# Papahānaumokuākea Marine National Monument: Biodiversity

## Grade Level

- 7-12

## Timeframe

- 2 45 minute periods or one 90 minute class

## Materials

- Computers (exercise can also be done as a class or small groups/partners and modified with calculators)
- Shannon-Wiener Diversity Index Excel file
- Biodiversity PowerPoint
- Google Earth

## Key Words

- Biodiversity
- Alpha diversity
- Beta Diversity
- Endemic

## Activity Summary

The objective of this lesson is for students to understand the concept of biodiversity, its importance, and how changing biodiversity affects an ecosystem. Using ecosystems found in Papahānaumokuākea Marine National Monument, they will learn how to quantitatively measure biodiversity and compare different areas of the monument. They will also be introduced to some of the local flora and fauna of the Northwestern Hawaiian Islands.

## Learning Objectives

- Discover the importance of biodiversity in an ecosystem
- Explore the biodiversity within Papahānaumokuākea MNM
- Practice and experience different methods of quantifying biodiversity

## Background Information

Papahānaumokuākea MNM encompasses 140,000 square miles and extends northwest of the main Hawaiian Islands. Though the majority of the Monument is open ocean and submerged reef, there are a

## Outline

ENGAGE – Digital exploration of Papahānaumokuākea MNM and its flora and fauna

EXPLORE – Introduction to biodiversity

EXPLAIN – Experiencing biodiversity through music

ELABORATE – Learn some quantitative methods for measuring biodiversity

EVALUATE – Class discussion to ensure understanding of concepts

## Vocabulary

BIODIVERSITY – the variety of plant and animal species in an ecosystem

ALPHA DIVERSITY – the number of species in one habitat

BETA DIVERSITY – the variation in types of species between two different habitats

ENDEMIC – a plant or animal species that has a highly localized or restricted geographic distribution

ECOSYSTEM – a biological community of interacting organisms and their physical environment

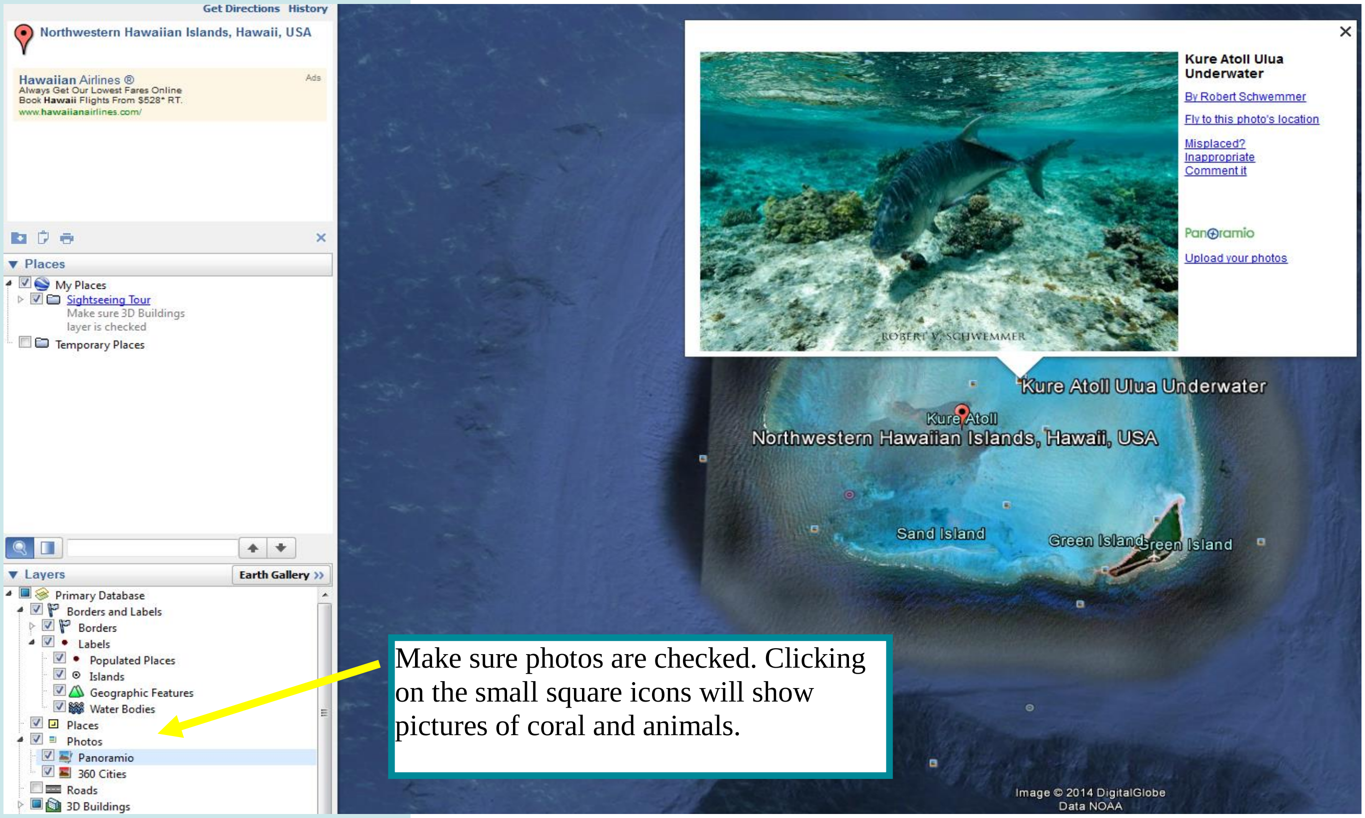
few atolls and islands with emergent land. Its remote location and historically low level of human impact has left Papahānaumokuākea MNM in a relatively pristine condition providing excellent habitat for resident species and a unique environment for scientists to study and to better understand how humans are affecting coral reef ecosystems elsewhere. This Monument is home to over 7,000 marine species and has a very high level of endemism with roughly one fourth of those species endemic and found only in the Hawaiian Archipelago (NOAA). Several endangered and threatened species reside in the waters of the Monument, including the Hawaiian monk seal, Hawaiian green turtle, and the Laysan duck.

Papahānaumokuākea MNM has been the focus of much scientific research and is a great model ecosystem for Ocean Literacy Essential Principle 5 – *the ocean supports a great diversity of life and ecosystems*. There is a latitudinal gradient reflected in the community composition across the Papahānaumokuākea MNM. Temperate and subtropical fish species are found around the northern islands while tropical fish species are found in the southern waters. Shark species vary with latitude as well (Friedlander et al., 2009) Papahānaumokuākea MNM has high levels of endemism due to its isolation (Friedlander et al., 2009; Fautin et al., 2010). Recent dive surveys report that 46% of reef fish in the Papahānaumokuākea MNM are endemic. Endemism appears to vary with latitude as well; at the southern end of the islands there was 16% endemism ranging up to 92% at the northern extent of the chain (Kane, Kosaki, and Wagner, 2014). Another feature frequently noted is the apex predator dominated food web; a feature not seen in coral reefs in less pristine condition (Friedlander et al., 2009).

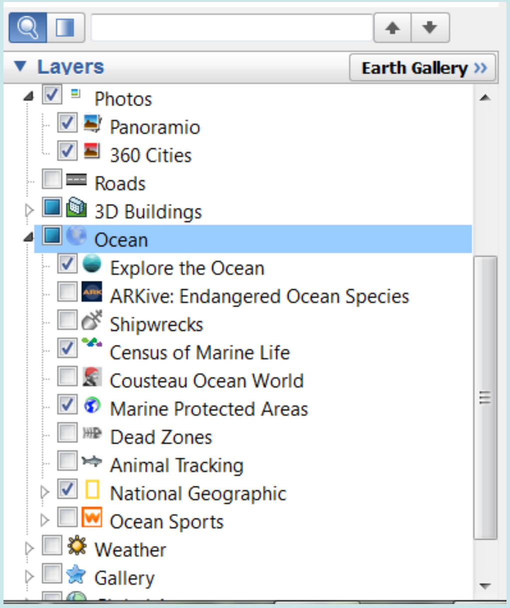
## Preparation

- Familiarize yourself with Google Earth for Papahānaumokuākea MNM and how you can find pictures of plants and animals by clicking on the icons.
    - Note – If you type Papahānaumokuākea into the search bar on Google Earth, sometimes it takes you to the Visitor's Center in Honolulu as opposed to the actual Monument. Searching Northwestern Hawaiian Islands or the name of any of the atolls will take you to the right area.
- Make sure the other internet and computer activities (the YouTube music and PowerPoint) are working.
- Familiarize yourself with the math in the Elaborate section where there are biodiversity calculations. Depending on your class's math skills level you may want to make it a group activity or only do the easier questions. Unless your class is very advanced, it is

likely the math in this section is too difficult for most 7th and 8th graders.




