Coral Reef Management | Lesson Plan

CORAL REEF LESSON PLAN

Keeping Watch on Coral Reefs

Focus
Management of coral reefs

Grade Level
9-12 (Earth Science)

Focus Question
Why are coral reefs important, and what can be done to protect them from major threats?

Learning Objectives
• Students will be able to identify and explain five ways that coral reefs benefit human beings.

• Students will be able to identify and explain three major threats to coral reefs.

• Students will be able to describe major components of the Coral Reef Early Warning System.

• Students will be able to identify and discuss actions that can be undertaken to reduce or eliminate threats to coral reefs.

• Students will be able to obtain and analyze several types of oceanographic data from remote-sensing satellites.

Materials
• Copies of “Satellite Imagery Worksheet,” one copy for each student or student group
• Copies of either “Coral Reef Subject Review” (fill-in-the-blank version, with or without word bank) or “Coral Reef Subject Review Crossword Puzzle,” one copy for each student or student group
• Computers with internet access
Audio/Visual Materials
None, unless students require A/V equipment for their public education programs

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom style or groups of 4-6 students

Maximum Number of Students
30

Key Words
Coral
Zooxanthellae
Symbionts
Remote Sensing

Background
Coral reefs are one of the most biologically productive ecosystems on Earth. Most people have seen images of brightly colored fishes and other reef-dwelling organisms, yet many do not understand why these systems are personally important. Programs and articles about coral reefs typically point out benefits that include protecting shorelines from erosion and storm damage, supplying foods that are important to many coastal communities, and providing recreational and economic opportunities. These benefits are obviously important to people who live near reefs, but there is another aspect of coral reefs that can benefit everyone: the highly diverse biological communities are new sources of powerful antibiotic, anti-cancer and anti-inflammatory drugs.

Despite their numerous benefits to humans, many coral reefs are threatened by human activities. Sewage and chemical pollution can cause overgrowth of algae, oxygen depletion, and poisoning. Fishing with heavy trawls and explosives damages the physical structure of reefs, as well as the coral animals that build them. Careless tourists and boat anchors also cause mechanical damage. Thermal pollution from power plants and global warming cause physiological stress that kills coral
animals and leaves the reef structure vulnerable to erosion. Many of these impacts are the result of ignorance; people simply aren’t aware of the importance of coral reefs or the consequences of their actions, but the damage and threats to reefs continues to increase on a global scale.

Some of the most severe damage appears to be caused by thermal stress. Shallow-water reef-building corals live primarily in tropical latitudes (less than 30° north or south of the equator). These corals live near the upper limit of their thermal tolerance. Abnormally high temperatures result in thermal stress, and many corals respond by expelling the symbiotic algae (zooxanthellae) that live in the corals’ tissues. Since the zooxanthellae are responsible for most of the corals’ color, corals that have expelled their algal symbionts appear to be bleached. Because zooxanthellae provide a significant portion of the corals’ food and are involved with growth processes, expelling these symbionts can have significant impacts on the corals’ health. In some cases, corals are able to survive a “bleaching” event and eventually recover. When the level of environmental stress is high and sustained, however, the corals may die.

Prior to the 1980s, coral bleaching events were isolated and appeared to be the result of short-term events such as major storms, severe tidal exposures, sedimentation, pollution, or thermal shock. Over the past twenty years, though, these events have become more widespread, and many laboratory studies have shown a direct relationship between bleaching and water temperature stress. In general, coral bleaching events often occur in areas where the sea surface temperature is 1°C or more above the normal maximum temperature.

In 1998, the President of the United States established the Coral Reef Task Force (CRTF) to protect and conserve coral reefs. Activities of the CRTF include mapping and monitoring coral reefs in U.S. waters, funding research on coral reef degradation, and working with governments, scientific and environmental organizations, and business to reduce coral reef destruction and restore damaged coral reefs. Using high-resolution satellite imagery and Global Positioning System (GPS) technology, the National Oceanic and Atmospheric Administration
(NOAA) has made comprehensive maps of reefs in Puerto Rico, the U.S. Virgin Islands, the eight main Hawaiian Islands and the Northwestern Hawaiian Islands. Maps of all shallow U.S. coral reefs are expected to be completed by 2009. NOAA monitors reefs using a system of specially designed buoys that measure air temperature, wind speed and direction, barometric pressure, sea temperature, salinity and tidal level, and transmit these data every hour to scientists. Satellites are also used to monitor changes in sea surface temperatures and algal blooms that can damage reefs. Research and restoration projects on selected coral reefs are conducted by NOAA’s National Undersea Research Program.

