"SPINES ACROSS THE WATER"
Modules

Module 1- Lessons in Coral Reef Ecology

Objectives: 1) Provide an overview of what reef ecology is, 2) Discuss how reef ecology relates to conservation of habitat, and 3) Describe the importance of *Diadema* and *Acropora* corals on Caribbean reef tracts

Vocabulary

Acropora cervicornis
Acropora palmata
Biodiversity
Calcium carbonate
Coral colony
Coral polyp
Diadema antillarum
Herbivory
Ecosystem services
Keystone species
Mutualistic symbiotic relationship
Niche
Outplanting
Overfishing
Positive feedback loops
Scleractinian corals
Symbiotic
Zooxanthellae

What is a coral reef and why are they so important?

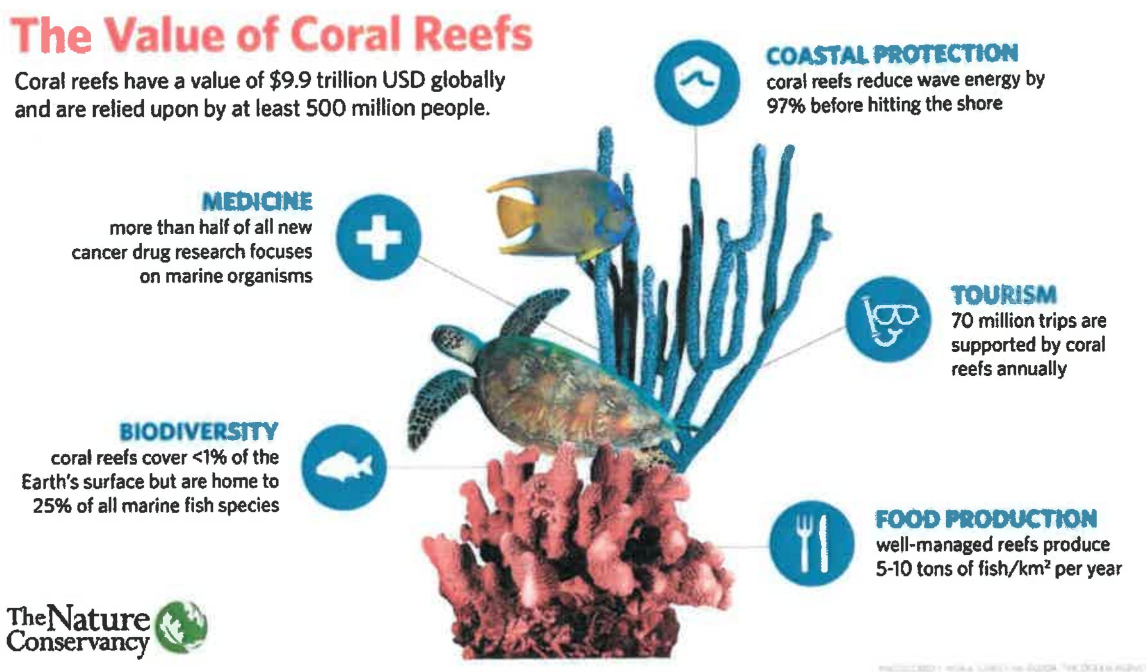
What is a coral reef?

Coral reefs are some of the most complex and intricate ecosystems on this planet. Think of a tropical rain forest, with tiny microorganisms in the soil, the roots of trees that grow from the soil, and the shelter and protection the tree canopies provide for the animals living there. Now consider the animals that get their food and protection from the trees, and the many interactions that occur. Now imagine that underwater- that is a coral reef. Coral reefs that have been evolving for millions of years forming into one of the most **biodiverse** and economically important ecosystems. Coral reefs make up less than 1% of the ocean floor but provide oxygen exchange services that are essential for all land and aquatic life and house nearly 25% of all marine species That means one-fourth of the entire ocean depends on healthy coral reefs to keep our oceans stabilized.

What are the benefits of a coral reef?

Coral reefs provide something called **ecosystem services** (services that would normally cost us money to do ourselves, but the ecosystem provides them naturally at no cost to us). This includes things like shoreline protection from erosion and storms, fisheries services for economic income and food sources, even to something like cleaning the fish we eat and keeping them parasite free. Without coral reefs, the ocean would be a very different place, and without the ocean, our world would be a very different place.

Figure 1: Coral reef benefits (Source: Nature Conservancy)



How is a coral reef formed?

The foundation of coral reefs is the vibrantly colored and slow-growing hard corals, or **scleractinian** corals. These corals are considered to be "reef-building" as they secrete a hard, **calcium carbonate** skeleton that resembles a rock. The coral secretes layers of the skeleton overtime forming the reef substrate that supports new coral growth and formation of habitat. The animal that builds this skeleton and structure is called the coral **"polyp"**. The polyp is in the same family as jellyfish, and contain stinging cells called nematocysts that help the polyp capture tiny zooplankton in the water column as a food source. The polyps also get nutrients from microscopic, single-celled algae in their tissue called **"zooxanthellae"**. In addition to the nutrients the coral needs to grow and maintain its health zooxanthellae also gives the coral its vibrant and distinct colors.

Question: Is a coral a rock, animal, or plant?

Corals come in many growth forms, including plate-like, encrusting, boulder, pillar, and branching. In the Florida Keys and Caribbean, branching corals in the genus *Acropora* were once the most abundant. Two species of *Acropora* are present in the Caribbean- ***Acropora cervicornis*** (staghorn coral) and ***Acropora palmata*** (elkhorn coral). These corals branch up from the reef structure, like skyscrapers in a city, creating an intricate three-dimensional habitat and structure for organisms living and growing on the reef to inhabit. This provides room for many species to occupy different **niches**, or roles, within the ecosystem.

Figure 2: *Acropora cervicornis* (Staghorn coral); *Acropora palmata* (Elkhorn coral)

Each organism has a special relationship to one another, for example, corals and macroalgae compete for space on the reef. Macroalgae can outgrow corals, but herbivorous fish and invertebrates, like the long-spine sea urchin ***Diadema antillarum***, eat the macroalgae allowing corals to continue growing.

Figure 3: *Diadema antillarum* aggregate

Why is *Diadema antillarum* important?

Together with other herbivorous fish and invertebrates, *Diadema* eat macroalgae that compete with corals for space on the reef. This exposes bare reef substrate that provides a place for crustose coralline algae (CCA) to form. CCA promotes recruitment of new marine life, and therefore this process is quite important to continue healthy coral reef functions. The bare substrate exposed by the urchins' intense grazing effects can be seen on both small and large scales. Local grazing effects reveal clear and distinct patches of "clean" reef substrate- where urchins have grazed- and macroalgae covered substrate right next to the grazing area- where urchins have not grazed. *Diadema* grazing effects can also be seen on a macro-scale from satellite images as "halos" around patch reefs. You can think of *Diadema* as the landscapers and gardeners of the reef. Just like a gardener continuously picks weeds out of their garden to ensure that the flowers can grow, *Diadema* consume algae, allowing the corals to grow.

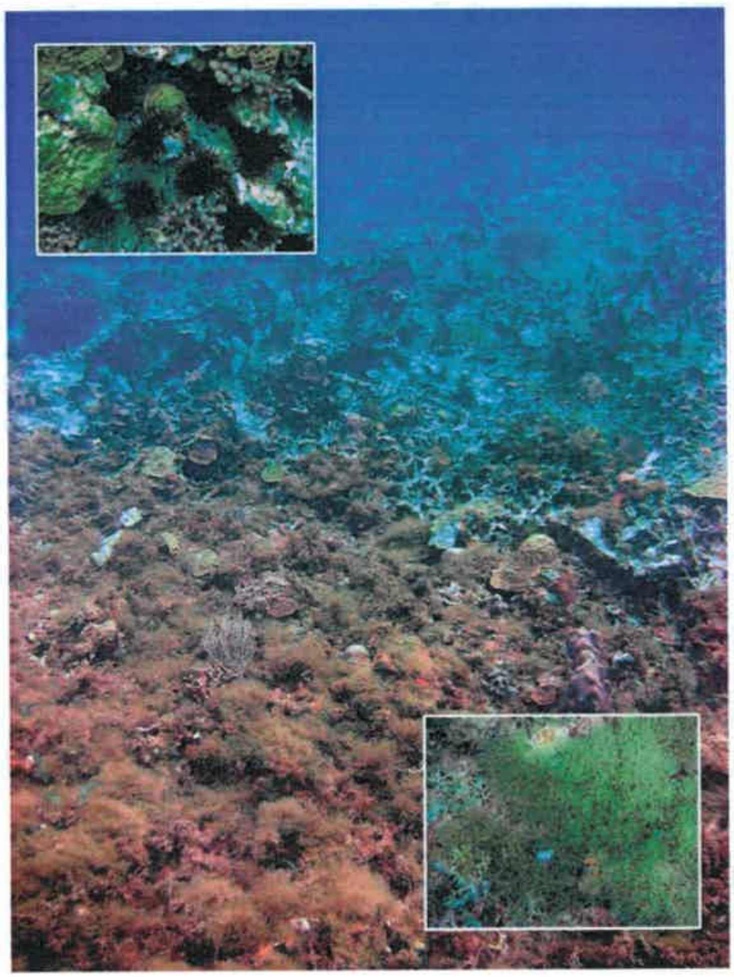


Figure 4: Grazing effects of *Diadema*

The relationship between corals and algae is a **symbiotic** relationship, meaning that two animals exist or live together and affect the condition of each other. The symbiotic relationship between corals and *Diadema*, is considered **mutualistic**, where the presence of each animal benefits the other. With a healthy herbivore abundance, corals are able to outcompete the faster-growing macroalgae on reefs, continuing to build reefs, and provide homes for thousands of animals.

What happened to our reefs?

While climate change progresses as the present most critical stressor affecting reefs today, historical fishing pressures are considered the starting point of reef decline. Overfishing of commercially and ecologically important fish species caused a decline in the overall abundance of herbivorous and omnivorous fishes that contribute to positive coral growth and health. In the early 1970s, hard coral cover, specifically that of the environmentally sensitive species *A. cervicornis* and *A. palmata*, drastically decreased due to an outbreak of coral disease. Bouts of coral bleaching and consistent, poor water quality over the next several years compounded the issues, and greater coral numbers began to decline.

Weakened coral populations were able to persist however, as *Diadema* grazing kept the stress of competing macroalgae and corals in check, until 1983, when a plague swept through *Diadema* populations... Over the period of one year, the plague spread from Panama throughout the Caribbean over an area of approximately 3.5 million km^2.*Diadema* populations perished up to 93% in most areas of the Caribbean. The *Diadema* die-off was one of the largest documented near mass extinction events ever recorded for a marine species. The cause of the mortality remains unknown, but is suspected to be a species-specific water-borne pathogen, whose spread was facilitated by currents throughout the entire Caribbean. While exact cause of the pathogen is unclear, the pathogen that initiated mass mortalities is thought to no longer persist at present, and therefore, not considered a threat to current *Diadema* populations.

