Keeping Watch on Coral Reefs

Monitoring Coral Reefs / Grades 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.

Links to Overview Essays and Resources Useful for Student Research

http://oceanservice.noaa.gov/topics/ocean/coralreefs
http://www.coris.noaa.gov/about/biology
http://oceanservice.noaa.gov/education/kits/corals/coral01_intro.html
http://oceanservice.noaa.gov/education/kits/corals/coral08_naturalthreats.html

Materials

- Copies of “Satellite Imagery Worksheet,” one copy for each student or student group (Click here for separate printable worksheet)
- 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 (from the Corals Tutorial at (*http://oceanservice.noaa.gov/education/kits/corals*)
- Computers (optional) with internet access; if students do not have access to the internet, you can download copies of materials cited under “Learning Procedure,” and provide copies of these materials to each student or student group

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

(top)

Background Information

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.

As co-chair of the CRTF, and as directed by the Coral Reef Conservation Act of 2000, NOAA has the responsibility to conserve coral reef ecosystems. NOAA's coral reef conservation efforts are carried out primarily through its Coral Reef Conservation Program (CRCP). Under this program, NOAA works with scientific, private, government,

and nongovernmental organizations at the local, federal, and international levels to address conservation actions. Among other actions, the CRCP undertakes a variety of mapping and monitoring activities to understand:

- locations of coral reef ecosystems;
- how they function;
- how human activities impact reef processes; and
- how managers and the public can reduce or eliminate these impacts.

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.

(top)

Learning Procedure

Part 1

1. Direct students to the Coral Tutorials at: *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 Corals Subject Review (downloadable), 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 review the purpose and activities of the U. S. Coral Reef Task Force (CRTF) and the NOAA Coral Reef Conservation Program (CRCP), and highlight the monitoring functions that are intended to identify threatened reef areas and to improve understanding of reef ecosystems (visit *http://www.coralreef.gov* for more information on the CRTF and *http://coralreef.noaa.gov* for more information on the CRCP).

Tell students that a key CRCP activity is NOAA's Coral Reef Watch Program which uses remote sensing and in-situ measurements for near real-time and long term monitoring, modeling and reporting of physical environmental conditions of coral reef ecosystems. The Coral Reef Watch Satellite Bleaching Alert System monitors sea surface temperatures at 24 selected reef sites around the globe.

"Coral bleaching HotSpots" are defined as sea surface temperatures that are greater than the normal maximum temperature. Some coral bleaching events have been noted in areas where the HotSpots are greater than 1 degree C. More often, coral bleaching results from thermal stress that accumulates over several days or weeks.

"Degree Heating Weeks" (DHWs) indicate the accumulation of thermal stress that coral reefs have experienced over the past 12 weeks. One DHW is equivalent to one week of sea surface temperatures one degree Celsius greater than the expected summertime maximum. Two DHWs are equivalent to two weeks at one degree above the expected summertime maximum OR one week of two degrees above the expected summertime maximum.

HotSpots and DHWs are used to define a series of "alert levels" for the 24 reef sites:

- A "No Stress Level" means that no thermal stress has been detected (i.e., there are no HotSpots);

- A “Coral Bleaching Watch” means that low-level thermal stress has been detected, which is defined as a HotSpot greater than 0°C but less than 1°C;
- A “Coral Bleaching Warning means that thermal stress is accumulating as indicated by a HotSpot equal to or greater than 1°C and DHW greater than 0 but less than 4;
- “Alert Level 1” means that some level of bleaching is expected based on a HotSpot equal to or greater than 1°C and DHW equal to or greater than 4 but less than 8; and
- “Alert Level 2” means that significant bleaching is expected, possibly accompanied by some coral mortality, based on a HotSpot equal to or greater than 1°C and DHW greater than 8.

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 Jan 2001 to December 2007, using data at *http://coralreefwatch.noaa.gov/satellite/current/sst_series_24reefs.html*. Ask whether temperatures have reached Alert Level 1 at any of these reefs during this time period. Students should recognize that this level has been reached at:

- Lee Stocking Island in September, 2005; and
- Sombrero Reef in August, 2003; September, 2004; August, 2005; and July, August, and September, 2007

If you want to investigate the history of temperature conditions prior to December 2000, visit *http://coralreefwatch.noaa.gov/satellite/archive/sst_series_24reefspath.html*.

3. Lead a discussion of how data from the CRCP 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 presentations, 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.

(top)

The Bridge Connection

The Bridge is a growing collection online marine education resources. It provides educators with a convenient source of useful information on global, national, and regional marine science topics. Educators and scientists review sites selected for the Bridge to insure that they are accurate and current.

http://www.vims.edu/bridge/reef.html

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

1. 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.

