Understanding Biodiversity: Hawaii

1. Understanding Biodiversity
    a. This is a presentation meant to communicate the important aspects of biodiversity to school classes. This presentation covers a few basic concepts in evolutionary biology. The presentation is most appropriate for middle to high school groups and was written to help prepare student groups for the BioBlitz activity in Volcanoes National Park during May 2015. If you have any questions, suggestions or comments you can contact the author, Raphael Ritson-Williams at raphswall@gmail.com. Raphael is a PhD student at the University of Hawaii who studies coral reefs and is interested all aspects of evolution and biodiversity. He is funded by a STAR Fellowship Assistance Agreement # FP917660 awarded by the U.S. Environmental Protection Agency (EPA). This presentation has not been formally reviewed by EPA. The views expressed in this presentation are solely those of the author, and EPA does not endorse any products or commercial services mentioned in this publication.
2. Taxonomy: How we name things
    a. We must catalog life to understand biodiversity. A critical part of cataloging life is putting a name on a creature. There are many scientific rules for naming species. These are meant to ensure that each species has a unique name that identifies it and provides some information about relatedness to other creatures.
3. Taxonomy: How we name things
    a. Binomial names consist of a genus and then a species name. This allows us to see if two species are in the same genus (a very close relationship like a brother/sister). This slide shows two different cats, one is the house cat and the other is a tiger. Both of these are in the same family but they are distantly related so are not in the same genus.
4. Taxonomy: How we name things
    a. When we catalog a species we put it into a hierarchy of categories. The most broad is the domain then the kingdom. The main kingdoms are animal, plant or bacteria (there are a few other kingdoms including fungi and other microbes). Phyla are broad categories based on body plan. All vertebrates are in the phyla Chordata, this includes diverse creatures such as birds, amphibians, fish and mammals. Other phyla include Cnidaria (corals and anemones), Porifera (sponges), Arthropoda (insects and crustaceans), Mollusca (snails, clams and other shells), Annelida (worms) and many more smaller phyla. There are approximately 35 phyla of animals that are currently living on the planet (but we are still discovering how all these groups are related to each other). Class and Order are further categories that bring increasingly related species together. Family is a group of closely

related genera, you can think of this like your family tree, there are different last names but all are related. Genus and species are the most refined categories and every organism with a unique genus species name is considered different from other species.

5. Taxonomy: What is a species?
    a. A species is a unique name for an individual group of organisms. There are many concepts for how to differentiate one species from another. The most accepted definition of a species is two animals that can reproduce and produce a viable offspring. This is the biological species concept. Sometimes two species can reproduce and produce an offspring but it is not viable. This is the case with a horse and donkey, they produce a sterile mule. So these are two different species that can make a hybrid but because the mule is sterile they remain separate species.
6. Taxonomy: What is a species?
    a. How many species of butterfly do you think are on this slide? 8 species in 4 different genera. Scientists rely on the shape and color (their morphology) of individual organisms to determine their proper scientific name. This was true for hundreds of years but now technology is changing the way we define species. We can compare DNA from multiple organisms and measure their genetic similarity. Increasingly scientists are using DNA to distinguish one species from another (similar to a fingerprinting analysis) because many species look the same, or some species look different but have the same DNA. We are starting to build up an incredible database of species' DNA, but there are still many species that have not been sequenced so scientists still rely on morphology and color patterns to identify species during collecting trips (such as the BioBlitz).
7. Land Biodiversity
    a. The majority (80%) of living species are insects, they are thought to have 1 million species of the 10-12 million predicted species on the planet. Tropical rainforests can host a huge amount of different species and are critical habitats to protect to conserve biodiversity. For instance Columbia hosts 10% of all the species on earth. Over 1,900 species of birds (18% of the total alive), and more than 10% of the mammals currently found on the planet.
8. Marine Biodiversity
    a. There are 250,000 species that are cataloged in the oceans with an estimated diversity of 1 million species (the same as the number of insects!). There are currently 31,000 species of fish (Chordata), 85,000 snails/shells (Mollusca), 47,000 species of crabs and shrimp (Crustacea). At a larger taxonomic scale marine ecosystems host more than 95% of the living phyla, which include some groups exclusively found in marine habitats like the sea stars and sea urchins (Echinodermata).
9. Biodiversity: What we know

a. There are 1.9 million species that have names that are currently alive on the planet. There were even more species that have gone extinct, these are only known from fossils now.
b. More species live in tropical habitats such as rainforests and coral reefs. Locations like Hawai'i that have a variety of habitats (possible because of the drastic change in elevation from sea level to 13,796 ft at the peak of Mauna Kea) can contain lots of biodiversity in a relatively small area.