## Learning Procedure




### Engage

Give a short introduction to Papahānaumokuākea MNM. Play the video clips that explain the pronunciation and history behind the name. Move onto Google Earth showing where the islands are in relation to your location and Hawaii, then zoom in and investigate some of the individual islands. There are a few features of Google Earth that will help with the exploration (see image at right). On the lower left portion of Google Earth, click on the Ocean option and expand that tab by clicking on the triangle at the left. Start by checking Explore the Ocean, Census of Marine Life, Marine Protected Areas, and National Geographic. As time allows you can have your students check out the features of the other layers. If your students have access to computers, let them explore, otherwise do it as a class using a projector. The Marine Protected Area layer outlines the Monument and the other marine protected areas throughout the Pacific, making it easy to visualize the boundaries. Direct the student's exploration with the following questions:

- How many different species can you find in the images?

- How many different geographic features (atolls, islands, shoals, etc.) can you find?
- Do know anything about the animals that you see? What do they eat, how do they live or interact with other species in the ecosystem?

Watch the videos on the marine creatures and Hawaiian monk seals if desired. They can be accessed from the above links or from the square icon labeled Northwestern Hawaiian Islands Marine National Monument on Google Earth.

## Explore

What is biodiversity and why is it important? Use the biodiversity PowerPoint to explain the basic principles of biodiversity. Ask these questions as you start:

- What do you think of when you hear the term biodiversity?
- Is it important? Why or why not?
- How many different species of animals and corals did you discover when looking at the Google Earth image of the Monument?
- What are the challenges of studying animals in a marine environment?

The PowerPoint notes direct you to get students' predictions on species richness and endemism. When you get to the endemism slide, stop there for the day and discuss if the predictions were supported or refuted by the graphs and maps. Assign the Day 1 homework; use the Encyclopedia of the Sanctuary if needed to get ideas to help students to choose organisms.

## Explain

Start the lesson by asking students to share what they learned about the species they investigated. Stress to the students to share what role the organism plays in the ecosystem and links it has to other organisms. How would losing species affect those links and the overall ecosystem? To give your students perspectives on diversity complete the following musical exercise.

- Play two different versions of the 1812 Overture. First with full orchestra: https://www.youtube.com/watch?v=u2W1Wi2U9sQ&feature=related

### Internet Resources

Links to pronunciation and explanation of the name Papahānaumokuākea MNM

http://www.papahanaumokuakea.gov/about/pronounce.mp3

http://www.papahanaumokuakea.gov/about/meaning.mp3

Video of marine creatures of PMNM

https://www.youtube.com/watch?v=Y_9IPax5_HI&feature=player_embedded#at=37

Video about Hawaiian monk seal

https://www.youtube.com/watch?v=6eKIF66CEdQ&feature=player_embedded#at=46

Encyclopedia of the Sanctuary: Papahānaumokuākea MNM

http://www8.nos.noaa.gov/onms/park/Parks/?pID=12

- Then with violin and melodica. Start this clip at 5:23 so that each features the finale of the overture. https://www.youtube.com/watch?v=JmS7fKEE_nA
- Don't show the associated videos, just play the music and have students keep a tally on a piece of paper of how many instruments they can identify in each version. Then give them a few minutes to brainstorm answers the following questions.
    - Which version would you prefer to listen to? Why?
    - Can you draw any analogies between music and the concepts of biodiversity we talked about yesterday?
- Aim to have them come away with the understanding that the music with more diversity has a fuller sound just as an environment with more species is more complete.

Modified exercise for hearing impaired students.

- Print out two of the same coloring sheet from the Papahānaumokuākea MNM website http://www.papahanaumokuakea.gov/education/coloring_sheets.html
- Instruct the students that on the first sheet they can use any colors that they would like. One the second one they can only use shades of blue and green.
- Ask similar questions to those posed above after the musical exercise.
    - Which picture do you like more and how do limiting color options affect how you view the picture?
    - Can you draw any analogies between colors and the concepts of biodiversity we talked about yesterday?

## Elaborate

The next step is to give the students some tools to measure biodiversity. Is just counting plants and animals, like you counted the instruments sufficient or are there other methods that are more effective options?

- Complete the Measuring Biodiversity exercise. Have the students work in pairs or small groups and do the first part of question 1 as a class so that everyone understands how to calculate the Shannon-Wiener Diversity Index. This index is widely used in ecological research. Students will need calculators if not using computers.
- *If you do not have access to computers in class, you have options for question 3 involving Excel: you can do it together as a class via projector, assign for homework, or just ask them to make*

*predictions on how the index would compare between the two areas based on what they've learned.*

1. Use the Shannon-Weiner diversity index to calculate the diversity index of the following groups. What do the different index values mean? **Walk through the Reef 1 calculation as a group, and then have the students do 2 and 3 as individuals or in pairs. Explain to your students that the three listed species are reef fish that all live in the same environment together. Sample calculations can be found on the Student Worksheet Answer Key.**

$$H' = -\sum_{i=1}^{R} p_i \log p_i$$

H' = diversity
∑ = sum of each species calculation
$p_i$ = the proportion of individuals within the community

| | Reef 1 | Reef 2 | Reef 3 |
|---|---|---|---|
| Parrotfish | 30 | 14 | 18 |
| Angelfish | 4 | 12 | 0 |
| Triggerfish | 6 | 14 | 22 |

2. You do another survey of the three reefs and in addition to the fish listed above you find tiger sharks and green turtles living at Reef 1. What is the alpha of each reef and the beta richness when the reefs are compared?

3. Use the table of cetacean populations in the main Hawaiian Islands and the outer Exclusive Economic Zone (EEZ) and the Excel sheet for the Shannon-Weiner Index to calculate diversity for each area. The EEZ is the boundary of waters that belong to the United States and is 200 nautical miles from shore. What is the diversity index for each? How do they compare? Why do they vary?

*Table 6.1. Estimated abundance of 19 cetacean species in the MHI and outer Hawaiian Islands EEZ. Overall abundances, overall densities, and coefficients of variation (CV) are pooled from the MHI and outer EEZ estimates. Pooled abundance and density estimates are given for delphinids and beaked whales. Asterisk (*) indicates a more recent estimate of false killer whale abundance in offshore waters of the Hawaiian EEZ (484 individuals, CV=0.93) comes from Barlow and Rankin (2007). Source: Barlow, 2006.*

| SPECIES | MAIN ISLAND ABUNDANCE (n) | OUTER EEZ ABUNDANCE (n) | OVERALL ABUNDANCE (n) | OVERALL DENSITY PER 1,000 km² (D) | CV |
|---|---|---|---|---|---|
| Offshore spotted dolphin | 4,283 | 4,695 | 8,978 | 3.66 | 0.48 |
| Striped dolphin | 660 | 12,483 | 13,143 | 5.36 | 0.46 |
| Spinner dolphin | 1,488 | 1,863 | 3,351 | 1.37 | 0.74 |
| Rough-toothed dolphin | 1,713 | 6,997 | 8,709 | 3.55 | 0.45 |
| Bottlenose dolphin | 465 | 2,750 | 3,215 | 1.31 | 0.59 |
| Risso's dolphin | 513 | 1,859 | 2,372 | 0.97 | 0.65 |
| Fraser's dolphin | 0 | 10,226 | 10,226 | 4.17 | 1.16 |
| Melon-headed whale | 0 | 2,950 | 2,950 | 1.20 | 1.17 |
| Pygmy killer whale | 956 | 0 | 956 | 0.39 | 0.83 |
| False killer whale * | 0 | 236 | 236 | 0.10 | 1.13 |
| Short-finned pilot whale | 3,190 | 5,680 | 8,870 | 3.62 | 0.38 |
| Killer whale | 0 | 349 | 349 | 0.14 | 0.98 |
| Sperm whale | 126 | 6,793 | 6,919 | 2.82 | 0.81 |
| Pygmy sperm whale | 0 | 7,138 | 7,138 | 2.91 | 1.12 |
| Dwarf sperm whale | 0 | 17,519 | 17,519 | 7.14 | 0.74 |
| Blainville's beaked whale | 0 | 2,872 | 2,872 | 1.17 | 1.25 |
| Cuvier's beaked whale | 0 | 15,242 | 15,242 | 6.21 | 1.43 |
| Longman's beaked whale | 0 | 1,007 | 1,007 | 0.41 | 1.26 |
| Bryde's whale | 0 | 469 | 469 | 0.19 | 0.45 |
| Delphinids pooled | 13,267 | 50,087 | 63,354 | 25.83 | |
| Beaked whales pooled | 371 | 19,121 | 19,492 | 7.95 | |

Biodiversity is just one of a number of ways to measure biological activity in an area.