The first part of this lesson is intended to:
• introduce students to coral reefs and improve their understanding of why these systems are important, how they are threatened, and what can be done to protect and restore these unique and valuable ecosystems; and to
• introduce students to some of the data available from remote-sensing tools that can be used by anyone who wants to study the Earth’s oceans.

In the second part of this lesson, students design and prepare educational programs to improve public awareness of the importance of coral reefs and what needs to be done to reduce or eliminate harmful impacts from human activities. This activity offers many opportunities for cross-curricular activities, and may be extended over several weeks or months. If time is limited, you may choose to use the first part alone.

**Learning Procedure**

**Part 1**
1. Direct students to the coral reef tutorials at [http://oceanservice.noaa.gov/education/kits/corals/welcome.html](http://oceanservice.noaa.gov/education/kits/corals/welcome.html). You may want to assign different tutorial sections to each student group. Have each student or student group complete one version of the Coral Reef Subject Review, and lead a discussion to review the answers. Be sure that students understand the relationship between coral animals and their symbiotic algae (zooxanthellae), and that many corals under various types of stress will expel their zooxanthellae.
Briefly explain the purpose and activities of the U. S. Coral Reef Task Force (CRTF), and highlight the monitoring functions that are intended to identify reef areas threatened by thermal stress or algal blooms.

2. Briefly describe some of the satellites and sensors that currently provide various types of oceanographic data:

A great deal of information on oceanographic conditions is available from various satellites. NOAA’s Polar Operational Environmental Satellite (POES) carries the Advanced Very High Resolution Radiometer (AVHRR), which provides information on sea surface temperature (SST) for the entire Earth on a daily basis. NASA’s Terra and Aqua satellites cross the equator in the morning and afternoon, providing coverage of the entire Earth surface every 1 – 2 days. These satellites carry Moderate Resolution Imaging Spectrometers (MODIS) that provide information on chlorophyll-a as well as SST. NASA’s QuikSCAT satellite carries the SeaWinds sensor that provides global information on wind speed and direction near the ocean surface. Data from these (and other) satellites are available free via the internet.

Distribute copies of “Satellite Imagery Worksheet” to each student or student group. Tell students that their assignment is to use satellite data to answer the questions on the worksheet. When students have completed the worksheet, point out that the CRTF’s monitoring program keeps track of selected oceanographic conditions on an hourly or daily basis at twenty-four coral reef sites. You may want to have students visit http://www.osdpd.noaa.gov/PSB/EPS/CB_indices/coral_bleaching_indices.html to check out current conditions at these reefs.

Have students investigate the history of temperature conditions at each of the three reefs listed on the “Satellite Imagery Worksheet” over the period 1997 to present, using data at http://coralreefwatch.noaa.gov/satellite/current/sst_series_24reefs.html and http://coralreefwatch.noaa.gov/satellite/archive/sst_series_24reefspath.html (use Grand Bahama Island (GBI) instead of Lee Stocking Island for this exercise). Ask whether temperatures have reached the coral bleaching threshold at any of these reefs during this time.
period. Students should recognize that the threshold has been exceeded at:

- Glover's Reef in September 1997; August and September, 1998; October, 1999; October, 2003;
- Grand Bahama Island in July, August, and September, 1998; August, 1999; and
- Sombrero Reef in July, August, and September, 1997; August and September, 1998; July, August, and September, 1999

3. Lead a discussion of how data from the CRTF monitoring program help protect coral reefs. Student will probably realize that these data cannot directly improve the condition of reefs, since the root problem appears to be climate conditions that are beyond human control (at least in the short term). These data are very useful, however, in identifying sites that are at risk of environmental stress so that scientists and resource managers can learn more about the response of corals and coral reef systems to these conditions.

Ask students to discuss why coral reefs are at risk, and what they think can or should be done to reduce or eliminate the negative impacts of human activity on coral reefs. There is a strong possibility that a significant part of the current risk to coral reef systems is the result of human activity, particularly as it relates to global warming. Meaningful actions to address this type of issue depend upon widespread understanding of the problem and commitment to workable solutions. Public education is an important step toward building this sort of understanding and commitment. Have students brainstorm what “key messages” might form part of a public education program about coral reefs, what audiences should be targeted to receive these messages, and how these messages might be most effectively delivered to these audiences.