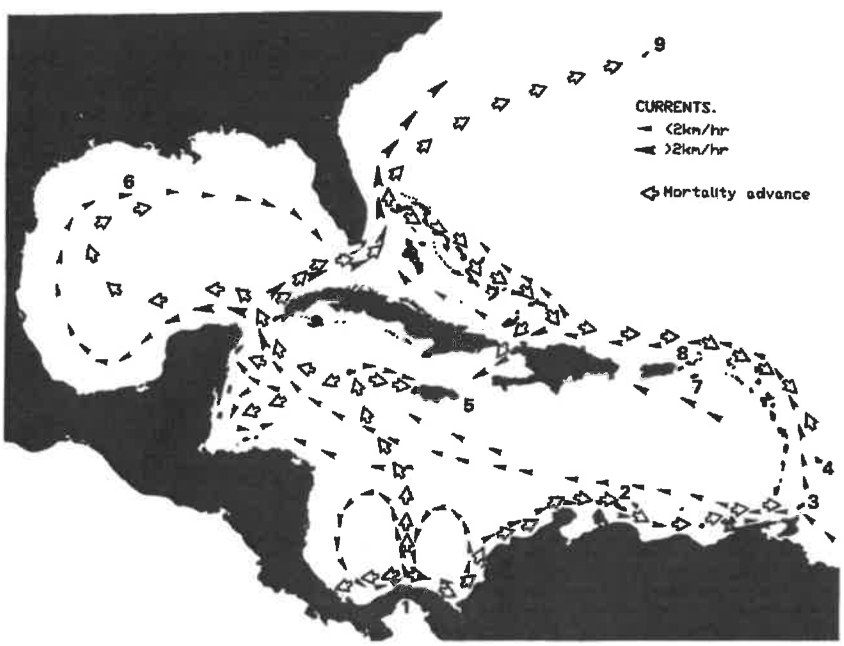


Figure: The spread of *D. antillarum* mass mortality through the Caribbean in relation to surface currents. The direction of spread was deduced from the timing of outbreaks at each locality. 1: Panama, 2: Curacao, 3: Tobago, 4: Barbados, 5: Jamaica, 6: Flower Garden Banks, 7: St. Croix, 8: St. Thomas. 9: Bermuda (Lessios, 1988).

Aside from the devastating impact to *Diadema* populations, the *Diadema* die-off marked a clear point in time where coral abundance decreased and macroalgae abundance spiked. This spike in macroalgae is correlated and thought to be the cause of mass mortality in the already failing Caribbean *Acropora* populations. Today, *Diadema* populations are 25 times less dense than populations on reefs before the mass mortality event. This drastic decline in herbivore abundance, coupled with an increase in macroalgae abundance, is thought to be the first signs of a possible shift on Caribbean reefs from coral-dominated to algae-dominated state.

Although declines in coral cover have slowed since the 1980s, recovery back to a coral-dominated state is not recorded for most regions of the Caribbean and in the Florida Keys. It is thought that the resilience of these ecosystems has been weakened by the multiple stressors they face, making them more susceptible to stressful events, decreasing the chances for reefs to reverse back to coral-dominated states. Research that has been conducted provides considerable evidence that the Florida Keys and areas of the Caribbean have currently shifted to this alternate algae state as a direct result of the *Diadema* die-off, leading to the conclusion that *Diadema* are a **keystone species** on Caribbean reefs.

Positive feedback loops now make it difficult for coral reefs to recover naturally. Because there is too much algae, there is not suitable habitat for new coral growth, and because there are less herbivores, macroalgae continues to outgrow corals. Decreased coral cover, has limited the building of reefs, and weakened the substrate that currently exists, resulting in a "flattening" of coral reefs and structure that is provided by the living coral. The current state of macroalgae dominated substrate offers little to no refuge for *Diadema* individuals. This, along with other factors like competition with other urchin species, increased predation pressure on *Diadema*, and asynchronous spawning events, are thought to inhibit recovery of *Diadema* populations at present. Because of these pressures, scientists are beginning to incorporate new methods to increase *Diadema* population numbers on reefs. Let's learn more about what different nonprofits, researchers, and government agencies are doing to help our reefs recover.

What is being done to help coral reefs?

Many organizations have established initiatives to reverse reef decline through local and regional action. Marine Protected Areas (MPAs) have been established across many reef areas to regulate fishing pressures, water quality, marine debris, and reef damage caused by anchors or boats. In conjunction with this, coral population enhancement efforts, including coral restoration and *Diadema* restoration, have also been established across Florida and the Caribbean to increase the amount of coral on reefs.

Coral restoration practices may provide a solution for decreasing coral populations. By raising threatened species of corals in offshore nurseries and **outplanting** them onto degraded reefs, coral restoration has been shown to increase the population trajectory of corals when corals are outplanted on a large-scale. Over 60 coral restoration programs have been established across Florida and the Caribbean to restore degraded reef sites at 14 countries. These programs focus on the restoration of several threatened species of corals, including *Acropora* species (staghorn and Elkhorn corals) which, grow quickly in nurseries, and are vital to providing reef structure and habitat. As coral restoration programs become well established, new techniques to promote their success are better understood, allowing coral restoration to have a positive impact for our reefs.

Even with positive benefits of coral restoration, it is clear that without addressing other environmental concerns- such as climate change, overfishing, poor water quality, and increased macroalgae abundance- coral reefs cannot recover to their full potential. Many scientists are beginning to address restoration at a more holistic level, now considering the restoration of animal niches (or roles) and incorporating their recovery into proper coral reef management plans.

Diadema restoration is currently under high scientific investigation. With many pressures limiting *Diadema* recovery, it is thought that growing juvenile *Diadema*, and relocating them to coral restoration sites may help to increase their population, and jump start natural population recovery. While not historically associated with *A. cervicornis* thickets, in the absence of more favorable coral species like *A. palmata*, star coral, and blade fire coral, *A. cervicornis*, when outplanted in the right densities, may act as an alternate habitat for *Diadema*. Coupling the relocation of *Diadema* individuals with already existing, *A. cervicornis* coral restoration sites could possibly lead to enhanced reef recovery, where *A. cervicornis* thickets can provide shelter to urchins and urchins can reduce macroalgae to increase coral growth and health at the restoration site.

Conclusion

Now that you understand the complexity of coral reefs, it is easy to see the importance of each animal on the reef. In turn, you also now see the complexities of managing a healthy coral reef. Past and present stressors have led to the degradation of coral reefs around the world, but with intervention strategies, such as coral restoration, *Diadema* restoration, and proper reef management, there are ways we can help these reefs recover. In the following modules, you will learn how to study some of these issues and how to present what you find to the public. In doing so, you are helping to protect and preserve our reefs for many generations to come!

References

Idjadi J, Haring R, Precht W (2010) Recovery of the sea urchin *Diadema antillarum* promotes scleractinian coral growth and survivorship on shallow Jamaican reefs. Marine Ecology Progress Series 403: 91-100 doi 10.3354/meps08463

Lessios, HA. 1988. Mass mortality of *Diadema antillarum* in the Caribbean: What Have We Learned? *Annual Review of Ecology and Systematics*. 19:1, 371-393

Module 1 – Lessons in Coral Reef Ecology (Activity)

Background

This lesson will demonstrate to students how organisms are interconnected on a coral reef. It will also demonstrate how a variety of negative events and poor management practices have affected reef life over time and how this can be corrected by helping to manage our reefs in more integrated and holistic ways.

Students will start by building a healthy reef and will then be given various scenarios mimicking past stressors and events of reef degradation. For each scenario, there is a different driving event that has an effect on the reef, changing and creating new animal-to-animal ratios on the reef. Pay close attention to these ratios and the scenarios depicted, as they will help students understand how the animal life changes on the reef and the specific impact of each event described in Module 1. This module can be completed on Microsoft PowerPoint, or through a classroom reef, or by students' hand drawing their reefs. Take a screen shot or picture of each scenario, and watch how the reef changes over time!

Materials Needed

This lesson can be completed in Microsoft PowerPoint, by hand drawing, or by creating a classroom reef where students cut out animal silhouettes and manually add them to the reef.

For PowerPoint, you will need:

Animal silhouette .jpeg images (provided here)

- 20 urchins
- 42 corals
- 80 fishes
- 8 sharks

For hand drawing, you will need:

10 sheets of white paper

An assortment of colored pencils or crayons

For constructing a classroom reef, you will need:

An assortment of colored construction paper

Cutouts of each animal

- 20 urchins
- 42 corals
- 80 fishes
- 8 sharks

Each scenario has discussion questions for students to ponder as they generate their reefs and try to understand the effects each event has on an ecosystem.

Scenario 1: A Healthy Reef

For this scenario, students will start by making a healthy coral reef ecosystem with corals, sea urchins, fishes, and sharks. This healthy reef will serve as the starting point for Scenarios 2-4. The ratio of animals for Scenario 1 is as follows:

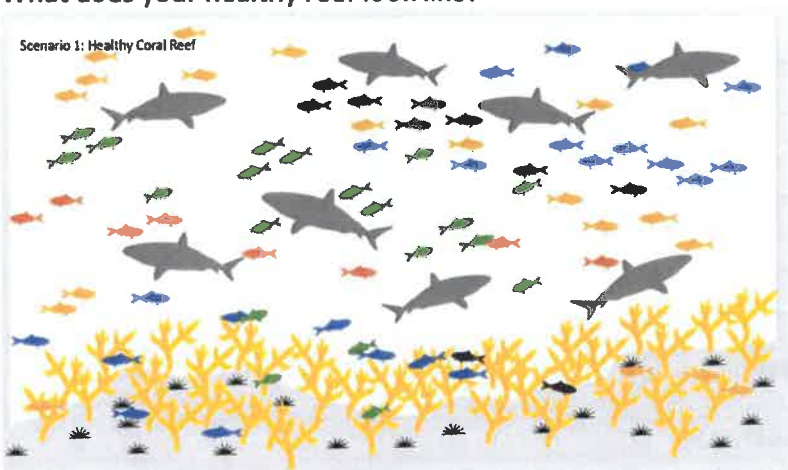
2 corals = 1 urchin
1 coral = 2 fishes
10 fish = 1 shark

Start your reef by adding 20 corals. Then, calculate the number of *Diadema*, fishes, and sharks that are on your reef. Add those to the reef, too.

My healthy reef has:

For Students:	Answer Key:
20 corals	40 corals
____ *Diadema*	20 *Diadema*
____ fishes	80 fishes
____ sharks	8 sharks

What does your healthy reef look like?



Scenario 2: Overfishing

Oh no! The amount of fish being taken off the reef is too much and too fast. The fishes cannot reproduce quickly enough to compensate for the fishing. Everything seems to be affected except for the urchins. What does your reef look like now? The ratio of animals is as follows:

2 fish = 1 coral
10 fish = 1 shark

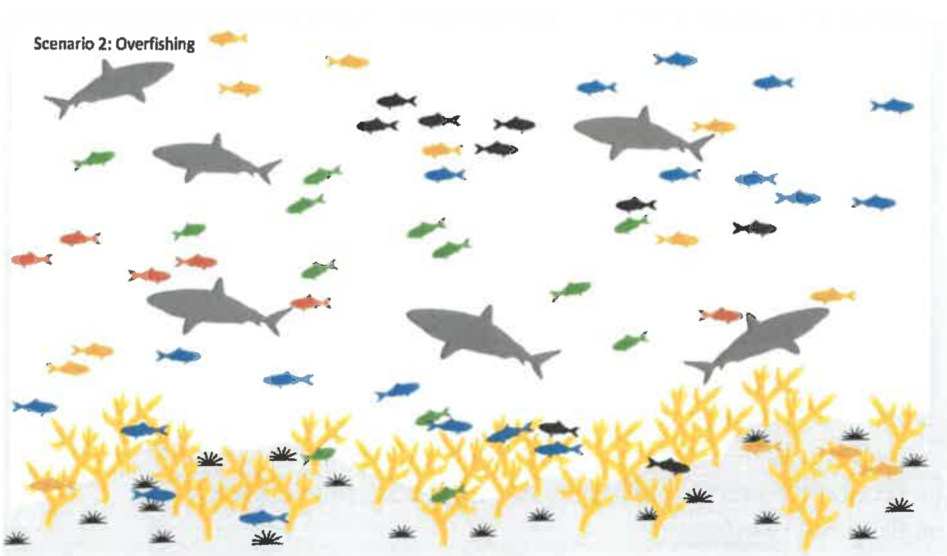
Take away 20 fishes. Then, calculate the number of corals and sharks left on your reef. The number of *Diadema* remains the same, because overfishing did not affect the *Diadema* population.

