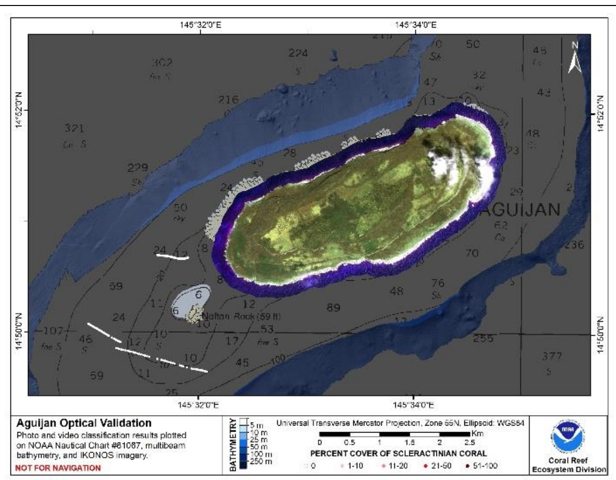
	Piscivore: 1.5
	Planktivore: 1.9
	Secondary: 3.4
	Primary: 6.3



Rota

Latitude x Longitude: 14.16°N x 145.21°E
Population: 3,283
Land Area: 85.4 km²
Reef Area: 12.1 km^2
Fish Biomass (g/m^2): 28.8

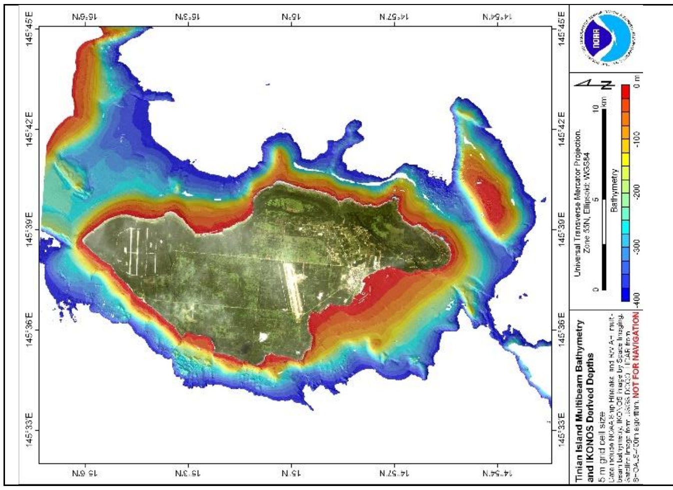
	Piscivore: 5.2
	Planktivore: 4.5
	Secondary: 7.6
	Primary: 11.5



Aguijan

Latitude x Longitude: 14.85°N x 145.55°E
Population: 0
Land Area: 7.1 km²
Reef Area: 2.6 km^2
Fish Biomass (g/m^2): 26.1

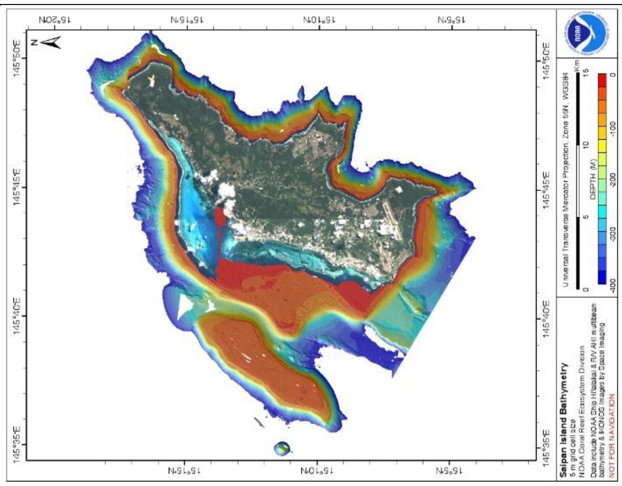
	Piscivore: 9.8
	Planktivore: 3.6
	Secondary: 2.7
	Primary: 10.0