Part 2
Have students or student groups prepare one or more public education programs about coral reefs, based on the results of their brainstorming sessions in Step 3. Encourage students to consider various media, including publications, visual pre-
sentations, drama, music, etc. You may want to have an entire class work on a single program, or have smaller groups work on multiple programs using the medium (or media) of their choice. There are many possibilities, depending upon the target audiences. These presentations also offer cross-curricular opportunities, particularly with social studies, English language arts, and fine arts. Whatever media students choose to work with, their final presentation should be accompanied by a list of sources for the information they present. A good starting point for this activity is the Roadmap to Resources: Corals (http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html), which provides links to many other sources of coral reef data and information.

The Bridge Connection
www.vims.edu/bridge/ – Click on “Ocean Science Topics” in the navigation menu to the left, then “Habitats”, “Coastal”, “Coral Reef.”

The “Me” Connection
Have students write a short essay on why coral reefs are personally important, what personal actions may contribute to human-caused threats to coral reefs, and what they could personally do to reduce these threats.

Extensions
Have students or student groups prepare a report on a specific aspect of coral biology, ecology, or management. Some possible topics include:

- coral diseases
- natural and anthropogenic hazards
- oil spills on coral reefs
- coral reef restoration
- species diversity on coral reefs
- benthic habitats associated with coral reefs
- relationships between coral reefs and seagrass or mangrove ecosystems

See Roadmap to Resources: Corals (http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html) for links to information on relevant topics.
Resources

http://oceanservice.noaa.gov/educationkits/corals/supp_coral_roadmap.html – NOAA’s National Ocean Service Web site’s Roadmap to Resources about corals, with links to many other sources of coral reef data, background information, and reports

http://coastwatch.noaa.gov/cw_dataprod.html – description and links to satellite remote sensing ocean data provided by NOAA CoastWatch

http://coastwatch.noaa.gov/interface/interface.html – search page for satellite remote sensing ocean data provided by NOAA CoastWatch; use navigation bar at left to select geographic region, type of data, and date range

http://www.coral.noaa.gov/index.shtml – NOAA’s Coral Health and Monitoring Program home page, with links to coral reef data, maps, and other resources

http://www.osdpd.noaa.gov/PSB/EPS/SST/climohot.html – coral bleaching hotspot chart

http://www.osdpd.noaa.gov/PSB/EPS/CB_indices/coral_bleaching_indices.html - Tropical Ocean Coral Bleaching Indices for 24 coral reef sites


National Science Education Standards

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms
- Matter, energy, and organization in living systems
- Behavior of organisms

Content Standard D: Earth and Space Science
- Energy in the earth system
- Geochemical cycles

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges
Two conditions that have been linked to coral bleaching are water temperatures that exceed 30°C and little or no surface wind. Your assignment is to use satellite data to investigate whether these conditions have occurred during the past week at three coral reef areas. These reefs are:
- Sombrero Reef in the Florida Keys, located at 25.0°N, 81.5°W;
- Lee Stocking Island in the Bahamas, located at 23.5°N 76.5°W;
- Glover’s Reef, in Belize, located near 16.5°N, 88.0°W.

I. Follow these steps to obtain the necessary information about sea surface temperatures (SST):

2. Click on the Access Coastwatch icon.
3. Click on the Database Query icon.
4. Build your query.
   a. Check all dates
   b. Uncheck “WC” and “EC” under “Regions,” and check the boxes for Florida Keys (FK), Bahamas (BH), and Belize (BZ).
   c. Under “Types”, check the boxes for daytime SST (D7), and uncheck the box for nighttime SST (S7).
   d. At the bottom of the page, click “Submit”
5. Select the most recent imagery for each of the three reefs, and determine the sea surface temperature (SST).
II. Follow these steps to obtain the necessary information about surface winds data

1. Go to http://coastwatch.noaa.gov

2. Click on “Link: Product Search”

3. Build Query:
   a. In the “View Results as” window, select “As Images”
   b. In the “Select a Region” window, select “Caribbean” or “Gulf of Mexico”
   c. In the “Select Product” window, select “Surface Winds”
   d. In the Sensor Select window, select “Seawinds”
   e. In the Satellite window, select “QUIKSCAT”
   f. In the From and To date windows, enter the dates from the most recent images of sea surface temperatures in exercise I above.

4. Click on “Search”
CORAL REEF LESSON PLAN

Coral Reef Subject Review

1. __________ organisms are composed of hundreds to hundreds of thousands of individual animals.