My overfished reef has:

For Students:
____ fishes
____ corals
____ sharks
____ *Diadema*

Answer Key:
60 fishes (80 – 20 fishes)
30 corals (40 – 10 corals)
6 sharks (8-2 sharks)
20 *Diadema* (*Diadema* are safe!)

What does your overfished reef look like?



Questions for discussion:

- Why do you think the *Diadema* were not affected by overfishing?
- Why do you think the corals were affected?
- Why do you think the sharks were affected?
- Do you think this reef is healthy? Why or why not?

Scenario 3: Coral Disease and Bleaching Mortality

The reefs are too hot, and the corals are getting sick. Many of the corals are showing signs of what is called coral disease and/or coral bleaching. This causes many of the corals to die-off. Much of the reef life is directly affected. Using your overfished reef model and numbers, take away 40% of the corals on the reef. Use the ratio of animals below to calculate new numbers for fishes and sharks. *Diadema* are, once again, not affected.

1 coral = 2 fish
10 fish = 1 shark

My coral bleached and diseased reef has:

For Students:
____ corals
____ fishes
____ sharks
____ *Diadema*

Answer Key:
18 corals (30-12 corals)
36 fishes
3 sharks
20 *Diadema* (Diadema are safe for now!)

What does your bleached and diseased reef look like?

Questions for discussion:

- Why do you think the *Diadema* weren't affected by the coral disease and bleaching?
- Why do you think the fishes were affected?
- Why do you think the sharks were affected?
- Why didn't all the corals die from coral disease and coral bleaching?
- Do you think this reef is healthy? Why or why not?

Scenario 4: Diadema Die-Off

The *Diadema* seemed to be healthy and not affected by many of the reef stressors, but an unknown water-born pathogen is now sweeping through the reefs! It started in the Panama Canal region and is now making its way through the Bahamas. *Diadema* are becoming ill and dying quickly. You have lost 90% of the *Diadema* population on your reef. The health of the reef is linked to *Diadema* populations in this scenario. Use your last reef model from the coral disease and bleaching events to calculate new numbers for *Diadema*, corals, fishes, and sharks. What does your reef look like after the Diadema die-off?

1 urchin = 2 corals
1 coral = 2 fishes
10 fish = 1 shark

My coral bleached and diseased reef has:

For Students:	Answer Key:
____ *Diadema*	2 urchins (20 -18 = 2 urchins)
____ corals	4 corals
____ fishes	8 fishes
____ sharks	0 sharks

What does your *Diadema* die-off reef look like?

Questions for discussion:

- Why do you think the fishes were affected?
- Why do you think the sharks were affected?
- Do you think this reef is healthy? Why or why not?
- Under which Scenario do you think the reef was most affected? Why do you think this is so?
- If coral reefs had not been affected by the other events such as overfishing, coral disease, and coral bleaching, do you think they would have still been affected by the *Diadema* die-off? Why or why not?

- How can we help our reefs return to their previous healthier states?

Scenarios 5-7

These scenarios will use the final reef product that was generated after years of stress (Scenario 4). These scenarios will bring your students through theories scientists are studying for how to bring reefs back to a healthy state. This will also demonstrate to students the difficulty in reversing the state coral reefs- or any ecosystem for that matter- that now exist in an alternate stable state.

Scenario 5: Coral Restoration

Your coral reef is not healthy, mostly because there aren't any corals left. What should you do now? Coral restoration seems like a good place to start, so in this Scenario, you start a coral nursery. Once your corals are large enough, you plant them onto your degraded reef. What happens when you add corals back to the reef? Use the ratios below to begin seeing changes when you add corals to the reef. Begin by adding 5 corals, then 10 corals, and then 20 corals. What happens to the other animals when you add more corals to the reef?

5 corals = 1 urchin
3 corals = 1 fish
15 fishes = 1 shark

My coral restoration reef has:

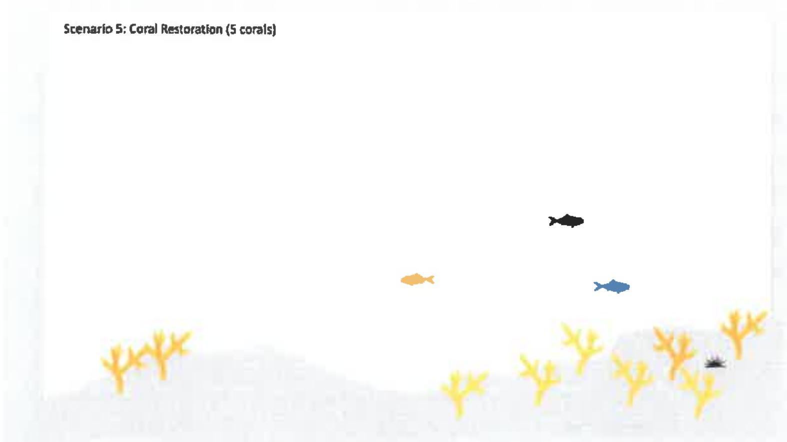
For Students:	Answer Key: 5 corals	Answer Key: 10 corals	Answer Key: 20 corals
____ corals	9 corals	14 corals	24 corals
____ *Diadema*	(4 + 5 = 9 corals)	(4 + 10 = 14 corals)	(4+ 20= 24 corals)
____ fishes	1 *Diadema*	2 *Diadema*	4 *Diadema*
____ sharks	3 fishes	4 fishes	8 fishes
	0 shark	0 sharks	0 sharks

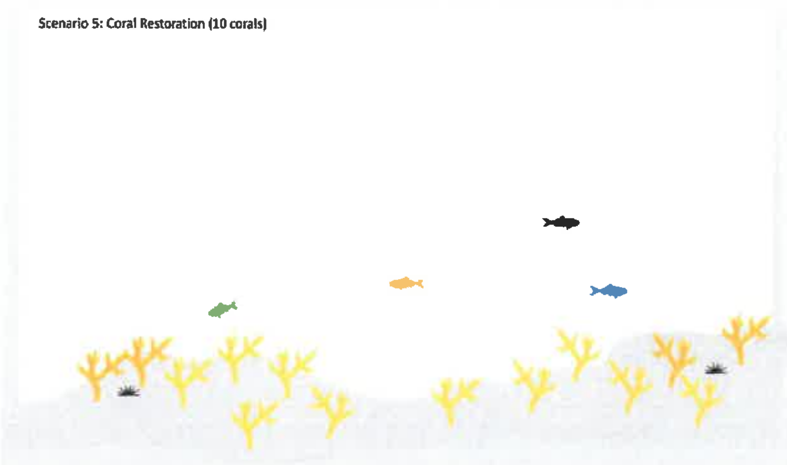
What does your coral restoration reef look like?

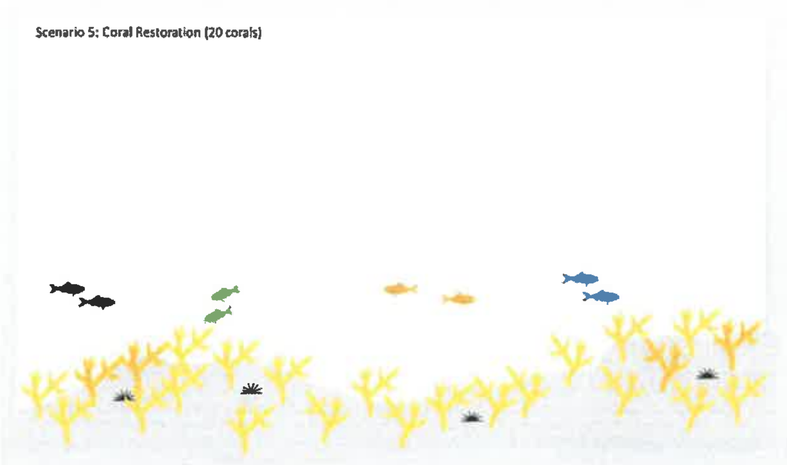
See page 7 for examples

Questions for discussion:

- Why are the animal ratios different here?
- Do you think this reef is healthy? Why or why not?
- Why is it harder to make changes on your degraded reef than it was to make changes when the reef was in the early stages of being stressed?
- Is there something else we can do to help the reefs get healthy again? If so, what?


Scenario 5: Coral Restoration (5 corals)


Scenario 5: Coral Restoration (10 corals)


Scenario 5: Coral Restoration (20 corals)

Scenario 6: *Diadema* Restoration

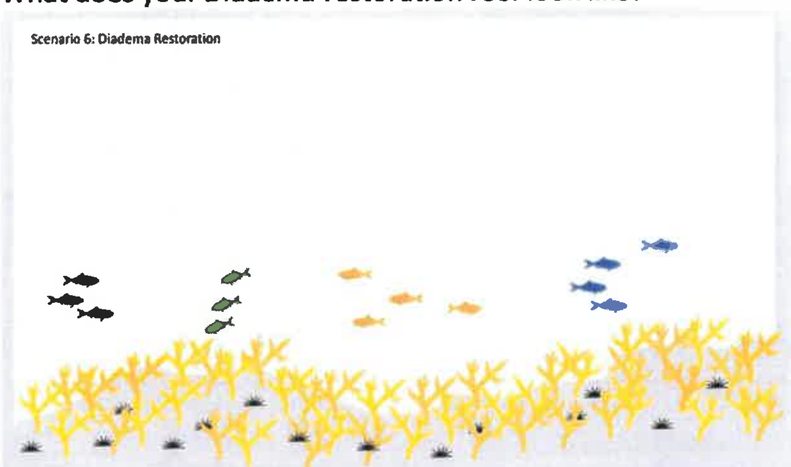
Now that coral is back on the reef, things are starting to get back to normal. It is still very difficult for the reef to begin recovering on its own because of all the algae. Algae are causing long-term stress on the corals, which die back in a few years after being on the reef. The *Diadema* have trouble repopulating naturally, too, because their numbers are so low. What would your reef look like if you were to add *Diadema* to the reef? Add 10 urchins to the reef, and calculate the number of corals, fishes, and sharks. Keep the same numbers of corals as before. What does your reef look like now?

5 corals = 1 urchin
3 corals = 1 fish
15 fish = 1 shark

My *Diadema* restoration reef has:

For Students:	Answer Key:
____ *Diadema*	14 *Diadema* (20 -18 = 2 urchins)
____ corals	42 corals
____ fishes	14 fishes
____ sharks	0 sharks

What does your *Diadema* restoration reef look like?



Questions for discussion:

- Do you think this reef is healthy? Why or why not?
- Is there something else we can do to help the reefs get healthy again? If so, what?

Scenario 7: Well-Managed Reef

The coral and the urchins are coming back, and the fish populations seem to be increasing as well. However, why are the fish numbers still lower than they were on a healthy reef? You talk to your local government and fishermen/ fisherwomen, and you realize that there are ways you can help protect fish populations while still allowing your community to fish. The animal ratios change drastically; notice how the ratios change below. Use the reef you just made to correct for the fish ratio. What does your reef look like when your restore corals, restore urchins, and manage fishing properly?

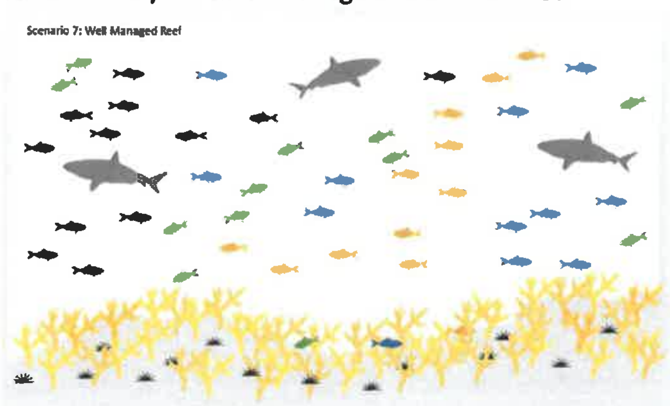
5 corals = 1 *Diadema*
1 coral = 2 fishes
10 fishes = 1 shark

My well-managed reef has:

For Students:
____ *Diadema*
____ corals
____ fishes
____ sharks

Answer Key:
14 *Diadema*
42 corals
48 fishes
4 sharks

What does your well-managed reef look like?



