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Silent Sentinels

A video produced by Australian Broadcasting Corporation, Science Unit
Directed by Dr. Richard Smith

Study Guide

by Leslie Karasin
with thanks to James M. Cervino, Marine Biologist, University of South Carolina

Silent Sentinels *is a documentary by Dr. Richard Smith on coral reefs and global warming. Focusing on the mass mortality of corals during the extreme 1998 El Niño, the film bridges subjects and demonstrates the relationships which tie the natural world together, as well as offering insight into the science and implications of climate change.*

The film is 57 minutes in length, and the classroom version is divided into segments: the first 26 minutes long and the second 31 minutes long.

About this guide:

This study guide is intended as an aid for teachers or anyone interested in the subject of the film. The subject reviews—Coral reef ecology and Climate change—are included to provide background information that may be useful in better understanding the video. They also provide some insight into areas that may be of interest for further study. Both deal with complex topics; the reader is encouraged to consult the resources listed to learn more, and for more ideas on ways to approach these topics. Users of the classroom version will find the questions and activities marked as they correspond with the first or second part of the classroom series.

Contents

Synopsis

Coral reefs are home to a dazzling array of life; they are one of Earth's richest reservoirs of biodiversity, and they are also showcases for amazing ecological interactions. But reefs world-wide are in danger, and their plight may be a warning of effects that will impact other ecosystems, wreaking havoc with the balance of climate and life as we know it the world over. Coral reefs are one of the most climatically sensitive ecosystems, and are the first to suffer during temperature fluctuations and other types of abiotic and biotic stresses.

In 1998, an immense and widespread coral die-off occurred. The cause of this die-off was coral bleaching, which is a process where coral expel their resident algae which provide them with food and energy thanks to the algae's photosynthetic capability. When water temperatures rise, even slightly, as they did in 1998 (just 1 to 2 degrees C above the norm for the warmest month can trigger the effect), the algae living in coral are unable to cope. Because of this narrow thermal tolerance, the coral expel the algae, which are their energy source. Eventually, without algae to photosynthesize light energy, coral starve and die. The impact on coral, in turn, affects many types of marine animals; bleached and dead, coral reefs are no longer a stable, vigorous habitat for the many life forms which live in them.

The 1998 bleaching event, which seriously affected many reefs worldwide, and particularly those in the Indian Ocean, was caused by a widespread rise in ocean temperatures, and was considered one of the worst ever. Triggered by "hot spots", which are areas of extreme warm waters, along with the climatological event known as El Niño, these rising temperatures, evidence suggests, reflect humans' impact on climate and global warming. Reefs, which are extremely sensitive to temperature changes, are a signal of the environmental distress which is affecting many of our ecosystems today.

In addition to discussing the physiology of corals and the ecology and importance of coral reefs, the film includes several scientists' studies involving the evidence of global warming and the specific processes which affect corals. Beyond the scientific analysis presented, the film raises serious questions about the potential implications of global warming.

Before viewing

Classroom version users: ♣ indicates questions and activities especially applicable to the first part; ♠ indicates questions and activities especially applicable to the second.

- ♣ Review coral biology and the ecology of a coral reef. (See *A Basic Introduction to Coral and Coral Reefs*, page 5) What is coral? Why is it important?

- ♣ Discuss the symbiotic association between the coral host and zooxanthellae, the single-celled algae from which coral gets much of its food and energy.

- ♣ Define biodiversity. (See glossary) Why is it important?

- ♣ What is a sentinel? Consider the title of the film; how might coral reefs be Silent Sentinels?

- ♣ Using a map, discuss the global distribution of coral reefs. What is the relationship between the distribution of reefs and warm water currents? Discuss the idea of thermal tolerance.

- ♣ Discuss the concept of environmental stress. What tools do species use to contend with environmental stresses? How do adaptations and evolution play a role in this process?

- ♠ What is climate change? Historically, has the Earth's climate been static? How is it changing today? (See *Topics in Climate Change*, p. 6)

- ♠ Discuss the concept of an indicator species. The presence or absence of certain species is often seen as a gauge of the health of an ecosystem. Locally, particular plants and animals are sometimes counted just for this reason. Globally, the decline of certain species is linked with international environmental problems. Research suggests a connection between falling numbers of amphibians world wide and the increased UV penetrating the atmosphere because of the depletion of the ozone layer. UV and increased temperatures are making conditions more favorable for microorganisms to proliferate. Many species from frogs to human are being subjected to various new strains of viruses and bacteria.

- ♠ Define and discuss El Niño. (See *Topics in Climate Change*, p. 8) El Niño is often mentioned in relationship to the weather in North America, even though it is a Pacific event. Why?

- ♠ What are the different ways in which coral polyps reproduce? (See *A Basic Introduction to Coral and Coral Reefs*, page 5) Visit the Waikiki Aquarium's website (http://www.mic.hawaii.edu/aquarium/research/index.html) to watch a coral bud and grow through an online web cam. Discuss the evolutionary differences between sexual and asexual reproduction, and the importance of mobility in allowing coral to adapt to changing conditions.