2. Individual coral animals are called __________.

3. The mouth of individual coral animals is surrounded by a circle of ____________.

4. After food is consumed by corals, waste products are expelled through the ____________.

5. Time of day when most corals feed: ____________

6. To capture their food, corals use stinging cells called ____________.

7. Nematocysts are capable of delivering powerful, often lethal, ____________.

WORD BANK

plants
clear
productive
calcium carbonate
habitats
encrusting
calyx
theca
basal plate
feed
branching
foliase
metamorphose
massive
polyps
mushroom
larvae
set
phototaxis
digita
table
elkhorn
colonial
zooplankton
planulae
broadcast
mortality
synchronized
lunar
tentacles
mouth
night
nematocysts
toxins
species
medicines
tourism
food
erosion
weather
algae
tidal emersions
El Niño
zooxanthellae
mutualistic
photosynthesis
poor
atoll
stresses
temperatures
CREWS
mucous
recycling
zooxanthellae
physical stress
predation
anthropogenic
pollution
algae
fishing
fringing
barrier
cm
flat
crest
buttress
seaward
slope
below
euphotic
sessile
asexual
millions
8. A coral’s prey ranges in size from nearly microscopic ani-
mals called __________________ to small fish.

9. Many corals collect fine organic particles in films and
strands of ______________.

10. Most reef-building corals contain photosynthetic algae
called __________ , which live in their tissues.

11. Corals and algae have a __________ relationship.

12. Symbiotic algae supply corals with glucose, glycerol, and
amino acids, which are the products of ____________.

13. Tropical ocean waters are generally [rich or poor]
__________ in nutrients.

14. The relationship between the algae and coral polyp facili-
tates a tight __________ of nutrients, which is the driving
force behind the growth and productivity of coral reefs.

15. The unique and beautiful colors of many stony corals are
caused by ________________.

16. __________ can cause coral polyps to expel their algal
cells.

17. Coral ____________ occurs when coral polyps expel their
algal cells, causing the colony to take on a stark white
appearance.

18. Because of their intimate relationship with symbiotic
algae, reef-building corals respond to the environment like
__________.

19. Because their algal cells need light for photosynthesis, reef
corals require ____________ water.

20. Although coral reefs require nutrient-poor water, they are
among the most ____________ and diverse marine environ-
ments.
21. Reefs form when polyps secrete skeletons of __________.

22. As they grow, coral reefs provide structural __________ for hundreds to thousands of different vertebrate and invertebrate species.

23. The skeletons of stony corals are secreted by the lower portion of the polyp. This process produces a cup, or ________, in which the polyp sits.

24. The walls surrounding the corals’ skeletal cup are called the ____________.  
25. The floor of the corals’ skeletal cup is called the ____________.

26. __________ is a system of specially designed buoys that measure conditions that may cause bleaching on coral reefs.

27. When polyps are physically stressed, they contract into their calyx so that virtually no part is exposed above their skeleton. At other times, polyps extend out of the calyx. Most polyps extend the farthest when they ________.

28. __________ corals have primary and secondary branches.

29. __________ corals look like fingers or clumps of cigars and have no secondary branches.

30. __________ corals form table-like structures and often have fused branches.

31. __________ coral has large, flattened branches.

32. __________ corals have broad plate-like portions rising in whorl-like patterns.

33. __________ corals grow as a thin layer against a substrate.

34. __________ corals are ball-shaped or boulder-like and may be small as an egg or as large as a house.
35. _________ corals resemble the attached or unattached tops of mushrooms.

36. Coral reefs begin to form when free-swimming _________ attach to submerged rocks or other hard surfaces along the edges of islands or continents.

37. _________ reefs project seaward directly from the shore, forming borders along the shoreline and surrounding islands.

38. _________ reefs border shorelines, but are separated from their adjacent land mass by a lagoon of open, often deep water.

39. An _________ is formed when a reef has developed around a volcanic island that subsides completely below sea level while the coral continues to grow upward.

40. Massive corals have growth rates of 0.3 to 2 _________ per year.

41. Bottom topography, depth, wave and current strength, light, temperature, and suspended sediments act on coral reefs to create horizontal and vertical zones of living species. The reef _________ is usually the zone closest to shore, followed by the reef _________ or algal ridge, then the _________ zone, and finally the _________.

42. Reef-building corals cannot tolerate water temperatures [above or below] _________ 18° Celsius (C).

43. Most reef-building corals require very saline water.

44. Reef-building corals’ requirement for high light explains why most reef-building species are restricted to the _________ zone, the region in the ocean where light penetrates to a depth of approximately 70 meters.