Questions for discussion:

- Why are the animal ratios different here?
- Do you think this reef is healthy? Why or why not?
- Why is the reef life not the same as when you started at the beginning with your healthy reef?
- What other factors do you think are harming the reefs?
- From our lessons here, is there anything we can do to help get rid of those stressors?

Elkhorn Coral

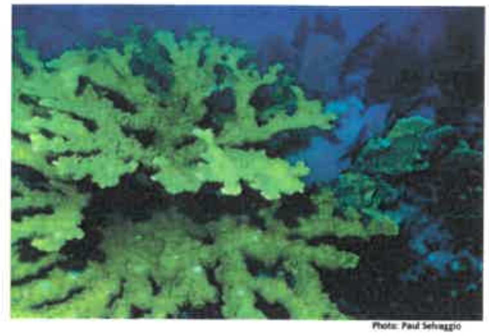


Photo: Paul Selvaggio

Family: Acroporidae

Diet: Photosynthetic and small zooplankton

Size: Branches reach large sizes of up to 10ft

Range: Florida, Bahamas, throughout Caribbean

Body Shape: Branching coral with wide, thick branches

Coloration: Brown to yellowish-brown

General Info: Found in shallow reef waters, rarely below 20ft

Staghorn Coral

Photo: coralpedia.bio.warwick.ac.uk

Family: Acroporidae

Diet: Photosynthetic and small zooplankton

Size: Finger size branches up to 2ft. Forms bushy monotypic stands

Range: Florida, Bahamas, throughout Caribbean

Body Shape: Forms thickets and dense branches

Coloration: Brown to yellowish-brown

General Info: Found in shallow reef waters down to about 30ft

Brain Corals

Photo: coralpedia.bio.warwick.ac.uk

Family: Faviidae

Diet: Photosynthetic and small zooplankton

Size: From a few inches in diameter up to 5ft in diameter depending on species

Range: Florida, Bahamas and throughout the Caribbean

Body Shape: Usually round mounds with various grooves and valleys

Coloration: Brown to light brown

Star Corals

Photo: coralpedia.bio.warwick.ac.uk

Family: Montastraeidae

Diet: Photosynthetic and small zooplankton

Size: Mounding colonies can get to large sizes over 15ft

Range: Florida, Bahamas and throughout the Caribbean

Body Shape: Forms mounding colonies and domes. Some species will also form spires

Coloration: Mostly various shades of green with some exhibiting red coloration

General Info: Star corals can form massive colonies that are hundreds of years old.

Macroalgae

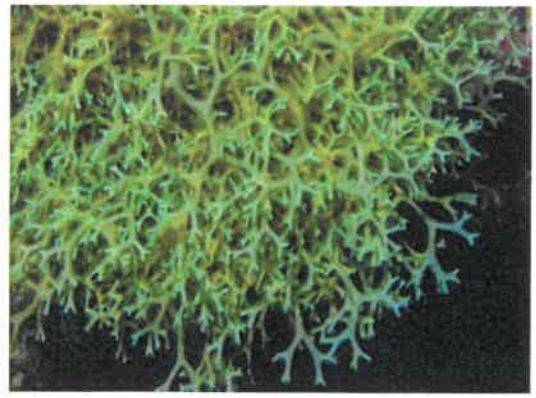


Photo: reefguide.com

Family: Various

Diet: Photosynthetic

Size: Ranges from small plants to large and fleshy

Range: Throughout the Caribbean

Shape: Forms various shapes and structures depending on species

Coloration: Mostly greens, browns and reds

General Info: Macroalgae is a catch all term for many different species of fleshy algae.

Crustose Coralline Algae (CCA)

Photo: reefguide.com

Family: Corallinaceae

Diet: Photosynthetic

Range: Found throughout the oceans

Body Shape: Grows flat and encrusting on the reef rock. Will sometimes form small spires or columns

Coloration: Various shades of pinks and red

General Info: CCA is the glue of the reef, bonding the reef structure together. It will usually be found in shaded areas and out of direct sunlight.

Turf Algae

Photo: reefcheck.org

Family: Various

Diet: Photosynthetic

Size: Usually less than 2" tall. Forms large mat like structures

Range: Found throughout the oceans

Shape: Short stringy filamentous branches

Coloration: Mostly greens, browns and reds

General Info: Turf algae is a fast growing type of algae that can quickly over-grow reef areas. Found on exposed reef rock, it can quickly outcompete new settled corals and other benthic animals.

Grunts

www.wikipedia.com

Family: Haemulidae

Diet: Feeds on shrimp, annelids, and mollusks

Size: 15-25cm (6 to 10 inches)

Range: Caribbean, Bahamas, Florida, Bermuda, Gulf of Mexico, especially warm, tropical waters at a depth of 10 to 60ft

Body Shape: long head with distinct snout, strong fixed lower jawbone

General Info: Named for pig-like grunts that they produce with their pharyngeal (throat) teeth. Typically found in groups around reef structures

Triggerfish

www.fineartamerica.com

Family: Balistidae

Diet: Carnivore—dig out prey such as crabs and worms, urchins

Size: 20-50cm (7.9 to 19.7 inches)

Range: Tropical and Subtropical in shallow, coastal habitats, especially coral reefs

Body Shape: Oval-shaped, high compressed body, large head terminating in small but strong-jawed mouth.

General Info: Typically found individually mid-water.

Surgeon fish

www.animalsindetail.com

Family: Acanthuradae

Diet: herbivorous, algae

Size: 39cm (15inches)

Range: Caribbean, Bahamas, Florida, Bermuda, Gulf of Mexico,

warm, tropical waters—at a depth of 10 to 60 feet

Body Shape: compressed body, disc shape

General Info: typically found in groups grazing on the reef

Sheepshead

https//urldefense.proofpoint.com

Family: Sparidae

Diet: crustacean and bivalve feeders

Size: up to 30 inches, but commonly 5 to 8 inches

Range: Shallow, temperate to tropical from Nova Scotia to Brazil

Body Shape: Oblong body. Deep, compressed head with steep upper profile.

Coloration: Lightly colored with vertical black bars, dorsal and anal fins with strong sharp spines

General Info: often called "convict fish"

Spotted Trunkfish

https//urldefense.proofpoint.com

Family: Ostraciidae.

Diet: Omnivore , feeding on mollusks, algae,
sea cucumbers, urchins, and marine plants

Size: 15-30 cm (6 to 12 inches)

Range: Found on reefs throughout the Caribbean, often hover near ledges or small holes at depths of 15 to 60 feet.

Body Shape: Triangular, bony box of armor, white around the mouth

General Info: Secretes a colorless toxin from glands on its skin when touched, though these present no harm to divers. When at ease, they swim using only dorsal, pectoral, and anal fins. Typically found individually just above reef structure.

Puddingwife

https//urldefense.proofpoint.com

Family: Labridae

Diet: Uses small protruding teeth to graze the bottom

taking in a variety of snails, worms, crabs, shrimps and eggs.

Size: can reach 51 cm (20 in) in total length, though most do not exceed 40 cm (16 in)

Range: native to the western Atlantic Ocean from North Carolina to Bermuda, through the West Indies and Gulf of Mexico. Found singly or in small groups, in shallow lagoons, sea-ward reefs and reef slopes

Body Shape: Elongated, compressed body.

General Info: Wrasses are always on the go during the day. Typically found ing small groups

Spanish Hogfish

https//urldefense.proofpoint.com

Family: Labridae

Diet: Adults feed on such prey as mollusks, crustaceans, and echinoderms (brittle stars and sea urchins), the juveniles act as cleaner fishes.

Size: can reach a length of 40 cm (16 in), though most do not exceed 28 cm (11 in)

Range: can be found from southern Florida and Bermuda through the Caribbean and the Gulf of Mexico to southern Brazil

Body Shape: Elongate body with large snout. Golden eyes

General Info: Highly diurnal and will bury themselves at night.

Parrotfish


www.wikipedia.com

Family: Scaridae

Diet: Primarily algae extracted from chunks of coral ripped from reef

Size: Ranging in size from less than 1 foot to 4 feet in length.

Range: Found in shallow tropical and sub tropical oceans throughout the world—on coral reefs, rocky coasts, and sea grass beds.

Body Shape: Medium size fish named for dentition—numerous teeth arranged in a tightly packed mosaic on external surface of jawbone.

General Info: Can change sex repeatedly throughout lives. Their feeding activity is important for the production and distribution of coral sands in the reef biome, and can prevent algal overgrowth of the reef structure.

Damselfish


https//urldefense.proofpoint.com

Family: *Pomacentridae*

Diet: Primarily algae but also on polyps of fire coral

Size: can grow 15 to 21cm

Range: Western Atlantic from Florida to Brazil

Body Shape: Laterally compressed

General Info: Typically found hiding around corals ether solo or in pairs. This fish can be aggressive when approached

Trumpetfish

https://www.floridamuseum.ufl.edu/discover-fish/species-profiles/aulostomus-maculatus/

Family: *Aulostomidae*

Diet: Primarily small fish

Size: can grow 40 to 80 cm (15.5 to 31.5 in) in length.

Range: Found in shallow tropical and sub tropical oceans throughout the world—on coral reefs, rocky coasts, and sea grass beds.

Body Shape: Elongated bodies

General Info: Typically found hiding around corals ether solo or in pairs.

Lizardfish

www.wikipedia.com

Family: *Synodontidae*

Diet: Carnivores—eating primarily small fish, shrimp,

or crustaceans.

Size: Reaching 40 centimeters (~15.74 inches)

Range: Tropical and subtropical waters

Body Shape: Elongated

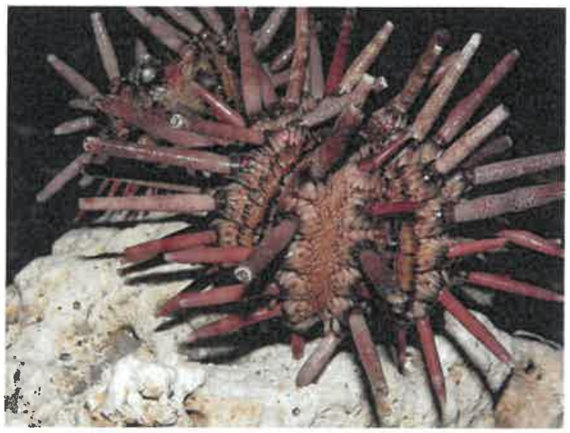
General Info: Benthic species, typically found partially buried, sandy areas .