- Ask your students if they can think of other things we might measure to learn about biological interactions in an ecosystem. Eventually facilitate the discussion towards food webs and energy transfers between species and trophic levels if they don't get there without a hint.
- Return to the PowerPoint used earlier and explain the idea of biomass pyramids and how the upside down pyramid with high levels of apex predators is unique to PMNM and a few other pristine reefs of the Pacific. Likely we would have seen patterns like this historically in many other islands where the current environment has been heavily affected by people.
- Summary option: watch this roughly 20 minute Ted talk that discusses the difference between pristine coral reefs like Papahānaumokuākea MNM and degraded reefs and ecosystems, the importance of marine reserves, and how reserves can benefit

society and the ocean.
http://www.ted.com/talks/enric_sala?language=en

## Evaluate

Lead a wrap up discussion to assess understanding:

- What is biodiversity?
- What does biodiversity mean for an ecosystem?
- Why is it important to protect this area?
- What are threats to biodiversity and what can individuals do to lessen those threats?
- Besides good habitat for these plants and animals, how does biodiversity benefit us?
    - *Intrinsic value knowing that it exists even if we can't visit it, ability to protect endangered species, larval disbursement to non-protected areas leading to more fish and biomass in surrounding waters, potential biological resources that we do not know about yet (e.g. medicine, compounds, etc.)*
- If you could see one plant or animal you've learned about, which one would it be and why?

## Extending the Lesson

- NOAA shiptracker: http://shiptracker.noaa.gov/Home/Map. Lots of the information on the biodiversity in PMNM came from surveys conducted from NOAA ships. This link allows you to see where the ships currently are and access data from previous cruises.
- For older students: assign a chapter of the Marine Biogeographic Assessment of the NWHI for reading. The whole report or individual chapters can be downloaded here: http://ccma.nos.noaa.gov/ecosystems/sanctuaries/nwhi/.
- Investigate biodiversity in a local ecosystem – challenge the students to write down all of the plants and animals they know that live locally. How well do they know the biological diversity in your local area? Your state Department of Natural Resources will likely be a good resource to find a list of species that live in your region.

- Use some of the additional education resources from Papahānaumokuākea: http://www.papahanaumokuakea.gov/education/for_teachers.html

## Connections To Other Subjects

- Ecology
- Biology
- Mathematics

## Related Links

NOAA Marine National Monument Program
NOAA Fisheries Pacific Islands Regional Office
Papahānaumokuākea Marine National Monument

## For More Information

NOAA Fisheries Pacific Islands Regional Office
NOAA Marine National Monument Program
1845 Wasp Blvd., Building 176
Honolulu, HI 96818
(808) 725-5000, (808) 725-5215 (fax) pirohonolulu@noaa.gov

## 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.

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All images are from NOAA unless otherwise cited.

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

## Sources

Fautin, D., Dalton, P., Incze, L.S., Leong, J-A.C., Pautzke, C., et al. (2010). An Overview of Marine Biodiversity in United States Waters. *PLoS ONE*, 5(8): e11914. doi:10.1371/journal.pone.0011914

Friedlander, A., Keller, K., Wedding, L., Clarke, A., Monaco, M. (eds.). (2009). A Marine Biogeographic Assessment of the Northwestern Hawaiian Islands. NOAA Technical Memorandum NOS NCCOS 84. Prepared by NCCOS's Biogeography Branch in cooperation with the Office of National Marine Sanctuaries Papahānaumokuākea Marine National Monument. Silver Spring, MD. 363 pp.

Kane, C., Kosaki, R. K., & Wagner, D. (2014). High levels of mesophotic reef fish endemism in the Northwestern Hawaiian Islands. *Bulletin of Marine Science*, *90*(2): 693–703. doi:10.5343/bms.2013.1053

NOAA. Papahānaumokuākea Maine National Monument. http://www.papahanaumokuakea.gov/welcome.html

## Education Standards

| | |
|---|---|
| **Next Generation Science Standards** | • MS-LS2-2. – Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.]<br>• 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.]<br>• HS-LS2-2. – Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.]<br>• • HS-LS4-6. – Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.] |
| **Ocean Literacy Principles** | • **5** – The ocean supports a great diversity of life and ecosystems.<br>• **5D** – Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and every transfer) that do not occur on land.<br>• **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.<br>• **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.<br>• **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. |

# Biodiversity in Papahānaumokuākea Marine National Monument

# What is biodiversity and why is it important?

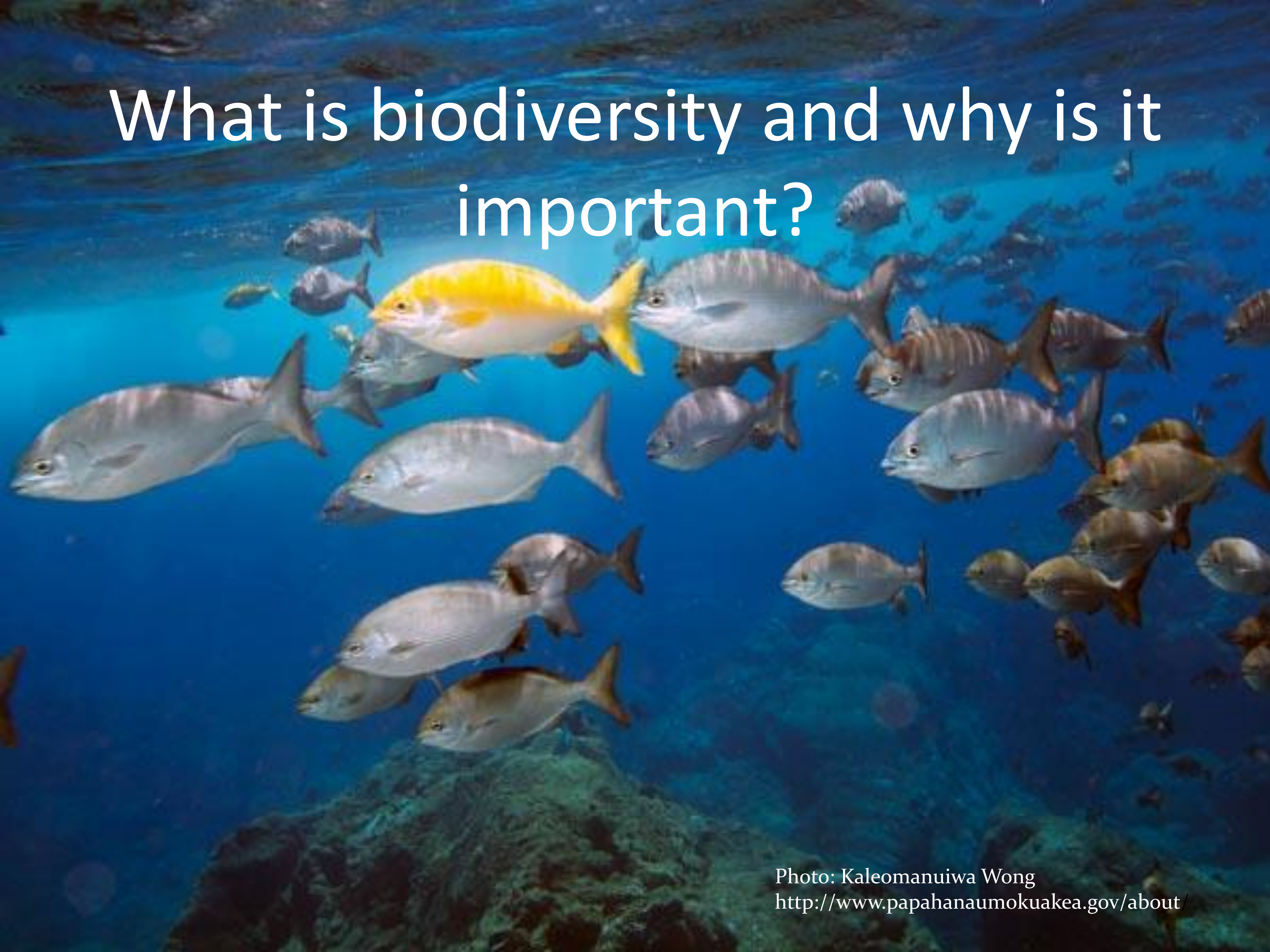


Photo: Kaleomanuiwa Wong
http://www.papahanaumokuakea.gov/about/

# What is biodiversity and why is it important?

- The variety of animals, plants, and other living things in a particular area.
- Each organism plays a role in its ecosystem and food web, for those systems to function properly diversity needs to be maintained.