45. As adults, almost all corals are _________, which means that they remain on the same spot on the sea floor for their entire lives.
46. In \_\_\_\_\_\_\_ reproduction, new polyps bud off from parent polyps to expand or begin new colonies.

47. In sexual reproduction, coral eggs and sperm join to form free-floating, or planktonic, larvae called \_\_\_\_\_\_\_.

48. Species that release massive numbers of eggs and sperm into the water to distribute their offspring over a broad geographic area are called \_\_\_\_\_\_ spawners.

49. The time between planulae formation and settlement is a period of exceptionally high \_\_\_\_\_\_ among corals.

50. Along many reefs, spawning occurs as a \_\_\_\_\_\_ event, when all the coral species in an area release their eggs and sperm at about the same time.

51. The long-term control of spawning may be related to temperature, day length and/or rate of temperature change (either increasing or decreasing). The short-term (getting ready to spawn) control is usually based on \_\_\_\_\_\_ cues.

52. The final release of gametes during spawning is usually based on the time of \_\_\_\_\_\_.

53. Planulae exhibit positive \_\_\_\_\_\_.

54. Once planulae settle on the bottom, they \_\_\_\_\_\_ into polyps and form colonies that increase in size.

55. Coral reefs support more \_\_\_\_\_\_ per unit area than any other marine environment.

56. Scientists estimate that there may be \_\_\_\_\_\_ of undiscovered species of organisms living in and around reefs.

57. Coral reef biodiversity is considered key to finding new \_\_\_\_\_\_ for the 21st century.
58. Healthy reefs contribute to local economies through __________.

59. In developing countries, coral reefs provide critical __________ resources for tens of millions of people.

60. Coral reefs buffer adjacent shorelines from wave action and prevent __________, property damage and loss of life.

61. Natural damage to coral reefs frequently occurs because of __________.

62. Slow-growing corals that are damaged by storms may be overgrown by __________ before they can recover.

63. Reefs also are threatened by __________ that can cause shallow water coral heads to overheat and dry out.

64. Increased sea surface temperatures, decreased sea level and increased salinity from altered rainfall can all result from weather patterns such as __________.

65. Corals are vulnerable to __________ by fishes, marine worms, barnacles, crabs, snails and sea stars.

66. Human-caused, or __________ activities are major threats to coral reefs.

67. One of the most significant human-caused threats to reefs is __________.

68. When some contaminants enter the water, nutrient levels can increase, promoting the rapid growth of __________ and other organisms that can smother corals.

69. In many areas, coral reefs are destroyed when cyanide or dynamite are used for __________ activities.

70. Coral diseases generally occur in response to biological __________, such as bacteria, fungi and viruses, and non-biological stresses, such as increased sea surface temperatures, ultraviolet radiation and pollutants.
71. Many scientists believe that the increased frequency of coral diseases over the last 10 years is related to deteriorating water quality and increased _______ that may allow for the proliferation and colonization of microbes.
Across