Ambush predator

Diadema

Varigated Urchin

Pencil Urchin

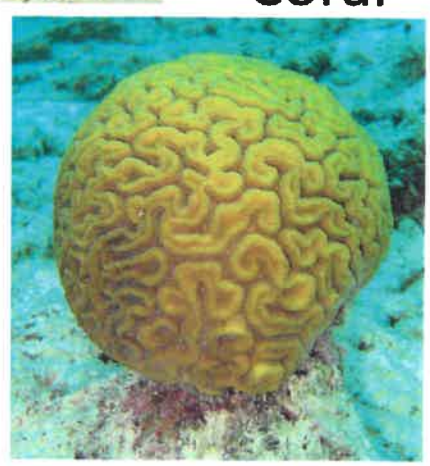


Helmet Snail

Staghorn Coral

Brain Coral

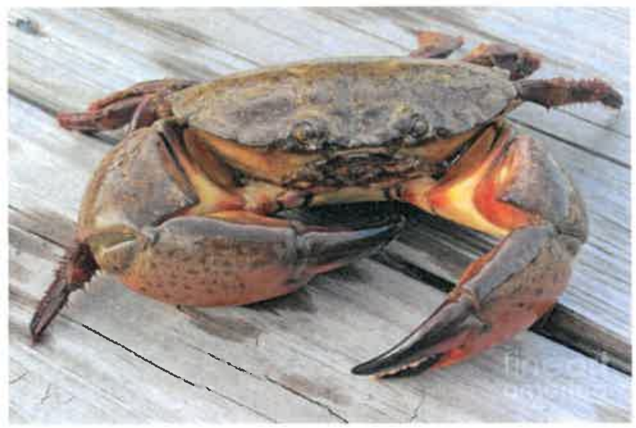
Elkhorn Coral



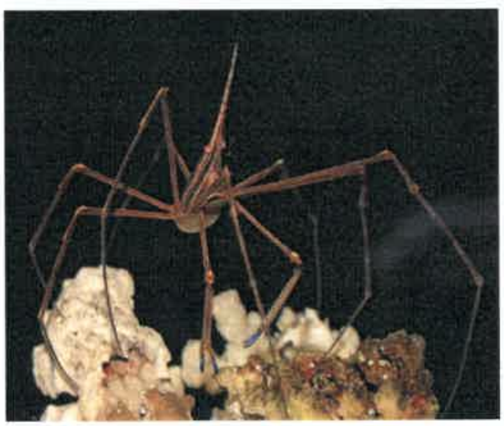
Peppermint shrimp

Banded Coral shrimp

Sexy shrimp



Stone crab



Arrow crab

Spiny lobster

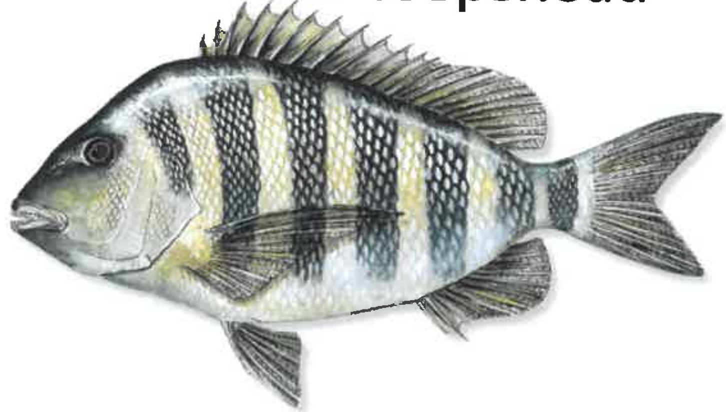
Slipper lobster

French Grunt

Parrotfish

Queen Triggerfish

Sheepshead



Spotted Trunkfish

Puddingwife

Surgeonfish

Spanish Hogfish

Peppermint Shrimp

Photo: freshmarine.com

Family: Hippolytidae

Diet: Ominivore feeding mostly on glass anemone

Size: 2 inches as an adult

Range: Atlantic Ocean from Long Island to Florida

Body Shape: Swimming crustacean with long, narrow tail, antennae, and slender legs

Coloration: Transparent with red stripes

Banded Coral Shrimp

Photo: aquaticlog.com

Family: Stenopodidae

Diet: Algae, detritus, and carrion, as well as parasites which it picks off from fishes

Size: Reaches a total length of 2.4 inches

Range: Found in the western Atlantic Ocean from Canada to Brazil, including the Gulf of Mexico

Body Shape: Swimming crustacean with long, narrow tail, antennae, and slender legs

Coloration: White body with 3 broad crimson bands supported by long bluish legs and slender red and white claws

Sexy Shrimp

Photo: catinthefridge.com

Family: Hippolytidae

Diet: Omnivores by nature

Size: Small shrimp growing to a length of 13 mm (0.5 in)

Range: Found across the Indo-West Pacific and and Atlantic Ocean.

Body Shape: It characteristically carries its abdomen curved upwards with its tail fan above its head

Coloration: Olive brown color with symmetrically placed white patches edged with thin blue line

General Info: Lives symbiotically on corals, sea anemones and other marine invertebrates in shallow reef communities.

Stone Crab

Photo: animaldiversity.com

Family: Menippidae

Diet: Prefer to feed on oysters, small mollusks, and other crustaceans.

Size: 5-6.5 inches

Range: Western North Atlantic, from Connecticut to Belize, including Texas, the Gulf of Mexico, Cuba, The Bahamas, and the East Coast

Body Shape: Stone crabs have a large crusher claw and a smaller pincer claw with numerous small teeth used for cutting

Coloration: Brownish red with gray spots and a tan underside, with large and unequally-sized claws with black tips

Slipper lobster

Photo: reefguide.org

Family: Scyllaridae

Diet: Eat a variety of mollusks, including limpet, mussels, oysters, and crustaceans and echinoderms.

Size: Up to 20"

Range: Bottom dwellers

Body Shape: 6 segments on head, 8 on thorax, and 6 on abdomen. Recognizable by enlarged antennae.

Coloration: Mottled in color—ranging from brown to yellow, orange, and purple.

General Info: Grow slowly and live to a considerable age.

Long Spine Urchin

Photo: sciencephoto.com

Family: Diadematidae

Diet: Mainly a grazer of turf algaes. Will occasionally eat corals or other opportunistic meals.

Size: Body 2-3 inches, spines 4-8 inches

Range: Found in the western and eastern Atlantic Ocean, from North Carolina down to Brazil, including throughout the Caribbean Sea.

Body Shape: Circular body with many long black, thin spines

Coloration: Most are black with an occasional white or mixed black/white spines

Spiny lobster

Photo: keywestaquarium.com

Family: Palinuridae

Diet: Eats snails, clams, sea hares, crabs, and sea urchins

Size: Averages 30cm (12 inches)

Range: Spiny lobsters are found in almost all warm seas, including the Caribbean and the Mediterranean Seas

Body Shape: Compressed carapace lacking lateral ridges. Also lack claws on first 4 pairs of walking legs. Long, thick, spiny antennae

Coloration: Mainly brownish-gray with stripes and yellow spots on tail segments

Rock boring Urchin

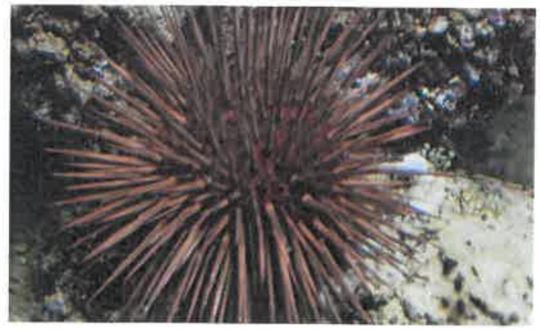


Photo: Wikipedia.com

Family: Echinometridae

Diet: Turf algae

Size: Body 1-3 inches, spines 1/4-1"

Range: Florida, Bahamas and throughout Caribbean

Body Shape: Short thick pointed spines.

Coloration: Black to olive with some having reddish coloration

General Info: Bore out holes in the rock, that they are found in during the day, venturing out at night to feed on algae. Mostly found in shallower water.

Variegated Urchin

Photo: Wikipedia.com

Family: Toxopneustidae

Diet: Turf algae and other forms of algae

Size: Body 2-3 inches, spines 1/2-3/4"

Range: Florida, Bahamas, throughout Caribbean and south to Brazil

Body Shape: Round squatty body covered in short spines.

Coloration: Commonly white or green, but can be red, purple or olive.

General Info: Usually found in seagrass beds and edges of the reef. Will often camouflage itself with seagrass, shells and other debris.

Pencil Urchin

Photo: bluezooaquatics.com

Family: Cidaridas

Diet: Turf algae and occasional starfish or coral

Size: Body 1 1/2”-2”, spines 1 1/2”-2”

Range: Florida, Bahamas, throughout Caribbean to Brazil

Body Shape: Round body with thick blunt spines

Coloration: light to dark reddish brown

General Info: Often found in seagrass and areas of reef rubble. Spines are often covered in reef debris.

King Helmet

Photo: antiguamarinelife.info

Family: Cassidae

Diet: Sea Urchins

Size: 4-6 inches

Range: Florida, Bahamas and throughout Caribbean. Has become increasingly rare due to shell collecting

Body Shape: Shell has a flattened lip that forms a triangle.

Coloration: Shades of reddish brown in wavy netted pattern with dark stripes over outer lip

General Info: Predator of Diadema urchins and can strike them with surprising speed.

Module 3- In Water Surveys

Objective

The objective of this module is to introduce students to data collection methods and to the datasheet for collecting data in water.

Overview

Following an introduction to coral reef ecology and reef species identification, students will be trained to collect scientific data on *Diadema* populations and their role in coral reef ecosystems. Here, we outline basic survey protocols that students will use for these assessments. They include a survey of *Diadema* and other urchins on the reef, major benthic community categories, and an optional survey for fishes in the area. These survey methods will allow students to assess the health of *Diadema* populations in their area as well as the impact that *Diadema* and other urchins may be having on the reef. The optional fish survey will target taxa that may also play a role as grazers on coral reefs and taxa that may be predators on *Diadema*, limiting their recovery.

Surveys are designed for students to use while they snorkel, so survey sites should be limited to reefs in less than 10 feet of water. As such, habitats surveyed may include rocky shorelines, shallow patch reefs, reef crest, and reef flat habitats. Surveys should not be conducted where currents or waves may be hazardous or make conducting surveys difficult. Student survey teams will consist of a pair of students working along a single 10m transect, with multiple teams spread out across the survey area.

Survey Materials

To conduct surveys, students will need the following materials:

- Transect line marked at 1m intervals (one per team)
- 1/2m PVC measuring stick
- Slate/clipboard with pencil and underwater data sheet (one per student)

Prior to entering the water, the surveyors will complete the top portion of the datasheet containing the metadata, including site name, GPS coordinates, date, and survey team members. Upon entering the water, the survey teams should spread out to be at least 10m from other teams. Survey teams should follow safety procedures at all times and remain horizontal on the surface of the water to avoid standing on or kicking corals.

In the water, each survey team will lay the 10m transect across a section of reef in a straight line, avoiding wrapping the transect around corals and other benthic organisms. Each member of the survey team will start at opposite ends of the transect, with one team member conducting the *Diadema* Survey and the other team member conducting the Benthic Survey. When both snorkelers have completed their respective survey along the 10m transect line, the line should be retrieved and redeployed with team members switching survey roles. Following the completion of *Diadema* and benthic surveys, both team members will have the opportunity to conduct the optional fish surveys.

***Diadema* Survey – 10m x 1m belt transect**
The student conducting the *Diadema* Survey will snorkel above the transect line, looking for urchins within 0.5m on either side of the transect for a total of 10m x 1m belt transect being searched. Students should try to thoroughly examine the reef structure, including any crevices or holes, but should avoid touching the reef. Within the 10m x 1m area, students will identify, count, and record all *Diadema antillarum* present and will also count and record the number of all other urchins and spiny lobsters. Other urchin species may simply be recorded as Unidentified Urchin on the data sheet or may be recorded to species based on the surveyor's level of comfort with species identifications following training.

Benthic Survey - 10m point intercept @ 1m intervals
The student conducting the Benthic Survey will snorkel above the transect line starting at the opposite end of the student doing the *Diadema* Survey and will record the benthic category under the transect line at pre-marked 1 m intervals (10 per transect). Benthic categories include:

- Elkhorn Coral
- Staghorn Coral
- Brian Coral
- Star Coral
- Other Stony Corals
- Fleshy Macroalgae
- Turf Algae
- Crustose Coralline Algae
- Other

Fish Survey
Following the completion of the *Diadema* and Benthic Surveys, survey teams have the option of conducting roving fish surveys. On these surveys, students will identify and record relative abundance of fish belonging to key taxa that may be predators on *Diadema* or contribute to grazing on reefs. Taxa include:

- Grazers:
    - Parrotfish
    - Surgeonfish
- Predators:
    - Triggerfish
    - Porcupine Pufferfish
    - Spanish Hogfish
    - Yellowtail Damselfish

Following REEF Fish Survey protocols, fish abundance should be recorded as:

- Single (1)

- Few (2-5)
- Several (6-10)
- Many (11-50)
- Lots (>50)

Fish Surveys should be timed so that they are limited to 10 minutes.