# Biodiversity

- **Endemic** – a plant or animal species that has a highly localized or restricted geographic distribution
- **Native species** – present in an area naturally, not as a result of human activity
- **Invasive species** – a nonnative species that has a negative effect on native species by outcompeting or reducing their numbers
- **Species richness** – the number of species in an ecosystem
- **Alpha diversity** – number of species in a habitat
- **Beta diversity** – the variation or difference in species between two habitats

# How will these characteristics of biodiversity vary throughout PMNM?


http://www.papahanaumokuakea.gov/visit/welcome.html

# Papahānaumokuākea Marine National Monument

- Over 7,000 species
- Includes marine mammals, seabirds, shorebirds, corals, and fish
- At least ¼ are endemic
- Home to the world's most endangered duck, the Laysan Duck
- Also home to endangered Hawaiian Monk Seals and threatened Green Turtles

Endemic Nihoa Finch.

A curious Hawaiian monk seal at Kure Atoll.

# Richness

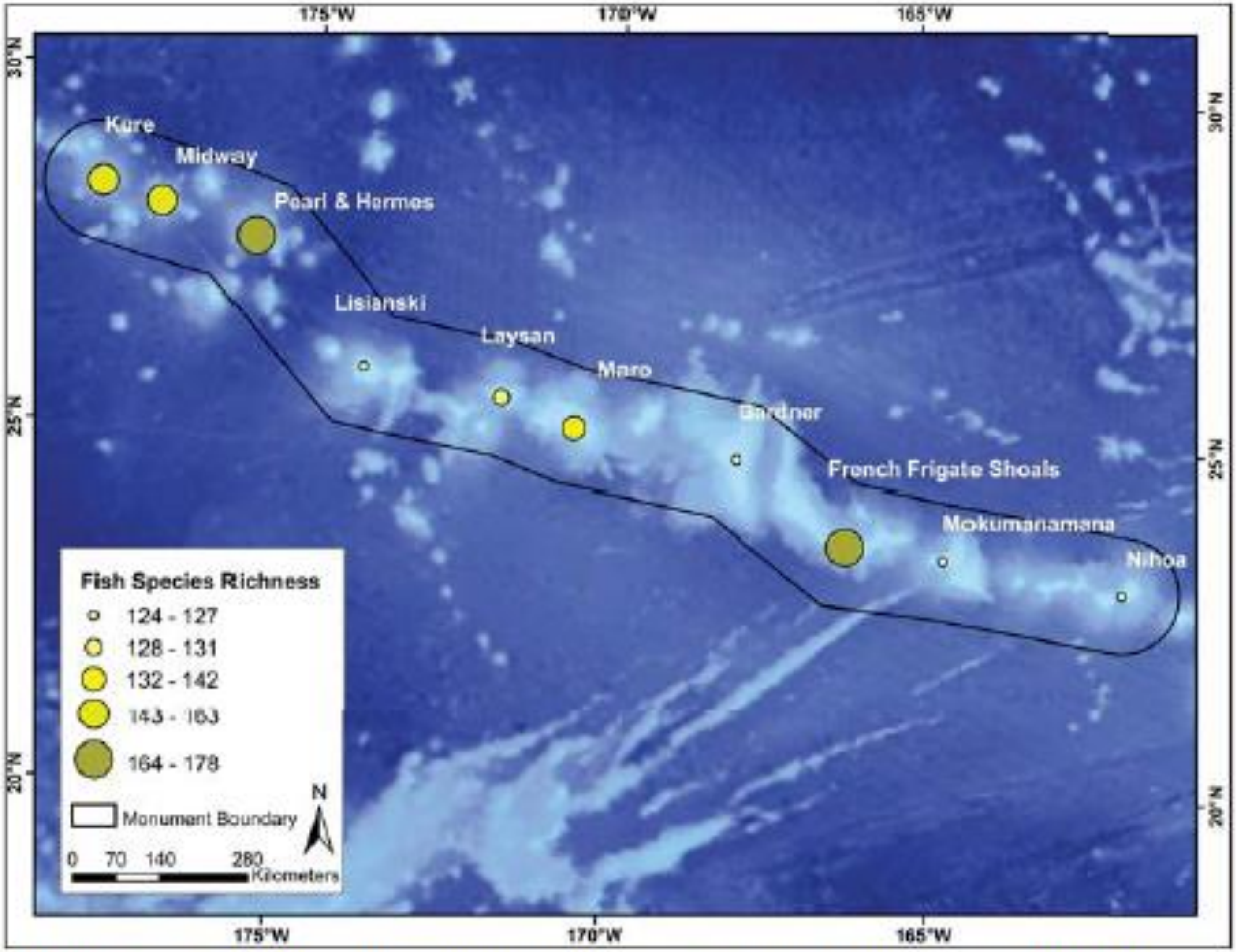
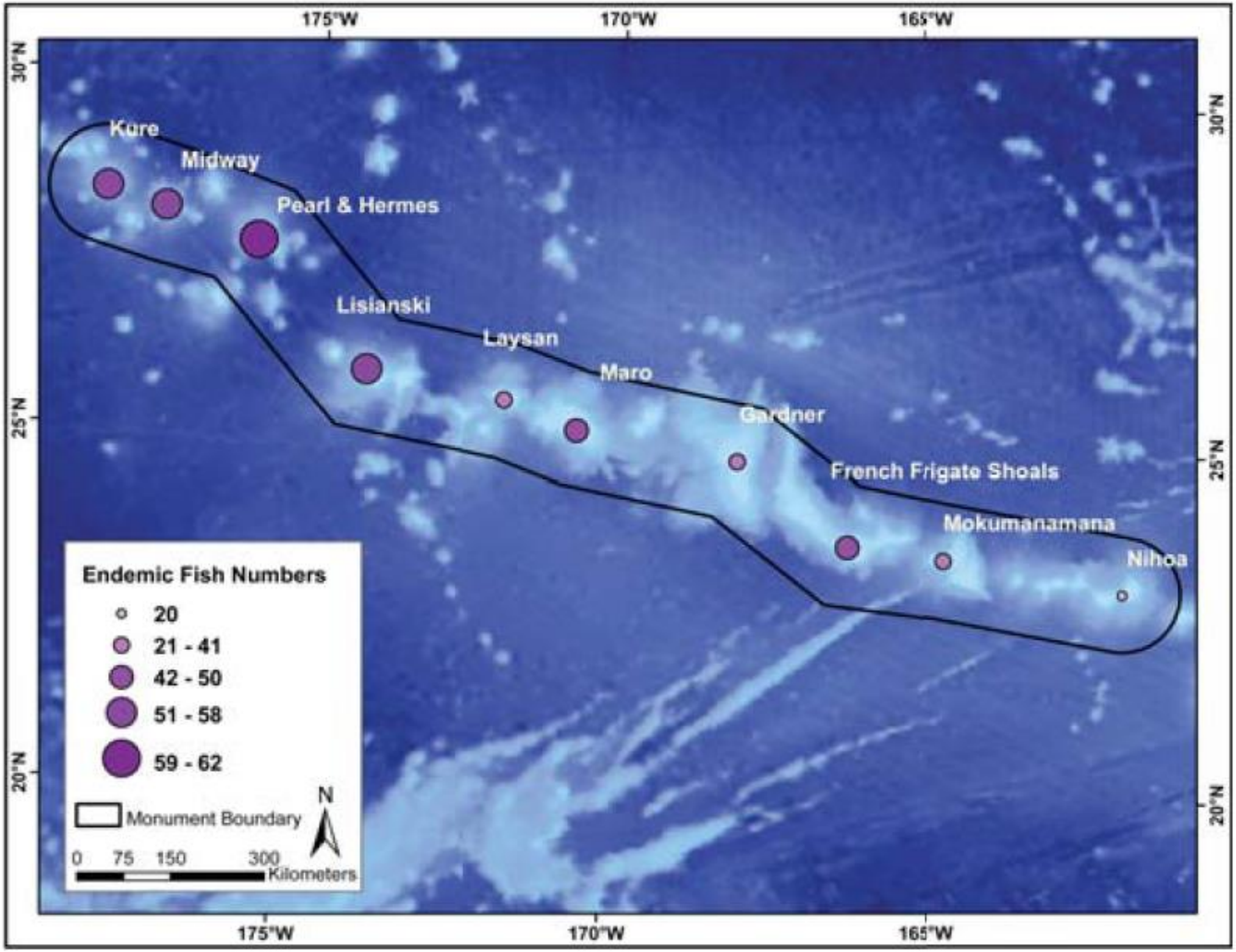