- ♠ Discuss the carbon cycle. Who/what produces CO_2? Who/what consumes it? How are humans involved? How is CO_2 related to global warming?

- ♠ Study a cross section of a tree trunk, or a diagram. What does the spacing of the rings reveal? If you know the year the tree died, what can you deduce by studying the rings? Can you match a particular ring pattern with a known climate extreme?

After viewing

- ♣ Reconsider the title of the film. What is the silent warning of coral reefs? How is it expressed? What are its implications?

- ♣ Review the process of coral bleaching. What causes it, and how does it happen? What does it mean for the reef?

- ♣ Discuss symbiotic relationships. What is the example of a symbiotic relationship highlighted in the film? What are some other symbiotic relationships?

- ♣ Look at NOAA's hot spot website. (http://www.coral.noaa.gov/images/images.html) NOAA scientists developed this database to predict and explain warm ocean temperatures and bleaching events. It is useful as a tool for these purposes, but can it prevent coral bleaching?

- ♠ Why is a threat to coral important? What are the impacts on biodiversity? What is the indication for other ecosystems? What are the direct implications of a coral die-off for humans? (eg, for people who fish the oceans or who rely on reef-related tourism)

- ♠ Revisit the topic of climate change. What causes it? How well is it understood? How is it studied? What are some of its possible consequences? What can we do to reduce these effects?

- ♠ Consider the positive steps that we can take to protect coral reefs and other ecosystems threatened by climate change. Discuss the opportunities for protection, and take action. Use the Climate Change and Resources sections to learn more; many NGO's have useful websites on opportunities to make positive changes.

- ♠ How can we differentiate between natural climatic cycles and aberrations caused by human behavior? Discuss climatic history, and the scientific analysis of ice, coral and tree cores as evidence of past climate patterns. What do these indicate?

- ♠ Discuss scientific methodology. How do the scientists in the film choose what to study? How do they evaluate information? How do they draw conclusions? Establish proof? Discuss a specific example from the film—e.g. the question of what causes coral bleaching, or the question of why bleached coral demonstrated a shading effect. Remember shading only partially protects corals: they still bleach when the water is warm.

- ♠ The film links two topics which one might not think are related (coral reefs and global warming.) Globally, many things are linked through connections which are not immediately apparent. Discuss the implications of this idea for human behavior. Do we understand ecology and climatology well enough to fully comprehend the impacts of our behavior?

- ♠ Discuss other coral reef stresses, such as cyanide fishing, coastal nutrient pollution and sedimentation. These stresses induce local bleaching, not the kind of mass coral reef bleaching event shown in the film. Nutrient pollution also causes algal overgrowth on the exposed coral skeleton after bleaching. Algae quickly colonize the skeleton when the tissue dies back.

- ♠ *Further study*: The film raises abundant subjects which might be the topic of further research or projects. A few of these topics include: paleoclimatology, coral ecology, weather modelling, and other topics in climate change science. Make use of the resources listed to learn more.

A Basic Introduction to Coral and Coral Reefs

Anyone who has seen photographs of coral reefs probably knows that they are home to many species of fish and other marine life, but fewer people understand that a coral reef ecosystem itself is made up of millions of organisms. Corals, the rock-like structures which provide habitat for fish, are themselves alive—or, more accurately, they are made up of thousands of living animals, as well as the physical result of a history of past generations of these animals.

To examine these ideas more clearly, we should start with the coral animal. This is a tiny creature called a polyp; each polyp has a mouth with a ring of tentacles to capture its prey. In the sense that it captures and ingests food (zooplankton and phytoplankton) and breathes oxygen, it is like other animals. Unlike most animals, however, it does not move; for its entire adult life, the polyp is fixed in one place. Polyps generally live in large colonies of members of their own species, and a polyp is connected to its neighbors with living tissue. The polyps and the connecting tissues naturally secrete calcium carbonate, which hardens and forms deposits of limestone, the rock upon which a reef lives. Through this gradual process of limestone secretion, polyps transform their landscape, gradually contributing to reefs, which are the largest structures made by living things on earth. Thus the rock of a reef is the product of generations of corals. Without the coral animals themselves, reefs lose the ability to grow and adjust to changing conditions; the structure remains, but much of the life is gone.

There are hundreds of species of coral, recognizable by their distinct shapes. Different species deposit calcium carbonate differently, leading to unique appearances. But coral share much in common across species.

While polyps are capable of catching plankton with their tentacles, much of their energy comes from algae. A single-celled species of algae called zooxanthellae coexists with many species of coral in a symbiotic, mutually beneficial, relationship. The algae live within the coral's tissue. For their part of the bargain, the algae receive a stable, safe habitat and CO_2 (the product of the coral's respiration). In exchange, they provide the polyp O_2 to breathe and carbohydrate. This carbohydrate is the biproduct of the algae's photosynthesis, and it provides for much of the energy needs of the polyp. As a result of this complex and fascinating relationship, coral are essentially fed by the algae without eating the algae themselves. One additional benefit of the algae's presence is that they facilitate and speed the process of limestone deposition which builds the reef.