Practice Surveys

Because conducting surveys in the water can be difficult for students, they should practice surveys on land to get used to the methods before practicing surveys in the water. This allows students to practice methods in an environment in which they are more comfortable and can ask questions easily. Following land-based practice surveys, students can practice survey methods in the water.

In the classroom or on the shore, students should practice rolling out and recovering transect lines as well as collecting data using each of the methods described above. For practice surveys, printed photographs or drawings of various benthic, invertebrate, and fish taxa included in the surveys may be used. These photos or drawings can be haphazardly placed on the ground, and students can deploy transect lines and practice recording data on their datasheets. If photos or drawings are not available, various objects available in the classroom or along the shore (chairs, books, etc.) can be used as proxies for various survey components. Students' proficiency can be tested by providing them with a pre-deployed transect to survey with various survey taxa deployed along the transect at intervals or distances where they should be included in the survey as well as some at intervals or distances where they should not be included. Results of this survey should be compared to the correct results and any issues discussed before students practice surveys in the water.

Spines Across the Water – Transect Datasheet

Surveyor:	Buddy:	
Site Name:		Date:
Latitude:	Longitude:	

Belt Transect	Transect #______	**Point Intercept**	Transect #______
Diadema		Elkhorn Coral	
Rock Boring Urchin		Staghorn Coral	
Variegated Urchin		Brain Coral	
Pencil Urchin		Star Coral	
Unidentified Urchin		Other Stony Corals	
Spiny Lobster		Fleshy Macroalgae	
Notes:		Turf Algae	
		CCA	
		Other	

Fish survey – 10 min. Start: ________ End: ________	Single (1)	Few (2-5)	Several (6-10)	Many (11-50)	Lots (>50)
Surgeonfish					
Parrotfish					
Grunts					
Triggerfish					
Porcupine Puffer					
Spanish Hogfish					
Yellowtail Damselfish					

Module 4 – Water Safety
PADI Skin Diver/*Diadema* Data Collector

Overview and Qualifications

This is a PADI certification course in Skin Diving to learn snorkeling and skin diving techniques including checking buoyancy, surface swimming, clearing water from your snorkel and performing effortless surface dives. This course will prepare the student to collect and gather data on the Long-Spined Sea Urchin, *Diadema antillarum*. Although the course will train students how to make surface dives, during data collection it is recommended they use only surface observation. Data collection maybe carried out without supervision therefore the activities and the areas observed must approximate those of training. The course is designed to develop safe skills for snorkelers as well as to provide the necessary training to safely gather data on *Diadema*.

The following is per the PADI Skin Diver Course Instructor Guide (2019 update)

Section One

Course Standards

Certification Requirements

- Participate in knowledge development session.
- Meet confined water performance requirements.
- For the purpose of *Diadema* data collection students must additionally meet open water requirements.

Diver Prerequisites

- 8 years old
- Adequate swimming skills and comfort in the water.

Equipment

Mask, fins, snorkel, exposure protection as needed and a buoyancy control device (snorkel vest)

Minimum Instructor Rating

PADI Divemaster

Materials

PADI Release of Liability/Assumption of Risk/Non-agency Acknowledgment Form – Discover Snorkeling and Skin Diving (10089)

Ratios

Confined Water

16:1

Open Water

10:1

Section Two

Knowledge Development

Conduct a knowledge development session or briefing that covers skin diving equipment, pressure-volume relationships that affect skin divers, the dive environment, proper interaction with aquatic life (if appropriate), the buddy system, problem management and local safe skin diving practices.

Section Three

Confined Water

Performance Requirements

1. Assemble, adjust, prepare, put on and remove skin diving equipment without assistance.
2. Perform the buddy predive safety check.
3. Demonstrate appropriate entry and exit, using local techniques.
4. Adjust for proper weighting at the surface; use weight system as necessary.
5. Breathe through a snorkel while controlling airway.
6. Orally inflate a BCD at the surface, then fully deflate it.
7. Continuously stay within 3 metres/10 feet of a buddy while at the surface.
8. Snorkel swim at the surface in water too deep in which to stand.
9. Make a vertical, head first dive from the surface in water too deep in which to stand.
10. Swim at least 15 metres/50 feet underwater on a single breath.
11. Ascend by looking up and around while swimming, holding one hand over the head.
12. Clear a snorkel using the blast method and resume breathing through the snorkel without lifting the face from the water.
13. Ascend, clear and breathe from a snorkel upon ascent without lifting the face from the water; use displacement and/or blast clear methods.
14. Maintain direction control while snorkeling on the surface and underwater.
15. If using a weight belt, remove and replace it at the surface in water too deep in which to stand.
16. Communicate using hand signals at the surface and underwater.

Section Four

Open Water (optional) – NOTE: For the purpose of *Diadema* data collection open water training component is mandatory.

Performance Requirements

1. Put on and adjust equipment.
2. Perform a predive safety check.
3. Adjust weighting.
4. Perform a surface swim using skin diving equipment.
5. Demonstrate proper surface dive descent and ascent techniques.
6. Clear water from the snorkel.
7. Explore the dive site.

Additional Academic and Water Skill requirements for Diadema data collection.

- **Safety:** Accident prevention, rescue and first aid as applied to skin diving. Dive planning, safety measures (personal flotation devices, dive floats and flags), and emergency procedures should be covered. Basic guidelines for first aid for shock, wounds, near drowning, and envenomation should be presented, and students must discuss how to activate local EMS.

- **Skills:**
  - 10-minute float/tread water (no equipment)
  - 200m swim (no equipment)
  - Surface assists and tows

- **Environment:** Aspects pertinent to the Skin Diver. The basics of conservation and preservation of the environment should be stressed. Hazards associated with water movement (currents, surge, surf, etc.) should be explained along with avoidance and escape techniques. Aquatic plant and animal hazards should be addressed so that the student can identify and avoid hazards as well as render first aid for injuries.

Diadema Surface Observer/Data Collector
Module 4

Overview and Qualifications

This is a recognition course in basic snorkeling that will prepare the student to collect and gather data on the Long-spined sea urchin, *Diadema antillarum*. Upon successful completion of this course, graduates are considered competent to engage in open water surface observation only activities without supervision, provided the activities and the areas observed approximate those of training. The course is designed to develop safe skills for swimmers as well as to provide the necessary training to safely gather data on *Diadema*.

Who May Conduct This Course

- Any active-status NAUI Instructor or active-status NAUI Skin Diving Instructor who:
    - Has submitted NAUI Specialty Instructor Application and received written approval to teach this course from the NAUI Training Department.

Pre-Requisites

- **Participant age:** Minimum age is 12 years by the water phase of the course.
- **Certification/Experience/Knowledge:** There is no certification required to enter this course.

Policies

- **Ratios:** Standard ratios apply (See "Policies Applying to All Courses: Assistants and Ratios").
- **Daily Hours:** No more than eight hours of training shall be conducted during any one day.
- **Academics (estimated hours):** 8 hours.
- **Practical Application:**
    - MINIMUM REQUIRED HOURS: 8 hours, including at least 2 water hours.
    - MINIMUM REQUIRED DIVES: The minimum number of open water sessions is 1 (one).
    - DEPTH: This is a surface only class. Diving under the surface is not allowed in this course.
- **Equipment:** Mask, snorkel, fins, snorkel vest or lifejacket, exposure protection as needed.
- **Materials:** See "Policies Applying to All Courses: Forms, Records and Reports."
- **Course Results:** This is a recognition course only.

Requirements – Academic

- **Applied Sciences:** Those aspects of physics, physiology and medicine which are needed to understand skin diving risks. Emphasis is to be placed on the aspects which have a practical application so that the student will understand personal limitations. Non-technical terminology is to be used. Specifics to be included are:
    - Temperature as related to thermal protection needs, hypothermia, and hyperthermia (heat stroke/exhaustion).
    - Buoyancy as related to buoyancy vest.
    - Vision as related to seeing and judging distances underwater.
    - Gases and respiration as related to shallow water blackout and overexertion.

    - Health and diving fitness as related to personal risk management.
- **Diving Equipment:** The purpose, features, types and use of skin diving equipment. The main emphasis is to prepare the student to select, use, and care for the equipment. Equipment to be covered includes mask, snorkel, fins, personal flotation device, surface float with flag, and protective suit (if used in the area where diving is intended).
- **Diving Safety:** Accident prevention, rescue and first aid as applied to skin diving. Dive planning, safety measures (personal flotation devices, dive floats and flags), and emergency procedures should be covered. Surface assists and tows are to be taught and rescue breathing introduced. Basic guidelines for first aid for shock, wounds, near drowning, and envenomation should be presented.
- **Diving Environment:** Aspects pertinent to the diver. The basics of conservation and preservation of the environment should be stressed. Hazards associated with water movement (currents, surge, surf, etc.) should be explained along with avoidance and escape techniques. Aquatic plant and animal hazards should be addressed so that the student can identify and avoid hazards as well as render first aid for injuries.
- **Diving Activities:** The how, who, when, where, what, and why of diving. References to diving clubs, boats, stores, locations, books and periodicals, continuing education, and scuba training are to be included. A limited introduction to specific diving activities should be given.
- **Coral Reef Ecology**
- **Reef Species Identification**
- **Survey Development**
- **Scientific Field Data Collection**
- **Data Collation and Analysis**
- **Data Reporting**

Requirements- Skills

- **Swimming Skills (confined or open water):** No equipment. Demonstrate novice level swim stroke proficiency in any of the following strokes: crawl, side, breast, elementary back, or backstroke. Classic stroke combinations are not necessary to meet this requirement as long as forward progress is achieved (i.e., no particular kick or arm action is necessarily required, and a lack of either is also acceptable). Students shall complete at least 15 continuous stroke cycles while being evaluated by an instructor. A stroke cycle is considered to be either arm or leg action or a combination thereof resulting in forward movement until repeated.
    - Survival swim for 10 minutes
    - Tow a person of similar size 20 yards (18 m).
- **Skin Diving (confined or open water):** Minimally equipped with mask, fins, and snorkel.
    - Swim 450 yards (412m) nonstop, breathing from snorkel at least one-half the distance.
    - Survival swim for five minutes; during the period, remove and replace in turn mask and fins.
    - On the surface, transport a diver of equal size 40 yards (37 m).
- **Skin Diving (open water):** Equipped with mask, snorkel, fins, skin diving vest and/or wet suit, weight system, protective suit if required for locality.
    - Don, doff, and care for equipment.

- Demonstrate the proper use of the snorkeling vest to maintain positive buoyancy at the surface.
- Demonstrate correct procedures for entries and exits in prevailing conditions.
- Demonstrate the correct procedures for clearing water from the mask and snorkel.
- On the surface, remove and replace in turn mask and fins.
- Demonstrate self-rescue techniques, including establishing buoyancy and relieving simulated muscle cramps.
- On the surface, assist and transport another diver 40 yards (37 m).

REQUIREMENTS – EXAMS:

No written exam required as this is a recognition course.

Module 5: Scientific Field Data Collection

Objectives

Students that have been trained in (1) species identifications, (2) survey development, and (3) water safety will survey nearshore shallow reefs to collect data on reef health, *Diadema antillarum* populations, and other key species coral reefs. This module explains how surveys will be conducted and data entered into an online database (Shared Google platform- Excel).

Site Selection

The selection of suitable reefs to survey is critical for successful surveys. First and foremost, reefs selected should be safe for student surveyors. Many students may be new to snorkeling, and even those comfortable with snorkeling will be using new skills to identify species while collecting and recording scientific data. These new skills are best accomplished in environments in which water and weather conditions do not add any additional challenges. Sites with strong currents, waves and surge, or poor visibility should be avoided. Similarly, snorkeling surveys are also best conducted in depth ranges of 3 to 10 feet, as shallower sites may result in contact with the reef that could result in damage to the reef and possible injury to the student. Deeper sites may also present challenges with data collection from the surface. Reefs selected should also be accessible from the shore or boat without requiring a long swim. Students should be reminded not to stand on the reef and avoid contact with the reef with their hands, body, or fins. There should also be someone on the shore or boat to keep track of students and to provide support if needed.