Tinian

Latitude x Longitude: 14.99°N x 145.63°E
Population: 3,540
Land Area: 101.0 km²
Reef Area: 14.7 km^2
Fish Biomass (g/m^2): 18.8

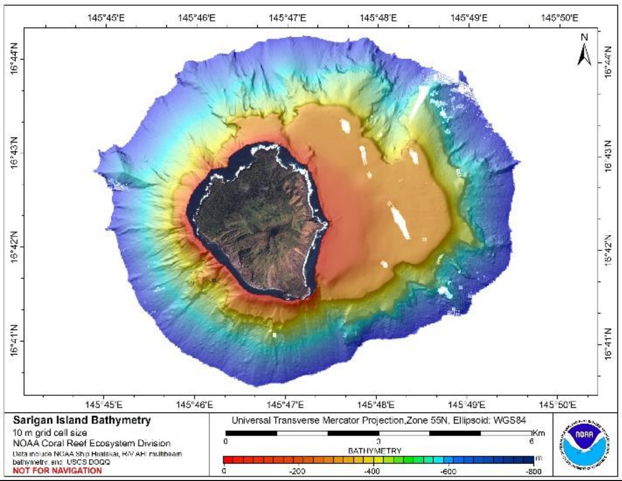
	Piscivore: 1.4
	Planktivore: 1.5
	Secondary: 3.4
	Primary: 12.5



Saipan

Latitude x Longitude: 15.19°N x 145.75°E
Population: 62,392
Land Area: 115.4 km²
Reef Area: 56.8 km^2
Fish Biomass (g/m^2): 18.2

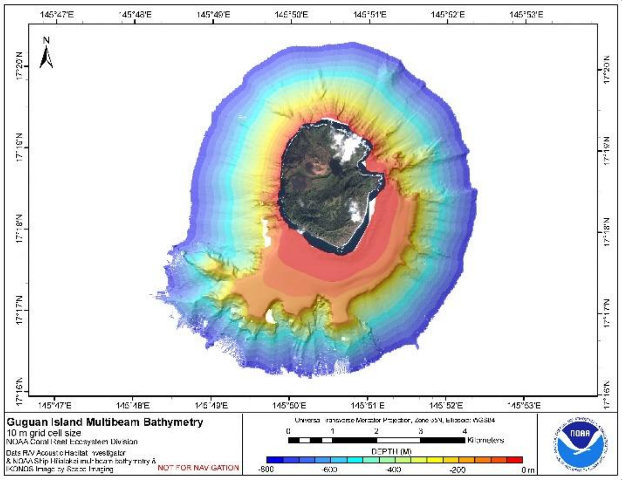
	Piscivore: 2.2
	Planktivore: 1.8
	Secondary: 5.4
	Primary: 8.8



Sarigan

Latitude x Longitude: 16.71°N x 145.78°E
Population: 0
Land Area: 4.5 km²
Reef Area: 1.9 km^2
Fish Biomass (g/m^2) 39.8

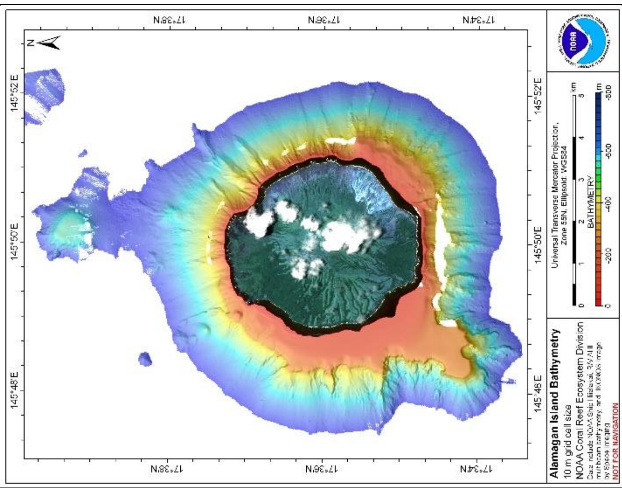
	Piscivore: 11.2
	Planktivore: 3.6
	Secondary: 5.3
	Primary: 19.7