*Figure 5.3. Total fish species richness at each of 10 emergent NWHI reefs. Source: NWHI RAMP, unpub. data; map: L. Wedding.*

Map from *A Marine Biogeographic Assessment of the Northwestern Hawaiian Islands*

# Endemism

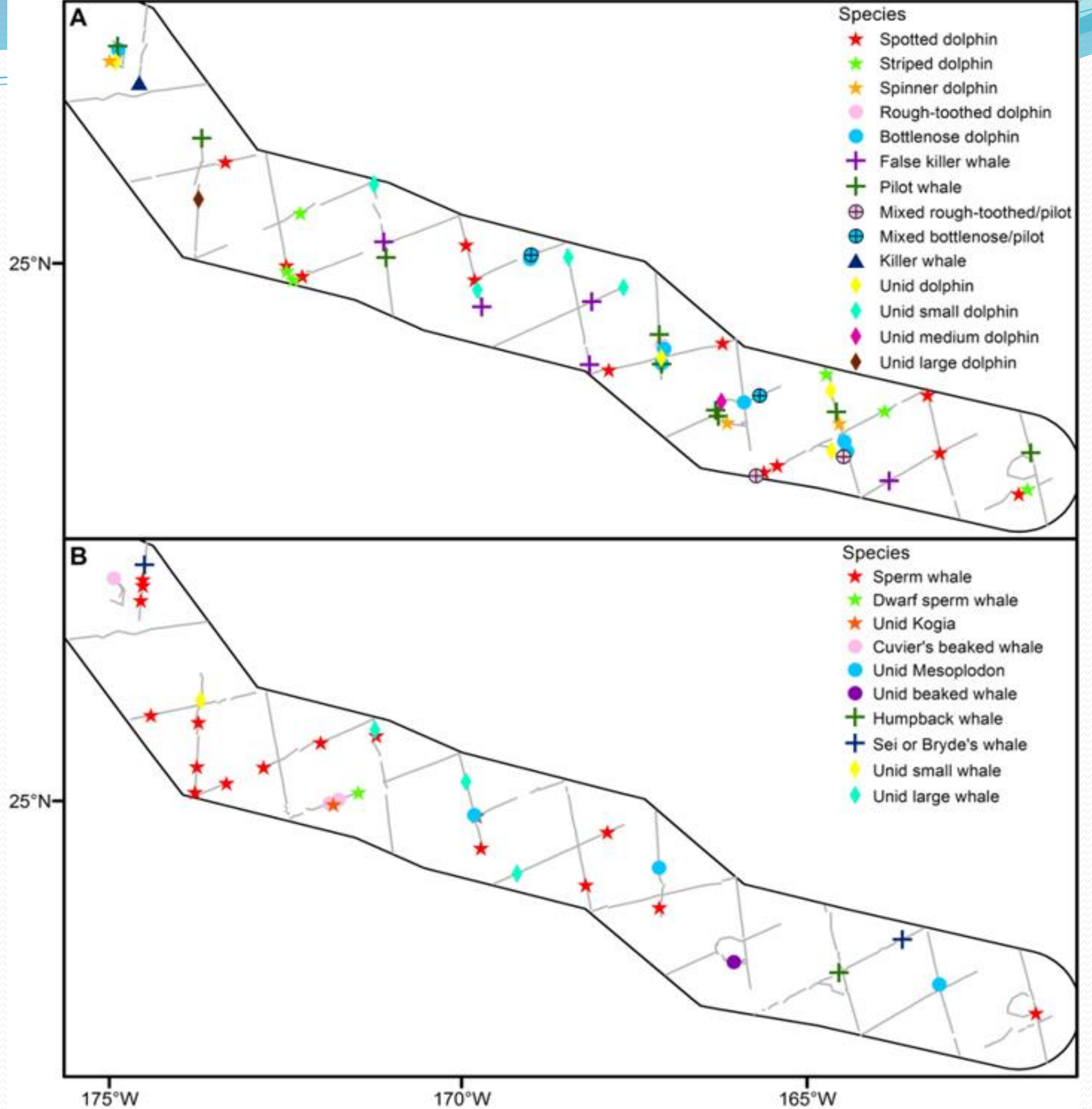



Map from *A Marine Biogeographic Assessment of the Northwestern Hawaiian Islands*

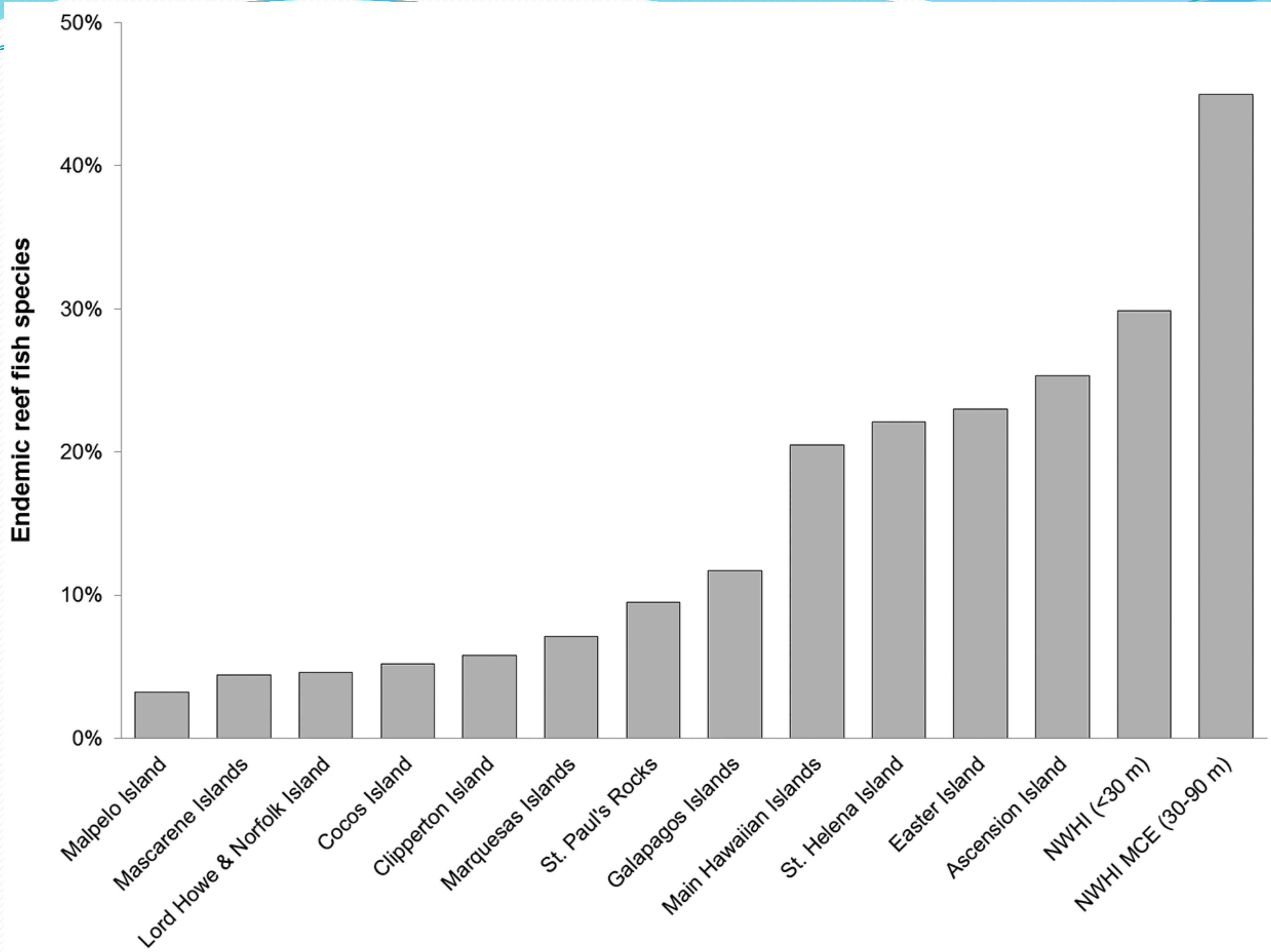
NOAA Cetacean Survey – May 7 to June 5, 2013 aboard the *Oscar Elton Sette.*

Observations were made visually and using acoustic instruments.