2. Review and discuss "Things You Can Do to Protect Coral Reefs" at *http://coralreef.noaa.gov/outreach/thingsyoucando.html*. Even if you don't live near a reef, you can help protect coral reefs in the U.S.A. and around the world.

3. For more lesson plans and activities related to coral reefs, visit the education web pages for NOAA's Ocean Explorer Cayman Islands Twilight Zone 2007 Expedition at http://oceanexplorer.noaa.gov/explorations/07twilightzone/background/edu/edu.html.

(top)

Resources

http://oceanservice.noaa.gov/education/kits/corals/supp_coral_roadmap.html – National Ocean Service website's Roadmap to Resources about corals, with links to many other sources of coral reef data, background information, and reports

http://www.oneocean.org/overseas/200009/coral_bleaching_the_hows_and_whys_and_whats_next.html

Diamante-Fabunan, D. 2000. Coral Bleaching: the Whys, the Hows and What Next? OverSeas, The Online Magazine for Sustainable Seas.

http://www.crc.uri.edu/download/COR_0011.PDF – "Coral Bleaching: Causes, consequences and response;" a collection of papers from the ninth international coral reef symposium.

http://www.nmfs.noaa.gov/habitat/habitatconservation/publications/Separate%20Chapters/Cover%20and%20Table%20of%20Contents.pdf – "The State of Deep Coral Ecosystems of the United States," 2007 report from NOAA providing new insight into the complex and biologically rich habitats found in deeper waters off the U.S. and elsewhere around the world.

http://www.latimes.com/news/local/oceans/la-oceans-series,0,7842752.special – "Altered Oceans," five-part series from the Los Angeles Times on the condition of Earth's ocean; published July 30 – August 3, 2006

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

Hughes, T.P., et al. 2003. Climate Change, Human Impacts, and the Resilience of Coral Reefs. Science 301:929-933. Available online at http://ioc.unesco.org/coralbleaching/Hughes%20et%20al.pdf

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

(top)

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1. The Earth has one big ocean with many features.

- Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 6. The ocean and humans are inextricably interconnected.

- Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

Essential Principle 7. The ocean is largely unexplored.

- Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
- Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

(top)

Keeping Watch On Coral Reefs

Student Worksheet

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 25.00°N, 81.52°W;
- Lee Stocking Island in the Bahamas, located at 23.51°N 76.51°W;
- Glover's Reef, in Belize, located near 16.57°N, 87.93°W.

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

1. Go to *http://coastwatch.noaa.gov/interface/interface.html*

2. Build your 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 "Sea Surface Temperature"

   d. In the Sensor Select window, select all of the options

   e. In the Satellite window, select all of the options (NOTE: Select all of the options for sensors and satellites because you may not be sure which systems are operating during the dates of interest. This search will retrieve all available images for the dates you specify, so you can select the ones that are most useful.)

   f. In the From and To date windows, enter the dates that correspond to the past week.

3. Click on “Search”

4. Select 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/interface/interface.html*
2. Build your 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 all of the options

   e. In the Satellite window, select all of the options

   f. In the From and To date windows, enter the dates enter the dates that correspond to the past week.

3. Click on “Search”

4. Select imagery for each of the three reefs, and determine the surface winds.

(top)

Keeping Watch On Coral Reefs

Student Worksheet

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 25.00°N, 81.52°W;
- Lee Stocking Island in the Bahamas, located at 23.51°N 76.51°W;
- Glover's Reef, in Belize, located near 16.57°N, 87.93°W.

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

1. Go to *http://coastwatch.noaa.gov/interface/interface.html*

2. Build your 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 "Sea Surface Temperature"

   d. In the Sensor Select window, select all of the options

   e. In the Satellite window, select all of the options (NOTE: Select all of the options for sensors and satellites because you may not be sure which systems are operating during the dates of interest. This search will retrieve all available images for the dates you specify, so you can select the ones that are most useful.)

   f. In the From and To date windows, enter the dates that correspond to the past week.

3. Click on "Search"

4. Select 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/interface/interface.html*
2. Build your 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 all of the options

   e. In the Satellite window, select all of the options

   f. In the From and To date windows, enter the dates enter the dates that correspond to the past week.

3. Click on “Search”

4. Select imagery for each of the three reefs, and determine the surface winds.

(top)

Corals 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

algae
anthropogenic
asexual
atoll
barrier
basal plate
below
bleaching
branching
broadcast
buttress
calcium carbonate
calyx
clear
cm
colonial
crest
CREWS
digitate
El Niño
elkhorn
encrusting
erosion
euphotic
feed
fishing
flat
foliase
food
fringing
habitats
larvae
lunar
massive
medicines
metamorphose
millions
mortality
mouth
mucous
mushroom
mutualistic
nematocysts
night
photosynthesis
phototaxis
physical stress
plants
planulae
pollution
polyps
poor
predation
productive
recycling
saline
seaward slope
sessile
species
stresses
sunset
synchronized
table
temperatures
tentacles
theca
tidal emersions
tourism
toxins
weather
zooplankton
zooxanthellae

8. A coral's prey ranges in size from nearly microscopic animals 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 facilitates 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 environments.