Guguan

Latitude x Longitude: 17.31°N x 145.84°E
Population: 0
Land Area: 3.9 km²
Reef Area: 1.1 km^2
Fish Biomass (g/m^2): 128.6

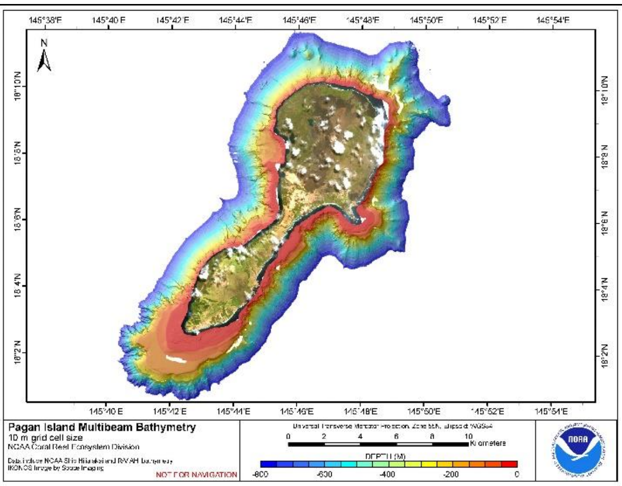
	Piscivore: 31.9
	Planktivore: 46.6
	Secondary: 19.1
	Primary: 31.0



Alamagan

Latitude x Longitude: 17.60°N x 145.83°E
Population: 6
Land Area: 13.0 km²
Reef Area: 3.2 km^2
Fish Biomass (g/m^2): 147.6

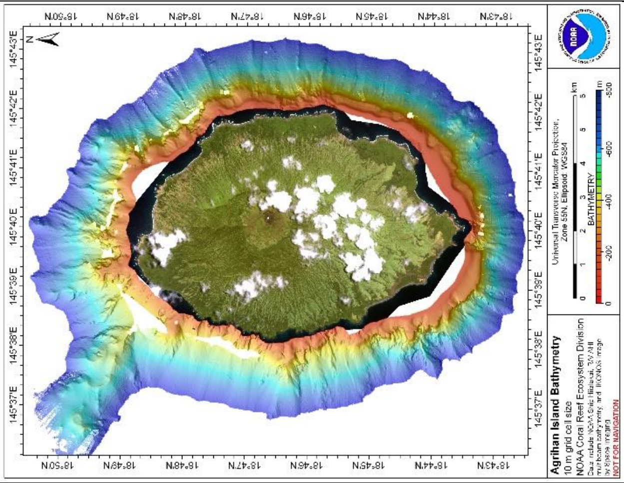
	Piscivore: 41.9
	Planktivore: 46.1
	Secondary: 38.5
	Primary: 21.1



Pagan

Latitude x Longitude: 18.11°N x 145.76°E
Population: 0
Land Area: 47.2 km²
Reef Area: 11.1 km^2
Fish Biomass (g/m^2): 59.0

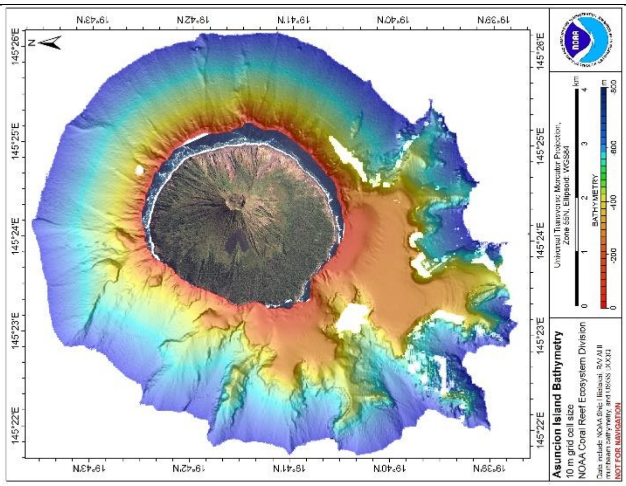
	Piscivore: 21.8
	Planktivore: 10.4
	Secondary: 9.5
	Primary: 17.3