- *NOAA PIFSC Quarterly Research Bulletin Oct. 2013*



# Endemism

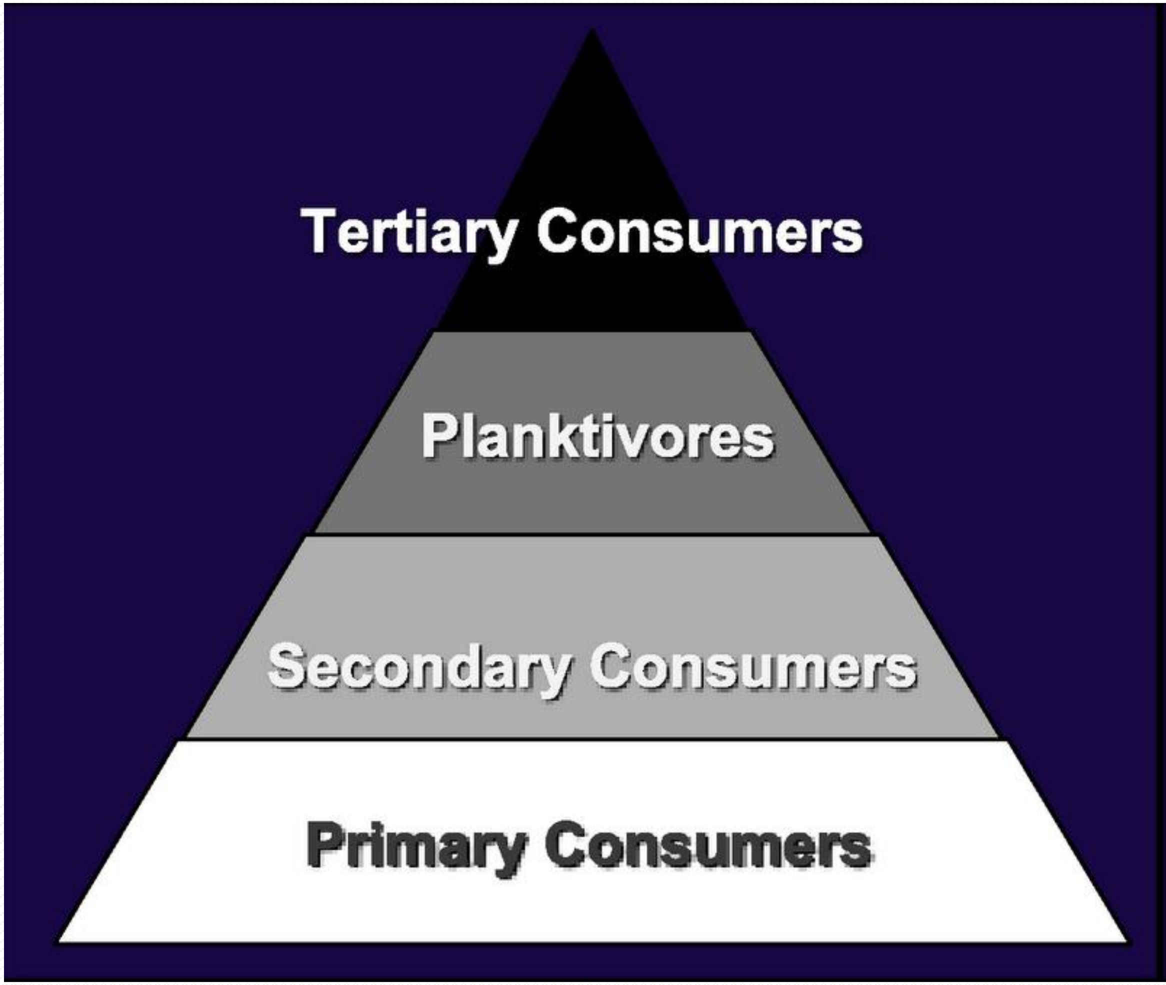



MCE – mesophotic coral ecosystems

Kane et al (2014) High levels of reef fish endemism in the Northwestern Hawaiian Islands.

# Biomass Pyramid

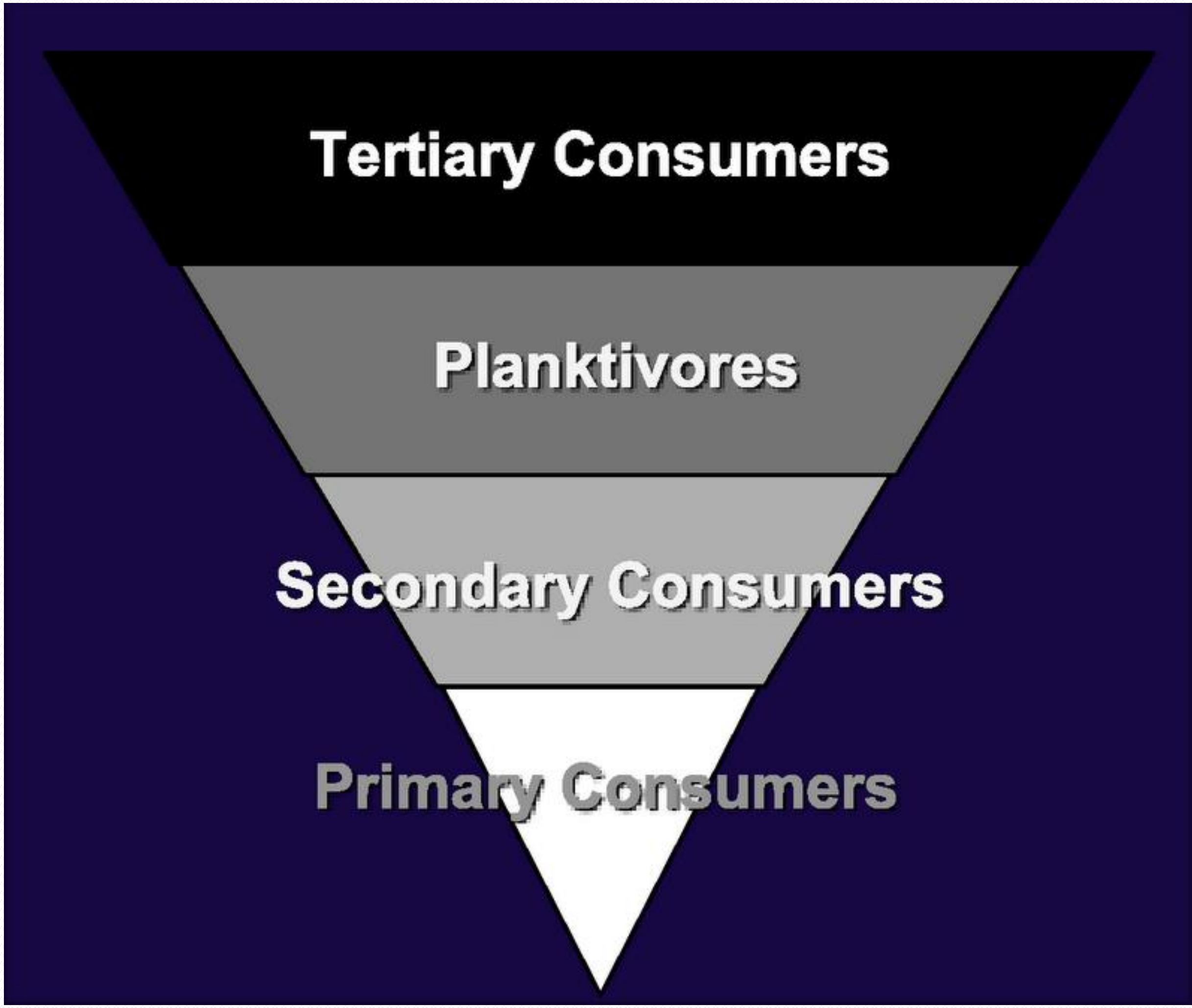
- People survey and record species number and size
- The data are converted to biomass and grouped together by tropic level
- In most coral reefs in the world, the biomass pyramid has fewer predators and more lower level consumers