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 _____ 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. [how many?]

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 _____.

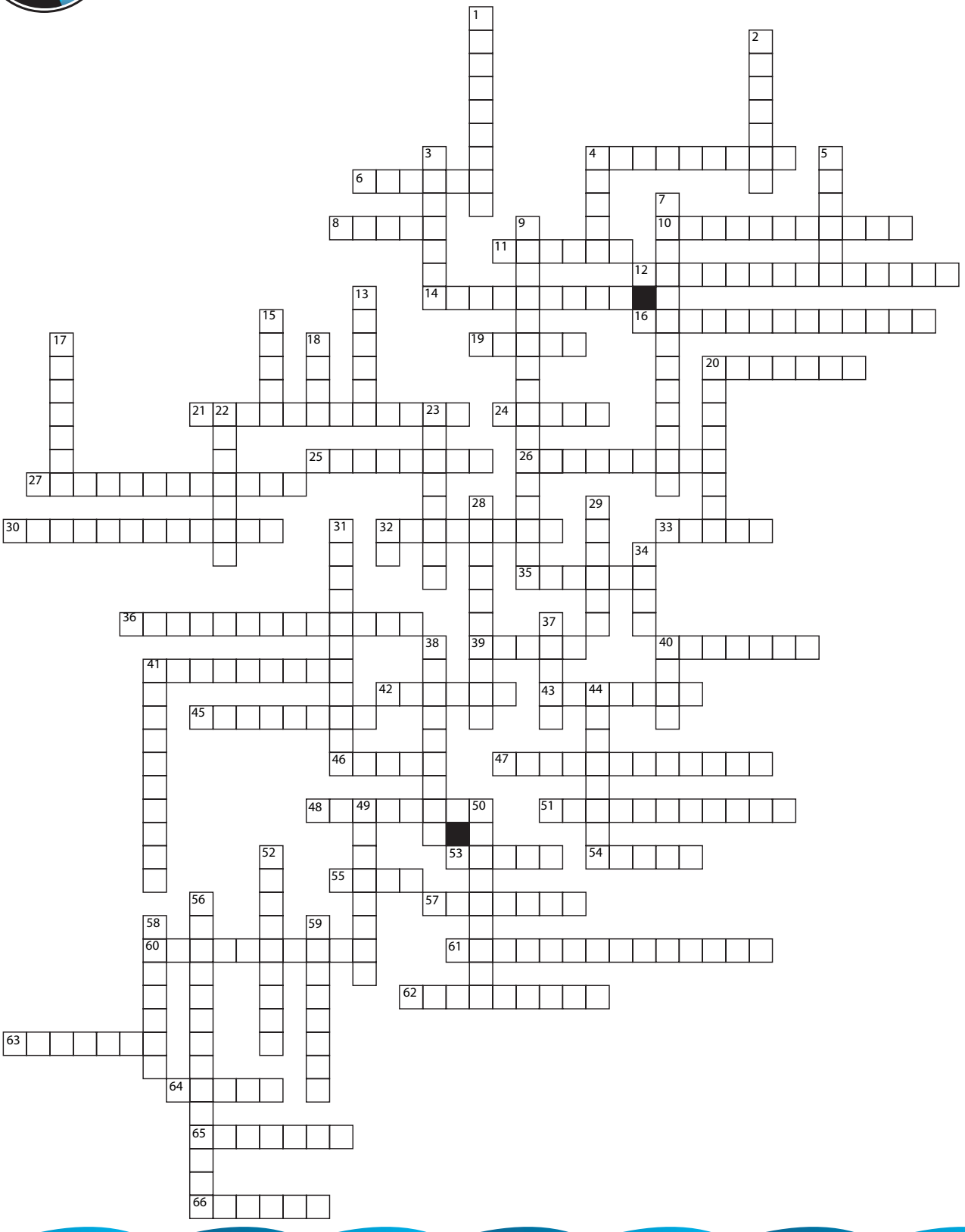
68. When some contaminants enter the water, nutrient levels can increase, promoting the rapid growth of _____ and other organisms that can smother corals.

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.

Corals Crossword Puzzle



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. The skeletons of stony corals are secreted by the lower portion of the polyp. This process produces a cip or _____ in which the coral sits.
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 non-biological 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.