Argihan

Latitude x Longitude: 18.76°N x 145.66°E
Population: 0
Land Area: 43.5 km²
Reef Area: 8.6 km^2
Fish Biomass (g/m^2): 56.7

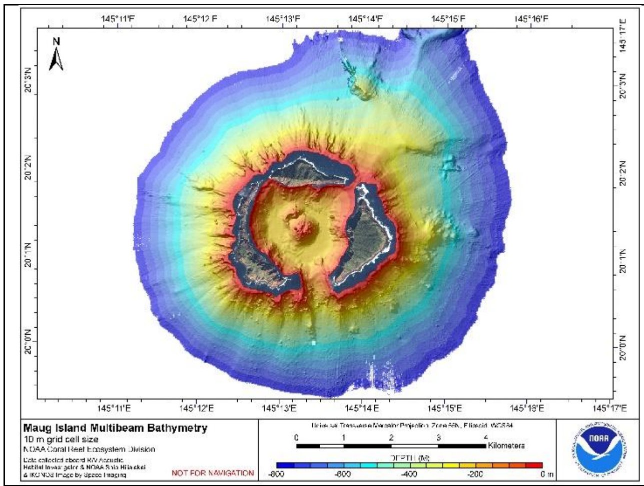
	Piscivore: 18.5
	Planktivore: 8.4
	Secondary: 8.8
	Primary: 21.0



Asuncion

Latitude x Longitude: 19.69°N x 145.40°E
Population: 0
Land Area: 7.9 km²
Reef Area: 0.5 km^2
Fish Biomass (g/m^2): 92.6

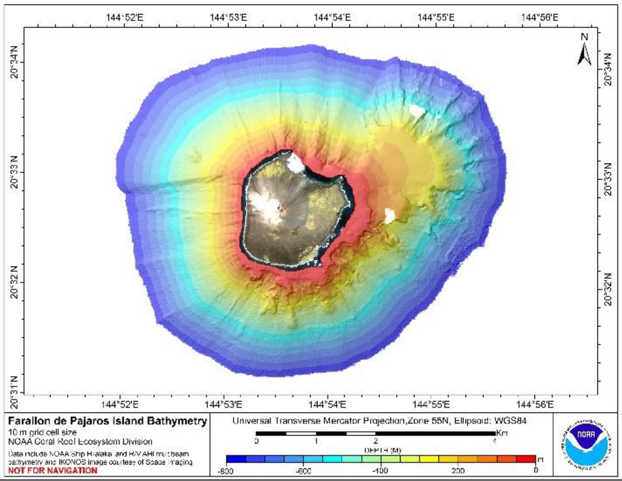
	Piscivore: 42.1
	Planktivore: 16.2
	Secondary: 7.8
	Primary: 26.5



Maug

Latitude x Longitude: 20.02°N x 145.22°E
Population: 0
Land Area: 2.1 km²
Reef Area: 2.1 km^2
Fish Biomass (g/m^2): 42.9

	Piscivore: 9.4
	Planktivore: 8.4
	Secondary: 6.5
	Primary: 18.6



Farallón De Pájaros (FDP)

Latitude x Longitude: 20.55°N x 144.89°E
Population: 0
Land Area: 2.3 km²
Reef Area: 0.8 km^2
Fish Biomass (g/m^2): 67.5

	Piscivore: 44.2
	Planktivore: 7.2
	Secondary: 5.6
	Primary: 10.5