NOAA PIFSC Coral Reef Ecosystem Division

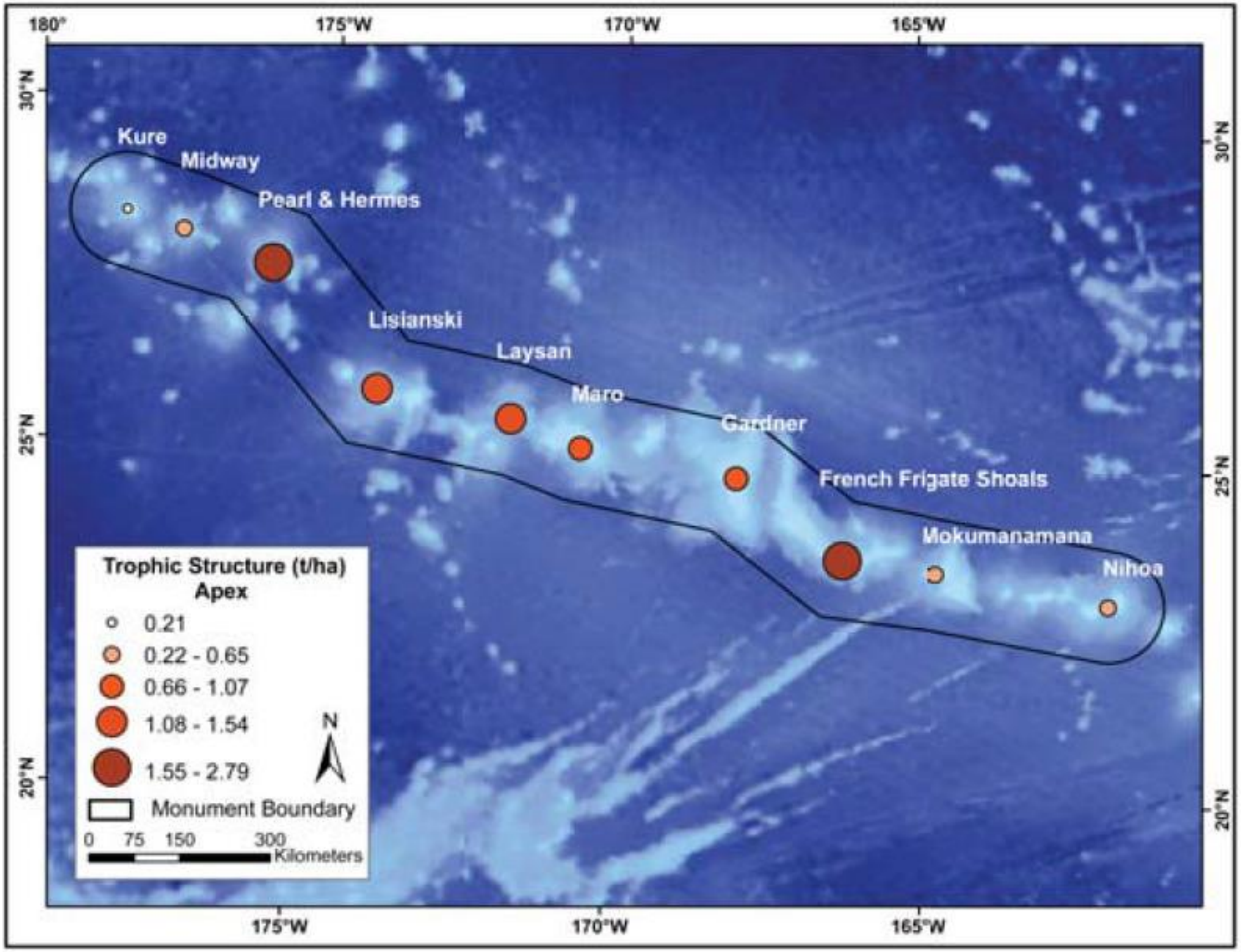
# Biomass Pyramid

- In the NWHI, there in an inverted biomass pyramid with more biomass found at the top predator level
- Apex predators account for 47% of total fish biomass in the NWHI
- Even higher at Pearl and Hermes (67%), French Frigate Shoals (61%), and Lisianski-Neva Shoal (58%)




NOAA PIFSC Coral Reef Ecosystem Division

# Apex Predators




A Marine Biogeographic Assessment of the NWHI

# Sharks

- Tiger sharks
- Grey Reef Sharks
- Galapagos Sharks
- Whitetip Reef Sharks

- University of Hawaii scientists are learning about where sharks go by catching and implanting small ultrasonic transmitters

Galapagos Sharks at Kure Atoll
Randy Kosaki NOAA

# Threats to biodiversity

- Water quality
- Development
- Shipping
- Invasive species
- Warming water temps
- Ocean acidification

# Papahānaumokuākea Marine National Monument: Biodiversity Student Worksheet

Name_______________________________________ Date___________________________________________

## Part 1: Species Investigation

1. Pick one organism (plant or animal) that lives in Papahānaumokuākea and research some basic facts about that organism. Where does it live? How does it behave? What does it need to survive?

2. What role does this organism play in the community? Is it a predator or prey? Does it help or take advantage of any other animals? Write down at least 3 interactions between your species and others in the ecosystem.

*Potential interactions include:*

- *animals/plants the organism eats or is eaten by*
- *plants/coral the organisms uses for shelter or to hide*
- *other organisms that the chosen species competes with for food or shelter*

Types of relationships they may mention:

- *Mutualistism – both organisms benefit from their relationship*
- *Commensalism – one organism benefits from the relationship without affecting the other organism*
- *Parasitism – one organism benefits from the relationship while the other is harmed*

## Part 2: Measuring and Comparing Biodiversity

There are several ways to measure biodiversity. Species richness is a measure of the number of species in a habitat, but it does not take into account how many of each species and how they are distributed. Diversity indexes, like the Shannon-Wiener Diversity Index, give scientists a metric to assess and compare different ecosystems. The value of the index gets higher as there are more species and the population of each is close (like 10 turtles and 8 fish as opposed to 10 turtles and 2 fish).

1. You do a survey of three coral reefs to find what type of species live in each and how their populations vary from place to place. The results of the survey are in the table below. Use the Shannon-Weiner diversity index to calculate the diversity index of each reef.

$$H' = -\sum_{i=1}^{R} p_i \log p_i$$

H' = diversity
∑ = sum of each species calculation
pi = the proportion of individuals within the community

| | Reef 1 | Reef 2 | Reef 3 |
|---|---|---|---|
| Parrotfish | 30 | 11 | 13 |
| Angelfish | 4 | 10 | 0 |
| Triggerfish | 6 | 9 | 17 |

<u>To calculate the index use the following steps.</u>

1. *Find the total population for the community:*
   *30 + 4 + 6 = 40*
2. *For the first species, Parrotfish, find the $p_i$, or what portion of the total population it equals:*
   *30/40 = 0.75*
3. *Use that value to find $p_i \log p_i$ :*
   *0.75log(0.75) = -0.094*
4. *Repeat for the two other species:*
   *4/40 = 0.10* *6/40 = 0.15*
   *0.10log(0.10) = -0.10* *0.15log(0.15) = -0.124*
5. *Get the sum of those values and multiply by -1:*
   *-0.094 + -0.10 + -0.124 = -0.318(-1) = 0.318*
6. *Repeat for the 2 other reefs and compare the final values*
7. *Reef 1 = 0.318* *Reef 2 = 0.465* *Reef 3 = 0.299*
8. *Reef 2 has the highest value, it has populations of all 3 species and they have very similar population numbers (it's evenly distributed). Reef 1 is next - it has all 3 species but heavily favors the parrotfish in terms of population. Reef 3 has only 2 of the 3 species represented.*

See *http://bumperscollege.uark.edu/west/3103/08diversityexercise.htm for additional numbers and explanation*

2. You do another survey of the three reefs and in addition to the fish listed above you find that there are tiger sharks and green turtles living at Reef 1. What is the alpha richness of each reef and the beta richness when the reefs are compared?