From the ecological perspective, surveys are designed to be conducted in areas where corals are common. As such, sandy areas should be avoided, as should flat hardbottom areas. Hardbottom areas with coral and other structures that provide habitat for urchins and fishes are ideal. Other habitats are also suitable, including rocky shorelines with corals, patch reefs, reef crest areas (provided that waves, surge, and currents do not present hazards), and shallow fore reef zones. Sites should also be big enough for students to conduct 10m-long transects without interfering with each other.

Entering the Water and Collecting Data

Prior to entering the water, students should be given a briefing on the site that includes potential hazards of the site, such as any currents, surge, or biological hazards such as fire coral, jellies, and lionfish. The pre-dive briefing should also remind students of the objectives of the dive and confirm dive buddy pairing. Students should also fill out their datasheets to record metadata in the box at the top of their datasheet prior to entering the water.

Upon entering the water, student snorkel teams should have all survey gear, including transects, clipboards with data sheets and pencils, and measuring sticks. Students should take a few minutes before starting surveys to get comfortable, check their gear, and orient themselves to the site. Once they are comfortable, students should lay their transect along the reef structure randomly. If the transect crosses large sand areas, deep areas, or other potential hazards, students should roll up their transect lines and deploy them in another part of the reef. Since a pair of students will be working together on each transect, it is recommended that one student deploy the transect while the second student holds the rest of the survey gear. These roles may be reversed upon completion of the transect when it is time to recover the transect line or if a second set of benthic surveys and Diadema surveys will be conducted at the same site by the buddy team.

Once the transect is deployed, students should conduct their survey of either the benthic community or *Diadema*. To minimize interfering with each other, students should start at opposite ends of the transect line with one student surveying urchins and other mobile invertebrates within ½ meter of either side of the transect line. The second student, starting at the opposite end, should be recording what is on the seafloor at 1m intervals along the transect. Students should swim slowly when conducting surveys. When it comes time to record data, either when an urchin or other mobile invertebrate is encountered along the transect, or at 1m intervals for benthic surveys, students should make a mental note of their position along the reef so that they can resume surveys form that point once they finish recording data. Once both students have completed their transect, the transect line can be rolled up by one of the students. Care should be taken when recovering the transect to avoid dragging it across the seafloor or tangling it around corals.

Following urchin and benthic surveys, students may conduct optional fish surveys. Students should note the time at the start of fish surveys and limit their surveys to 10 minutes, recording the time at the end of the survey (even if it is shorter or longer than 10 minutes). During fish surveys, students can swim across the reef, making sure they are recording the number of all fish taxa listed on the datasheet. Students should avoid interfering with other students surveying the reef. Students should remain in buddy teams for fish surveys but should collect data independently.

Data Management

It is important to stress to students that collecting data on a reef is not the end of the survey. All data must be entered into a database, or it cannot be used in analyses. To this end, students should be encouraged to review their data sheets immediately following their survey back on the boat while the experience is fresh in their minds and to make sure that their data sheets are legible and data is accurate (e.g., 10 benthic data points were recorded for each transect). Data sheets should be kept in a safe place until students have the chance to enter data into an online data portal into spreadsheets (see Module 3 datasheet and the "Online Google Shared datasheet").

The spreadsheet has been designed to replicate the underwater datasheet that students will be used to collect data. For many students, this may be the first time using a spreadsheet, so the instructor should take some time to explain what a spreadsheet is and how it can be used to enter data for analysis and graphic display. For entering data into spreadsheets, students should work as buddy teams with one student reading out the data off the underwater data sheet to the student entering data into the spreadsheet. Once data are saved from one student's data sheet, students should switch roles for entering the other student's data.

Module 6 – Data Collection and Analyses

Objective

The objective of this module is to provide students the opportunity to manipulate data that they have collected (or simulated data) and to conduct analyses that will inform them of the health of reefs and how *Diadema* and other organisms affect reef health.

This will include summary statistics such as mean number of urchins at sites, or average percent cover of benthic components in an area, as well as the standard deviation around that mean. Students will also have the opportunity to report data graphically and in tabular form. Finally, simple parametric statistics may be used to compare various factors between sites (e.g., are *Diadema* densities at one greater than another site) or to examine the relationship between variables (e.g., is there a relationship between the number of *Diadema* at a site and the amount of macroalgae of CCA at a site).

Use of Data

Students should be familiar with collecting data in the field and with entering data into the spreadsheet provided (modules 3 and 5). This module will focus on how data may be used by students to address questions about the status of reefs and how various taxa affect reef health. Before exploring use of the data, students should be involved in a discussion about the surveys they have conducted, or about reef health in general if simulated data are to be used, and their observations. Then, based on their observations, the instructor and students can brainstorm as a group possible questions to explore using the data. Once that is completed, students in groups of two will select one hypothesis to investigate.

If students have had the opportunity to survey multiple sites, they may be encouraged to ask questions about the similarities or differences between sites and to form hypotheses about these similarities or differences. If students are only able to survey one site, they might be encouraged to characterize that site or compare it to other sites in readings or using a dataset located on the shared Google platform.

Data Analysis

Data collected by students can be analyzed in several ways, depending on the questions/hypotheses they are exploring. Students can use descriptive statistics to characterize their sites. Examples of these statistics include:

- Percent cover of coral
- Density of *Diadema* and other urchins
- Frequency of occurrence of fish taxa

These data may be expressed as averages such as the mean values (with or without standard error), or median values for a particular taxa or group of taxa. Students may also wish to compare their sites to other sites using simple parametric statistics such as analysis of variance and T-tests, or to examine the relationship between factors such as how % cover of macroalgae varies with *Diadema* densities across sites using a linear regression.

Data will be assembled in Excel (or a similar program). Students can present their data through a short PowerPoint presentation, a trifold presentation board, or any other format the instructor prefers. Module 7 (Data Reporting) will move through the write-up steps for student groups.

Module 7- Data Reporting and Basic Scientific Writing

Objective
The objective of this module is to introduce students to the basic principles of taking data they have collected in the field and interpreted in the laboratory and then presenting it to the scientific community.

Helpful hint: Although the plural of datum (data) is often used in a singular manner (e.g., "the data is..."), remember that:

DATA= Plural
DATUM= Singular

1. What do the data mean? (recap from Module 6)

To the Student: In Modules 3 and 5, you learned how to collect data using a datasheet. These data were specifically selected to allow us to quantify (count) the presence or absence of *Diadema* in certain areas, the number of *Diadema* that were in an area, and what that area actually looked like. These data allowed us to compare different sites so that we could work out if any of the characteristics of a site may be encouraging, or allowing, the *Diadema* to be there.

In this module, we explore how to take those data, interpret the data based on Module 6 instructions, and then disseminate the content through writing a scientific report.

2. How to tell the story: the building blocks of a scientific report

Whether you are writing a report for school, for college, a technical report, or a manuscript for publishing in a journal, you will generally use the same basic building blocks to systematically tell your story. All reports start with an introduction that leads to outlining what is being tested (aims), how it got tested (methods), what you found (results) and what it meant (discussion). Summaries (abstracts and conclusions), thanking people (acknowledgements), and proving your case with your peers (references) are also included.

All scientists are trained to write what they found in a similar way so that they can read, understand, and interpret each other's results. This allows scientists all over the world to either support or deny the results you may have gotten and can inform future experiments to understand the questions further. Learning to write in this manner means you are speaking the language of scientists and furthering the studies that can be done.

For the remainder of this module, we will discuss each of these parts in more detail to give you the tools you need to write your own scientific report or presentation of the hypotheses you worked with in Module 6.

3. Introduction

The introduction provides the important information required to understand the background for the topic being discussed in the report. It should educate the reader on the topic and give the reasons you are doing the study. The amount of information you provide depends on the type of report you are writing and the audience to whom you are addressing. For example, a journal article in *Nature* (a widely recognized journal for scientists) only needs a short technical introduction, since we can assume scientists reading the journal will already have knowledge on the subject. However, an essay written to give citizen scientists studying coral reefs background in the ecology of the reefs of the Caribbean may require more information about general marine and ecology information, ultimately building up to reef structure and specific details.

The information you provide in an introduction should be limited to facts, so that your readers can form a foundation to interpret the speculations you will make in your discussion. While it may be tempting to speculate on issues here, it may only confuse the reader in their understanding of the subject. Speculations are better placed in the discussion and your interpretation of your results as a brief addition to what you have found. This provides a factual basis for the idea.

Facts require proof. In reports, to support a fact, you provide a reference. It is preferred that this reference is from a textbook or a peer-reviewed journal, although "grey literature" (non-reviewed) publications such as abstracts from conference proceedings, websites, and technical reports may be included if the peer-reviewed reference is not available.

How do you *write* an introduction? The simple format to follow is an inverted pyramid of information. Start with a broad statement on the topic such as, "Globally, coral reefs are in decline." Start to direct your statement to identify the specifics of your topic. An example of this is, "Human impacts such as overharvesting, climate change, and pollution have exacerbated this issue over the last five decades." Then identify the general problem, such as, "As a result, we have lost much of the species diversity and complexity of our reefs required to sustain a healthy ecosystem." The get specific, such as, "In the Caribbean, the rapid loss of *Diadema antillarum* by an unknown cause resulted in algal overgrowth and further suffocation of our reef tracts. More than 3 decades later we are seeing isolated recovery of *Diadema* species." The outline what we need to do (this leads to the aims), such as, "With this recovery, it is imperative we characterize the reefs that are encouraging *Diadema* to settle and live so that we may gain a better understanding of the critical ecology of this species and potentially identify strategies we can implement to assist this recolonization." Then state the aim of the study that will address this issue/question/need.

4. Aims, Objectives, and Hypotheses

Each study has to have a purpose. This is usually articulated as an aim, objective, or hypothesis. Although these terms are often interchanged, they are very different and mean different things in reports.

Aim(s): An **aim** identifies the purpose of the investigation. It is a straightforward expression of what the researcher is trying to find out from conducting an investigation.

Objective(s): **Research objectives** are the results sought by the researcher at the end of the research process (i.e., what the researcher will be able to achieve at the end of the study).

Hypothesis(es): A hypothesis (plural- hypotheses) is a precise, testable statement of what the researchers predict will be the outcome of the study. This usually involves proposing a possible relationship between two variables: the independent variable (what the researcher changes) and the dependent variable (what the research measures).

Hypotheses can be expressed in the following ways:

- The **null hypothesis** states that there is no relationship between the two variables being studied. Example: The abundance of *Diadema* at a site is NOT affected by habitat availability.
- The **alternative hypothesis** states that there is a relationship between the two variables being studied. Example: The abundance of *Diadema* at a site IS affected by habitat availability.

5. Materials and Methods

The purpose of the materials and methods section is to describe what is needed to do the research and how the research was done. More commonly, this is referred to simply as "methods" in many journals, as the need to describe each material used is not required past the basics of the type (e.g. species and age) of animal or plant or object used and any major equipment to analyze the samples or data.

However, describing the methods used is important and is required in enough detail for the reader to be able to repeat your experiments the same way you did them. This also allows the reader to make an informed decision as to whether what you did was done properly to support the results and findings you are presenting.

As such, the methods section of a project, such as the one you have conducted on the reef counting *Diadema*, should include the following parts:

I. Study design: An ideal study is designed before it is executed. While there are many study designs and possible ways to conduct research, this section is not intended to teach you how to design a study; hopefully some of these have been explained to you in Module 6 to give you an idea of your options. Regardless of the design, there are several elements that need to be considered when creating a study.