10. Biodiversity: What we need to know
    a. There are probably 11-12 million species on the planet. That means we have only given names to 15% of life on the planet! Scientific expeditions have cataloged much of the species diversity we know, but many habitats such as the deep sea continue to be difficult places for us to study. Even more troubling is that even as we are discovering unnamed species other species are going extinct. How can we hope to understand biodiversity if creatures are dying before we can name them? The BioBlitz program is a unique opportunity to participate in an effort to catalog and understand biodiversity in diverse habitats of Hawai'i.
11. Hawaii as a diversity laboratory
    a. When Hawai'ian islands first appeared out of the ocean they were just lava. This map has the approximate age of each of the islands, Kauai is 5.1 million years old, Hawai'i island is 0.01-0.43 millions years old, depending on which volcano you measure! Over time individual species found these islands. This is a very challenging task, organisms had to cross 1,000's of miles of open ocean. If a new colonizer arrived to the island it was very difficult to survive as there was probably little food and harsh conditions. However, some organisms were able to take advantage of unoccupied space. Those animals that did survive evolved into many unique creatures that are found nowhere else on the planet. This makes the Hawai'ian islands a great place to study the process of evolution in a place that had relatively few initial colonizers.
12. Hawaii, a history of colonization
    a. Those first colonizers have some common traits that allowed them to travel great distances across the ocean. Ferns colonized the islands because they had small spores that could be dispersed by the winds. Many of the new plant species had wind borne seeds. A few birds landed on the islands and diversified to fill many niches. Some insects also found the islands. These are flying insects or spiders that could also be dispersed by the wind. Interestingly almost no mammals found the islands (before man came here). How would a mammal get here? Fly or swim! The only two mammals that are native to Hawaii are a bat and the monk seal. No snakes or other reptiles (except sea turtles) found the islands. This lack of snakes and mammals means

that many organisms such as birds had no predators, an important factor for the extensive speciation that happened on these islands.

b. You can observe a similar process happening during your hikes at Volcanoes National Park. Compare the plants that are the first to live on a lava flow. This is the same type of process that was first used to colonize the islands. The only difference is there is an adjacent source of seeds (notice the forest that grows above and next to the lava). Do your students see how this is similar but different (much less distance to travel) than the initial colonization of the Hawai'ian islands?

13. Hawai'i is a cradle for endemic species
    a. Life in Hawaii had to colonize new land. When one species found the islands they diversified into different habitats evolving into many different species. Scientists call this process adaptive radiation, meaning that organisms have adapted to different niches causing a radiation of species from only a few initial species.
    b. Adaptive radiation is responsible for much of the diversity found in Hawaii, especially since there are so many different types of habitats. For instance, 110 Hawaiian birds evolved from 30 original ancestors that colonized the islands. 1,100 flowering plants evolved from 280 colonizers, and 10,000 endemic insects and spiders evolved from 350-400 original species. If a species is unique to Hawai'i and found nowhere else it is called **endemic**. **Indigenous** species naturally occur in Hawai'i and are also found in other places. **Invasive** species are introduced by humans and threaten native species.
14. Hawai'i is a diversity host spot: Honeycreeper adaptive radiation
    a. Birds-Honeycreepers have evolved (during 100,000 years) into 55 species from a single colonizing species (probably a Eurasian rose finch) that arrived on the islands. 38 of 55 Hawaiian honeycreepers are extinct. These birds have gone extinct due to invasive predators (mongoose, rat, cat), habitat destruction (land development and clearing for sugar cane), and disease (an invasive mosquito species carries avian malaria (a disease similar to human malaria) that is one of the most pressing threats to endemic birds).
15. Hawai'ian birds
    a. This is 'Apapane which is a honeycreeper species that is common at Volcanoes National Park, especially on its host the 'Ohi'a lehua tree. This species eats nectar from the lehua flowers and is very similar to the 'I'iwi which is rarely seen.
16. Hawai'ian birds
    a. These are two of the honeycreeper species that are still common (although much more rare than they used to be). The 'I'iwi on the right and the 'Apapane on the left. The 'I'iwi was cherished in the native Hawai'ian society for their feathers that were used to make cloaks and helmets for the nobility.
    b. You can distinguish these similar looking species by the white patch on the underside of 'Apapane, where 'I'iwi is all red. Also the 'I'iwi has

a salmon colored beak that is more strongly curved. Watch for the ‘Apapane and the ‘I’iwi that both feed on nectar from lehua flowers.