*Alpha richness is the number of species.*

*Reef 1 = 5 (tiger sharks, green turtles, parrotfish, angelfish, triggerfish) Reef 2 = 3 (parrotfish, angelfish, triggerfish) Reef 3 = 2 (parrotfish, triggerfish)*

*Beta Richness is the number of unique species in a community when compared to another.*

*Reef 1: compared to Reef 2 = 2 (tiger sharks and green turtles found at 1 but not 2), Reef 1 compared to Reef 3 = 3 (tiger sharks, green turtles, and angelfish found at 1 but not 3)*

*Reef 2 compared to Reef 3 = 1 (angelfish found at 2 but not 3), no unique when compared to Reef 1*

*Reef 3 has no unique species when compared to the other reefs*

3. Use the table of cetacean (whales and dolphins) populations in the main Hawaiian Islands and the outer Exclusive Economic Zone (EEZ) and the Excel sheet for the Shannon-Weiner Index to calculate diversity for each area. The EEZ is the boundary of waters that belong to the United States and is 200 nautical miles from shore. What is the diversity index for each? How do they compare? Why do they vary?

See Diverstiy Index Answer Key for completed spreadsheet

*SW Index for main islands = 0.80*
*SW Index for outer EEZ = 1.08*
*The outer EEZ has populations of 10 species the main islands don't have, while the reverse is only true for 1 species.*

*There are many factors that could contribute to the differences between the main islands and the outer EEZ. Human disturbance in the main Hawaiian Islands likely contributes somewhat to those islands have less species that the outer EEZ. The EEZ also encompasses a very large area and has some different features, like atolls and shoals, that are not found in the main Hawaiian Islands. Some of these species prefer to stay further offshore which may also be a factor differentiating the main islands from the outer EEZ.*

*Table 6.1. Estimated abundance of 19 cetacean species in the MHI and outer Hawaiian Islands EEZ. Overall abundances, overall densities, and coefficients of variation (CV) are pooled from the MHI and outer EEZ estimates. Pooled abundance and density estimates are given for delphinids and beaked whales. Asterisk (*) indicates a more recent estimate of false killer whale abundance in offshore waters of the Hawaiian EEZ (484 individuals, CV=0.93) comes from Barlow and Rankin (2007). Source: Barlow, 2006.*

| SPECIES | MAIN ISLAND ABUNDANCE (n) | OUTER EEZ ABUNDANCE (n) | OVERALL ABUNDANCE (n) | OVERALL DENSITY PER 1,000 $km^2$ (D) | CV |
|---|---|---|---|---|---|
| Offshore spotted dolphin | 4,283 | 4,695 | 8,978 | 3.66 | 0.48 |
| Striped dolphin | 660 | 12,483 | 13,143 | 5.36 | 0.46 |
| Spinner dolphin | 1,488 | 1,863 | 3,351 | 1.37 | 0.74 |
| Rough-toothed dolphin | 1,713 | 6,997 | 8,709 | 3.55 | 0.45 |
| Bottlenose dolphin | 465 | 2,750 | 3,215 | 1.31 | 0.59 |
| Risso's dolphin | 513 | 1,859 | 2,372 | 0.97 | 0.65 |
| Fraser's dolphin | 0 | 10,226 | 10,226 | 4.17 | 1.16 |
| Melon-headed whale | 0 | 2,950 | 2,950 | 1.20 | 1.17 |
| Pygmy killer whale | 956 | 0 | 956 | 0.39 | 0.83 |
| False killer whale * | 0 | 236 | 236 | 0.10 | 1.13 |
| Short-finned pilot whale | 3,190 | 5,680 | 8,870 | 3.62 | 0.38 |
| Killer whale | 0 | 349 | 349 | 0.14 | 0.98 |
| Sperm whale | 126 | 6,793 | 6,919 | 2.82 | 0.81 |
| Pygmy sperm whale | 0 | 7,138 | 7,138 | 2.91 | 1.12 |
| Dwarf sperm whale | 0 | 17,519 | 17,519 | 7.14 | 0.74 |
| Blainville's beaked whale | 0 | 2,872 | 2,872 | 1.17 | 1.25 |
| Cuvier's beaked whale | 0 | 15,242 | 15,242 | 6.21 | 1.43 |
| Longman's beaked whale | 0 | 1,007 | 1,007 | 0.41 | 1.26 |
| Bryde's whale | 0 | 469 | 469 | 0.19 | 0.45 |
| Delphinids pooled | 13,267 | 50,087 | 63,354 | 25.83 | |
| Beaked whales pooled | 371 | 19,121 | 19,492 | 7.95 | |

# Papahānaumokuākea Marine National Monument: Biodiversity Student Worksheet

Name________________________________________ Date____________________________________________

## Part 1: Species Investigation

1. Pick one organism (plant or animal) that lives in Papahānaumokuākea and research some basic facts about that organism. Where does it live? How does it behave? What does it need to survive?

2. What role does this organism play in the community? Is it a predator or prey? Does it help or take advantage of any other animals? Write down at least 3 interactions between your species and others in the ecosystem.

## Part 2: Measuring and Comparing Biodiversity

There are several ways to measure biodiversity. Species richness is a measure of the number of species in a habitat, but it does not take into account how many of each species and how they are distributed. Diversity indexes, like the Shannon-Wiener Diversity Index, give scientists a metric to assess and compare different ecosystems. The value of the index gets higher as there are more species and the population of each is close (like 10 turtles and 8 fish as opposed to 10 turtles and 2 fish).

1. You do a survey of three coral reefs to find what type of species live in each and how their populations vary from place to place. The results of the survey are in the table below. Use the Shannon-Weiner diversity index to calculate the diversity index of each reef.

$$H' = -\sum_{i=1}^{R} p_i \log p_i$$

H' = diversity
∑ = sum of each individual
pi = the proportion of individuals within the community

| | Reef 1 | Reef 2 | Reef 3 |
|---|---|---|---|
| Parrotfish | 30 | 11 | 13 |
| Angelfish | 4 | 10 | 0 |
| Triggerfish | 6 | 9 | 17 |

2. You do another survey of the three reefs and in addition to the fish listed above you find that there are tiger sharks and green turtles living at Reef 1. What is the alpha richness of each reef and the beta richness when the reefs are compared?

3. Use the table of cetacean populations in the main Hawaiian Islands and the outer Exclusive Economic Zone (EEZ) and the Excel sheet for the Shannon-Weiner Index to calculate diversity for each area. The EEZ is the boundary of waters that belong to the United States and is 200 nautical miles from shore. What is the diversity index for each? How do they compare? Why do they vary?

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| Rough-toothed dolphin | 1,713 | 6,997 | 8,709 | 3.55 | 0.45 |
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| Pygmy killer whale | 956 | 0 | 956 | 0.39 | 0.83 |
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| Killer whale | 0 | 349 | 349 | 0.14 | 0.98 |
| Sperm whale | 126 | 6,793 | 6,919 | 2.82 | 0.81 |
| Pygmy sperm whale | 0 | 7,138 | 7,138 | 2.91 | 1.12 |
| Dwarf sperm whale | 0 | 17,519 | 17,519 | 7.14 | 0.74 |
| Blainville's beaked whale | 0 | 2,872 | 2,872 | 1.17 | 1.25 |
| Cuvier's beaked whale | 0 | 15,242 | 15,242 | 6.21 | 1.43 |
| Longman's beaked whale | 0 | 1,007 | 1,007 | 0.41 | 1.26 |
| Bryde's whale | 0 | 469 | 469 | 0.19 | 0.45 |
| Delphinids pooled | 13,267 | 50,087 | 63,354 | 25.83 | |
| Beaked whales pooled | 371 | 19,121 | 19,492 | 7.95 | |