Replicates: Identical units under the same conditions used to test that the likelihood of something happening. The more replicates in your study, the better you can prove that the phenomenon is not happening by chance, but rather as a clear pattern that happens in nature.

Rigor: Studies should be designed to minimize the chance of external variables influencing the findings. Usually, a simple design is best. Compare a few variables with lots of replicates under controlled or predictable conditions.

Repeatable: Studies should be explained and conducted in a way that they can be done again, exactly the same way. This means all variables and conditions should be accounted for and measurable.

Equal: Comparing between like things is always better and gives more confidence in your results; whether these things are the same species, gender, or even number of animals being examined.

II. Animals Used: This usually describes the species of animal used, their gender, age, where they are from and any other factors that may influence the study. This is done so the experiment can be replicated by the reader and to show that the animals compared between treatments are the same. For example, using all males in one treatment of a nurturing study and all females in another treatment may create differences in the outcome regardless of the effect of the treatment.

III. Site description: This is an important part of the methods, as it allows the reader to imagine what the trial was like in terms of conditions and decide if parameters are comparable. Ideally, the site chosen or described should be controlled for variable that may affect comparison between treatments but also sufficiently mimic the natural habitat that "normal" responses can be expected.

IV. Sampling parameters and techniques: Defines what was collected and how it was collected. These are important to provide a "quality assurance" that the appropriate pieces of data were obtained and that they were gotten in a proven, conventional way that allow the data to be analyzed rigorously.

V. Data collection and collation: All research is conducted to collect data that can be used to "prove" something. As such, the collection of the correct data and how that data are handled is essential to the success of the project.

One way to ensure data are *collected* accurately is to clearly define what data are being collected prior to starting the work and how they are going to be recorded. That is, develop a data collection sheet, whether it is check boxes, rows for numbers, or lines to describe what you use. Then, consistently use it every time for every treatment or comparison you look at.

Often more difficult is to decide how to *collate* the data. This may require an idea of how you are going to analyze the information at the end of the trial. It could dictate whether you collect only "yes or no" responses (binary), or empirical values (numbers) for something, even to how you are going to record in rows versus columns, or under which heading you record something. For example, a group of *Diadema* could be counted to give a total number of the group but may also need to be ranked for size if found at different depths on the same crag of rock in the same group (if you are comparing depth as a parameter).

The best way to decide how to collect and collate data is to "think backwards" from the desired result, often the aim of the study and outlined in the objectives stated in your introduction. For example, if one of your objectives is to "understand the relationship of habitat availability and *Diadema* abundance at a site," then you want to be able to measure the number of *Diadema* at a site, the habitat characteristics (substrate type, rock ledges, etc.), and the depth of the site. Habitat is not the only thing that affects *Diadema* abundance, so you will also need to include data collected on other factors to tease out the cause of the patterns you are seeing. To tease out other factors, you may also want to collect information on the size of *Diadema* present, fish abundances, type of habitats, and additional abiotic parameters such as current speed and direction, water temperature, light intensity, and geographic location.

VI. Data analysis: This is probably the most intimidating part of any report. Most people are wary of statistics and do not like to try analyze their data, as it may be perceived as "too hard." While statistics can get very complicated very quickly, basic principles are easy to follow, and a lot of information can be gained from some very simple comparisons. Analysis is also made easier by good data collation. If you've thought out your initial experimental design very well, this step will be much easier.

Most data analysis is managed in spreadsheets such as Excel. Setting up rows of data in columns that can be compared is a simple way to see what you have found. Often, averages and standard deviations (the amount a column of data varies) can give a good feel for the data. These measures are also the first descriptive statistical tests that you will report! Averages show the middle point for each group being examined. This is helpful but means nothing unless you know if this trend is consistent or if it really is just the mid-point of random numbers. To see how representative of the data this is, standard deviations (or also standard errors) are used to show how far the dataset varies from the average value. The standard deviation is the square root of the variance of a dataset, whereas variance is the distribution of the data. A simpler way to express these data is to show its range, the difference between the maximum and minimum value. This shows the statistical dispersion of the data.

Always remember that you can only perform descriptive statistics on numbers, so data need to be converted to empirical values. For things like yes and no answers, it may be as simple as counts for each group that can be expressed as percentages (e.g. 20 out of 50 *Diadema* are "yes" for hiding in a crevice, therefore 40% of *Diadema* are seeking shelter). For descriptions such as "none, some, or lots", you need to assign a value or score (e.g. none = 0, some = 1 and lots = 2) and use counts and/or averages.

From here, you can further test the data for the likelihood that they are different or similar (probability, or p-tests). This can be done a variety of ways using a variety of tests, but nearly all accept or reject similarity based on whether there is a 5% chance of the two columns differing ($p \leq 0.05$), called probability statistics. Sometimes in biology, this arbitrary limit is extended to 8% ($p \leq 0.08$). Regardless, results falling within the argument that a less than 5-8% likelihood of this result occurring by chance is deemed "statistically significant," an important achievement if you are trying to show one variable or another is having an effect on your test subjects.

It may seem like a lot to remember and report, but by the end of reading the methodology, the informed reader should be able to understand what has been done and how it was analyzed so that they can look at and interpret the results without the need to look up anything else.

6. Results: How to present these data- Tables, Graphs, and Statistics.

Once you have all data sifted, sorted, and tested to determine whether or not your aims were met, the question of how to present the findings can be asked. It is tempting to show everything you have done, as after all, there is an argument that you have done a lot of work and made a lot of decisions to get to this point, so your thought processes and conclusions should be relevant. However, most reports and journals rely on you being able to select the relevant information, quickly justify the data not included, and present a concise summary of what you have found and how significant it is. In your results section, it is important to be as objective as possible. In this section, you are not forming your own opinions. You are simply stating and showing your results through graphs, tables, and statements. Speculations about your results should be included in the "Discussion" section of your report. While it may seem boring and dry, think of this section as your numbers section, which will allow the reader to go back quickly and compare their results to another study they read, or a study that they are conducting.

The most common ways to summarize large blocks of data is to present it as (i) a table, showing averages and variance supported by probability statistics; (ii) a graph that compares the change of one or more subject against two or more variables; or (iii) a brief written description supported by key values.

Picking which one to use to be difficult. As a general rule of thumb, if you have multiple comparisons (many data) a table may be a good choice. If you have two or three trends to compare, a graph may be best. If you have "complex" data (like an average, deviation, confidence interval and p-value) text may be more appropriate.

Think back to your objectives and hypothesis(es) in this section. Choosing what data to include should be made based on what is required to comprehensively demonstrate the acceptance or rejection of the success of your aim. What is included should be restricted to what has been described in the methods, without leaving anything out.

Whatever is included, it must be presented in a way the reader can understand it. If it is a graph/figure or a table, it will need a caption. Every time you add a figure or table to your report, it is important to include a short title that describes what the dataset being presented is. For example, a table showing the distribution of *Diadema* could be simply titled, "Table 1. Distribution of *Diadema* on three rocky reefs in Smith Bay, Bahamas." A standardized abbreviation of this title (e.g. Table 1) will serve as a reference when you refer to your figure in the body of text.

7. Discussion:

Now you get to show how you interpreted your results from the experiment! The discussion section is the critical thinking part of your report and is meant to show readers how you synthesize your results, what may have led to them, and areas for more research. There are many ways to lay out a discussion depending on the journal or report being written and personal preference. The data may also dictate the order in which your discussion is presented. If you included it in your results, you need to talk about it in your discussion. Regardless, there are some basic elements that should be included:

1. Does your study meet the aim/ objective/ hypothesis outlined at the beginning of the article? In many cases, this should be the opening statement of your discussion. A straightforward sentence, such as "This study met/ did not meet the stated aims," allows the reader to know if your study answered your posed questions. It does not matter if it does not, as the discussion is the opportunity to explain why and what this means.

2. Can you explain your findings with current literature and rationales? This is your opportunity to interpret your results and demonstrate why what you have done is important and what it means to the scientific community. Importantly, in the field we operate in (conservation science), it is also an opportunity to show how what you have done may apply to the "real world" (that is, what can be done in the field to make a difference) under the umbrella of conservation biology. Compare your results to other studies and show that your results either support or say something different from studies similar to yours.

3. Identify any limitations of the study. No study is perfect and, especially for field experiments, things can happen that cannot be controlled, which may influence the results. This does not make the work null and void, but a good reporter will acknowledge these limitations, put them in context of what their influence may be, and identify ways this can be minimized in future. Common study limitations are sample size in wildlife studies that cannot be controlled, an adverse event (like a hurricane or a power outage) during the trial period, or a flaw in the study design that became apparent after the work began that was fixed (creating a confounding effect) or continued to have a less-than-desirable effect. Limitations are often stated at the start of the discussion after the aims statement. However, they can also be listed throughout the body of the discussion after each point as a rationale for the results.

The discussion is the one place in a scientific report or article that allows for some minor speculation on the findings. It may or may not have backing in the literature. Speculation should be kept to a minimum but may be argued as an important component of a report if the findings are novel and/or have no prior similar published results to support the assertion.

8. Conclusions and Abstracts:

Conclusions and abstracts may be thought of as short statements that wrap it all up (the conclusion, at least) and summarize the project. They convey the pertinent information of the research in a few sentences, typically. The exact content of each varies depending on whom you are writing for, but there are some parts which may be common.

Abstract: The opening paragraph of most journal articles, the abstract is the concise summary of the article for the reader to quickly determine what the study is about and what the findings were. As such, an abstract usually contains an introductory sentence on the topic, a sentence on the aims and methods, a summary of only the most pertinent results, and a final sentence discussing those findings in the context of the topic.

Some journals require specific subheadings to direct the reader, whereas other journals or reports may allow more flexibility.

Usually, abstracts are less than 300 words, do not contain references, and should address the paper title.

Conclusion: The conclusion should be a concise summary of the study with emphasis on the discussion. It does not necessarily have to contain data and may include a concluding sentence that is more speculative than something that would be accepted in an abstract.

A conclusion may contain a statement on meeting the objective and what this means to the field, including current recommendations and future directions.

No new data or information should be presented in a conclusion. The conclusion is meant to be only a summary of what has already been presented. Many journals are now removing the need for a conclusion, as it is often viewed as repetitious of what has already been concisely articulated. However, a conclusion is still common in a report and should contain the above-mentioned elements.

9. Acknowledgements:

Acknowledgements are included to thank all those who helped. This section should be brief and restricted to only those who contributed to the article or study but not enough to warrant being included as an author. This may include funding bodies and, in some instances, ethics or permit approval numbers (although the latter is usually presented elsewhere such as the methodology or as a subheading at the start of the article).

10. References and bibliographies:

References are articles cited to support your case. They are usually represented as names and dates in parentheses at the end of a statement or as a superscripted number. The specific style of in text and bibliographic referencing varies enormously and will not be discussed here.

However, common elements of references are the author(s), publication date, title, and publisher. It is commonly required that the original work is cited for definitions and techniques to ensure accuracy, and the literature cited should still be current to show relevance. While this may seems like a contradiction, it is essential for referencing.

References are lists of resources specifically cited in the text, whereas bibliographies are general topic references. Most journals and reports use references as opposed to bibliographies.

11. General hints to write "Science:"

Writing scientifically doesn't have to be difficult or onerous. Here are some very basic final hints to help with your report.

- Many people know lots of "big words." You don't have to use them all in one sentence.
- Write simply and concisely.
- Do not be afraid to delete something you have written when proofreading. It is tempting to keep statements, as they sound good or took a long time to craft, but if they don't fit, get rid of them.
- Start a report/article with a title. It should be concise and describe what was done to what, and possibly where it was done. This will help you focus your paper.
- It may be easier to write bits of each section as you go along. This is personal preference. Do not feel you have to finish all of the introduction before you can write the methods or start putting the results together. You can build a paper as you would an essay.
- Word limits are important, but you do not have to write to a set number of words. Write what you need. Sometimes, shorter is better. If it is too long, you can delete later.