17. Hawai’ian birds
    a. This is the ‘Amakihi which is a honeycreeper species that is still common (although much more rare than they used to be). The ‘Amakihi feeds on nectar from lehua flowers and will also eat insects and spiders.
18. Hawai’ian spiders
    a. How many species of spiders do you think are on this slide? Only one! This species of spiders has many different color patterns but has been shown to be all the same species.
19. Hawai’ian insects
    a. There are many insect species that are endemic to Hawai’i. The Kamehameha butterfly is only found in Hawai’i and is the state insect. There are 4 species of dragonfly and 23 species of damselflies (very similar to dragonflies) in Hawai’i. Happy face spiders can be found under leaves in native forests. Fruit flies have also radiated into 800 species among the Hawai’ian islands.
20. Hawai’ian plants
    a. The Hawaiian silverswords are a great example of a plant adaptive radiation. The silverswords such as *Argyroxiphium sandwicense* have leaves in the shape of a sword and they have silvery hair that helps to protect them from UV radiation. This type of **adaptation** is an evolved trait that allows the use of a special niche. This usually means that an organism can live in a special place or use a food source than no other creature uses. Adaptation is key to adaptive radiations as it allows diversification of species that use different habitats.
    b. The silverswords are threatened species that live on the mountains in Maui and Hawai’i in elevations above 1,500 meters. Plants in this family have very different morphologies. They only bloom every 20-90 years so can be inconspicuous. Different species occur on different islands, but the critically endangered species *Argyroxiphium kauense* is found on Hawai’i in high elevations on Mauna Loa. There are probably fewer than 500 individual Mauna Loa silverswords, and they are most abundant in the Kahuku district of Volcanoes National Park.
21. Identifying Hawai’ian Plants
    a. This is the flower of the ‘Ohi’a lehua tree. Notice that this flower is made of stamens (not petals like many flowers) that grow out of the individual flowers. This is one of the most common plants in Volcanoes National Park. It is very important because many native birds eat the nectar from these flowers.
    b. ‘Ohi’a lehua has a distinct pattern of leaf growth. Two leaves grow opposite of each other, and then the next two leaves are rotated 90 degrees from the previous ones. This gives the branches a layered effect.

22. Identifying Hawai'ian Plants
    a. 'Ohi'a lehua can grow to be large trees in the rain and dry forest. These trees are critical habitat for all types of creatures including many of the endemic birds. One of the reasons this tree species is so common is that it can grow in a variety of different habitat types.
23. Identifying Hawai'ian plants
    a. This plant, 'Ohelo is related to the blueberry, but is endemic to Hawaii. It can grow as short shrubs and is important food for nene, the Hawai'ian goose. Make sure to tell your students to never eat wild berries, many of them are poisonous. Notice that this plant has larger glossy leaves with distinct veins, a point at the end, and serrated (toothy) leaf edges.
24. Identifying Hawai'ian plants
    a. Lobelioids are flowering plants that have radiated into 125 species on the Hawai'ian islands from one colonizer approximately 13 million years ago. These plants have very few natural herbivores so are not well defended. This makes them especially susceptible to invasive consumers including goats, sheep, deer, pigs and rats.
25. Identifying Hawai'ian plants
    a. Lobelioids have special curved flowers. Which bird is better adapted to reach the nectar at the bottom of this flower? Most birds can not reach the nectar at the end of these flowers. A few birds have evolved to take advantage of these curved flowers, this type of evolution of a trait that allows the use of a special resource is called an **adaptation**. The curved beak of the 'I'iwi (on the right) allows it to take advantage of the nectar in these flowers.
26. Identifying Hawai'ian plants
    a. This is a fern. There are many different fern species endemic to Hawaii and often ferns are the first to colonize lava flows since they have air borne spores. The large tree ferns are common in the park and are called Hapu 'u pulu, these are endemic to Hawaii.
27. Identifying Hawai'ian plants
    a. Gingers are quite common in Volcanoes NP. Notice the broad leaves growing alternate (one above the other on different sides of the stalk) and how the leaves grow directly from the stalk, there are no branches. Gingers are prized for their beautiful flowers but these plants are invasive, and have rapidly spreading roots. They occupy understory space outcompeting endemic species such as the tree fern.
28. Conserving Hawai'ian biodiversity
    a. There are many threats to the endemic species found in Hawai'i and other tropical rainforests around the world. Habitat destruction by development removes natural forests and fragments the remaining forest. Invasive species such as mongoose, rats, cats, all eat endemic birds finding them easy prey because they had no predators before people. Pigs, goats and sheep dig up plant roots and eat native trees that are critical habitat for native birds and insects. Invasive plants

such as ginger are displacing native species reducing available habitat. Climate change is already shifting temperatures making it difficult for some species to survive in their unique habitats such as the silverswords on Mauna Loa.

29. Identifying plants: A local exercise
    a. The next two slides can be printed front and back and can be an exercise during class (if you have access to a safe space with some different plants) or can be a homework assignment. This is meant to be an exercise to students to get used to observing species in the field. They should take 5-15 minutes observing and sketching their plant. I recommend drawing a plant rather than taking a photo, it should make the student pay close attention to the details like what type of leaf and branching pattern that they might not notice in a photo. Ask your students to use the bold words in the glossary so that they can learn some important scientific vocabulary. You can assign the name of the species as homework, giving your students a chance to try to find scientific information on the web. Sometimes this can be hard so don't expect a perfect identification but often the easiest thing is to enter a common name into a search engine. Alternatively you can encourage your students to use iNaturalist if they have access to the app) as a way to identify and get used to using this application. In iNaturalist ask them to download a copy of the guide "Plants of Hawaii Volcanoes National Park" and choose a plant species to use for the exercise.
30. Worksheet can be printed for active learning exercise
31. Glossary can be printed for active learning exercise