4. The mouth of individual coral animals is surrounded by a circle of _____.
6. Many corals collect fine organic particles in films and strands of _______.
8. The long-term control of spawning may be related to temperature, day length and/or rate of temperature change (either increasing or decreasing). The short-term (getting ready to spawn) control is usually based on __________ cues.
10. To capture their food, corals use stinging cells called ____ ___.
11. Coral reefs begin to form when free-swimming _______ attach to submerged rocks or other hard surfaces along the edges of islands or continents.
12. _______ can cause coral polyps to expel their algal cells.
14. Coral reef biodiversity is considered key to finding new _______ for the 21st century.
16. Most reef-building corals contain photosynthetic algae called _______ which live in their tissues.
19. After the food is consumed by corals, waste products are expelled through the __________.
20. _______ corals have broad plate-like portions rising in whorl-like patterns.
21. The _______ is usually the zone farthest from shore.
24. plate The floor of the corals’ skeletal cup is called the _______.
25. As they grow, coral reefs provide structural _______ for hundreds to thousands of different vertebrate and invertebrate species.
26. Coral _______ occurs when coral polyps to expel their algal cells, causing the colony to take on a stark white appearance.
27. Once planulae settle on the bottom, they _______ into polyps and form colonies that increase in size.
30. Many scientists believe that the increased frequency of coral diseases over the last 10 years is related to deteriorating water quality and increased _______ that may allow for the proliferation and colonization of microbes.
32. _______ organisms are composed of hundreds to hundreds of thousands of individual animals.
33. Slow-growing corals that are damaged by storms may be
overgrown by __________ before they can recover.
35. Increased sea surface temperatures, decreased sea level and increased salinity from altered rainfall can all result from weather patterns such as __________.
36. The unique and beautiful colors of many stony corals are caused by __________.
39. __________ corals form table-like structures and often have fused branches.
40. In many areas, coral reefs are destroyed when cyanide or dynamite are used for ________ activities.
41. Corals are vulnerable to __________ by fishes, marine worms, barnacles, crabs, snails and sea stars.
42. Most reef-building corals require very ________ water.
43. In ________ reproduction, new polyps bud off from parent polyps to expand or begin new colonies.
45. __________ corals look like fingers or clumps of cigars and have no secondary branches.
46. Time of day when most corals feed [__________]
47. Along many reefs, spawning occurs as a ________ event, when all the coral species in an area release their eggs and sperm at about the same time.
48. __________ corals resemble the attached or unattached tops of mushrooms.
51. Corals and algae have a ________ relationship.
53. __________ is a system of specially designed buoys that measure conditions that may cause bleaching on coral reefs.
54. The skeletons of stony corals are secreted by the lower portion of the polyp. This process produces a cup, or ________, in which the polyp sits.
55. When polyps are physically stressed, they contract into their calyx so that virtually no part is exposed above their skeleton. At other times, polyps extend out of the calyx. Most polyps extend the farthest when they ________.
57. Natural damage to coral reefs frequently occurs because of ________.
60. Although coral reefs require nutrient-poor water, they are among the most ________ and diverse marine environments.
61. Reefs also are threatened by ________ that can cause shallow water coral heads to overheat and dry out.
62. The relationship between the algae and coral polyp facilitates a tight ________ of nutrients, which is the driving
force behind the growth and productivity of coral reefs.

63. As adults, almost all corals are __________, which means that they remain on the same spot on the sea floor for their entire lives.

64. An __________ is formed when a reef has developed around a volcanic island that subsides completely below sea level while the coral continues to grow upward.

65. Coral reefs buffer adjacent shorelines from wave action and prevent __________, property damage and loss of life.

66. The final release of gametes during spawning is usually based on the time of __________.

**Down**

1. Species that release massive numbers of eggs and sperm into the water to distribute their offspring over a broad geographic area are called __________ spawners.

2. __________ reefs border shorelines, but are separated from their adjacent land mass by a lagoon of open, often deep water.

3. Healthy reefs contribute to local economies through __________.

4. The walls surrounding the corals’ skeletal cup are called the __________

5. Individual coral animals are called __________

7. Human-caused, or __________ activities are major threats to coral reefs.

9. Reefs form when polyps secrete skeletons of __________

13. Because of their intimate relationship with symbiotic algae, reef-building corals respond to the environment like __________.

15. Reef-building corals cannot tolerate water temperatures [above or below] 18° Celsius (C).

17. __________ corals are ball-shaped or boulder-like and may be small as an egg or as large as a house.

18. Tropical ocean waters are generally [rich or poor] in nutrients.

20. __________ reefs project seaward directly from the shore, forming borders along the shoreline and surrounding islands.

22. __________ coral has large, flattened branches.

23. In sexual reproduction, coral eggs and sperm join to form free-floating, or planktonic, larvae called __________.
28. ________ corals grow as a thin layer against a substrate.
29. Nematocysts are capable of delivering powerful, often lethal, ________
31. A coral’s prey ranges in size from nearly microscopic animals called ________ to small fish.
32. Massive corals have growth rates of 0.3 to 2 ________ per year
34. In developing countries, coral reefs provide critical ________ resources for tens of millions of people.
37. Because their algal cells need light for photosynthesis, reef corals require ________ water.
38. One of the most significant human-caused threats to reefs is ________.
40. The reef ________ is usually the zone closest to shore.
41. Planulae exhibit positive ________
44. Reef-building corals’ requirement for high light explains why most reef-building species are restricted to the ________ ______ zone, the region in the ocean where light penetrates to a depth of approximately 70 meters.
49. Coral diseases generally occur in response to biological ________, such as bacteria, fungi and viruses, and nonbiological stresses, such as increased sea surface temperatures, ultraviolet radiation and pollutants.
50. The time between planulae formation and settlement is a period of exceptionally high ________ among corals.
52. ________ corals have primary and secondary branches.
56. Symbiotic algae supply corals with glucose, glycerol, and amino acids, which are the products of ________.
58. Coral reefs support more ________ per unit area than any other marine environment.
59. Scientists estimate that there may be ________ of undiscovered species of organisms living in and around reefs.