Algae are, therefore, vital to the existence of many species of coral. As the film discusses, however, algae are expelled from the reef during periods of

environmental stress. Acutely sensitive to temperature fluctuations in the marine environment, resident algae become poisonous to their host coral during times of unusually high (or low) water temperatures and are expelled, leading to the process of coral bleaching. The film discusses the link between temperature and algae failure; in abnormally high temperatures algae are unable to process the energy from photosynthesis, and the energy turns oxygen into a toxic substance. In this way, a life-giving process actually generates enormous harm. Without the algae upon which they depend, coral eventually starve and die.

There are three ways in which coral reproduce and spread. Individual polyps can bud and create genetically identical polyps. This is the most common form of reproduction. Many corals also reproduce by fragmentation; if a piece of coral breaks off and lands in a suitable habitat, it can take hold and establish a new colony. The last way in which corals reproduce is the only form of sexual reproduction, and therefore the only way in which genetic variation from one generation to the next is possible. Sperm from male polyps and eggs from female polyps form larvae called planulae. Planulae drift with the current; this is the only mobile stage of a coral's life cycle. This process of sexual reproduction is also an important way for coral to have an opportunity to spread to more favorable conditions in times of environmental stress. When a drifting planula settles, it changes into a polyp, secretes a limestone case, and begins to form a new colony through budding.

The film discusses the peril of coral reefs as a result of sea water temperature rises and the mass expulsion of the life-supporting zooxanthellae. The tragedy of coral die-off should not be underestimated; teachers and scientists often point out that the diversity and intricacy of life in a coral reef is equivalent to that of a tropical rainforest. These intense concentrations of life represent a brilliant and important element of the natural world. Yet global warming is a pressing threat to their continued health; some scientists estimate that if present rates of bleaching and global warming continue, coral reefs may be wiped out worldwide in a century. Find out how you can preserve this resource by reading more and by consulting the resources listed.

Topics in Climate Change

Any scientist will freely admit that the science of climate change is far from complete, but what follows is a summary of some of the important concepts upon which the study of climate change is based. These are merely the building blocks of a complex and controversial topic. Some of the far-reaching implications of these ideas are discussed at the end; the reader is encouraged to seek out additional information.

Global warming

At the core of the climate change issue is the subject of global warming. Briefly defined, global warming is an increase in Earth's temperatures due to increasing concentrations of certain gases in the atmosphere. These "greenhouse" gases include primarily carbon dioxide, but also methane, chlorofluorocarbons, nitrous oxides, and low-level ozone. All of these gases have the property of absorbing heat that is reflected from the earth. After trapping radiant energy in this way, the gases radiate energy in all directions, sending some of the heat back towards Earth. Thus, what is often described as the greenhouse effect occurs; the earth's heat does not leave the atmosphere, but instead some of it remains "trapped" inside these gases in the atmosphere.

Historically, this phenomenon is nothing new. Carbon dioxide and other "infrared trapping" gases have been helping to keep the earth warm for thousands, if not millions, of years. But the concentrations of these gases have been changing recently as a result of human activity, giving rise to concern that humans may cause the climate to warm dangerously quickly. Since the mid-1700's, carbon dioxide levels have risen by 25%, and they continue to increase annually. The question of how these increases will affect climate is a topic of intense study.

Why are CO_2 levels in the atmosphere going up?

Since the start of the Industrial Revolution, people have been rapidly burning fossil fuels to provide warmth, energy and transportation. These fuels—coal, oil, and gas—represent significant amounts of stored carbon, since they originated from organic matter. When burned, the fuels undergo a chemical reaction that transforms solid or liquid carbon into gaseous carbon dioxide in the atmosphere. Carbon (and CO_2) have natural cycles of circulation, but this large scale release of CO_2 in the atmosphere is the dominating feature of recent changes. The differences are exacerbated by widespread deforestation; plants and trees remove CO_2 from the atmosphere during photosynthesis, and deforestation means that there are fewer trees to carry out this important function. This is particularly important in tropical rainforests, which carry on photosynthesis year-round, and therefore consume a lot of CO_2.

The two dominant factors affecting recent increases of CO_2 are therefore human comsumption of fossil fuels and destruction of the world's forests. If we think that the repercussions of global warming are distressing, we must consider our role in these destructive actions.

Modelling

To try to gain a clearer understanding of the effects of CO_2 level increases, and to try to predict climate changes, scientists construct mathematical models. Natural processes are expressed in mathematical terms, and a computer is used to process the effects of various changes. These models, however, are as complicated as the climate itself. In order to be accurate, a model must take into account the circulation patterns of air and water, the effects of low and high pressure, seasonal and daily variations, interactions between plants, animals, and the oceans and atmosphere, etc. Often a model must also take into account feedback loops—where one change triggers another, in a sort of a circular domino effect. The accuracy and predictive capabilities of models are therefore dependent upon an accurate understanding of world climate conditions. One important factor which climate models must consider is El Niño.

El Niño

Historically, El Niño was a periodic event in the Pacific of a warm current of water near the surface off the coast of Peru. This current would recur every few years, replacing what is generally a cool current, and it would be of concern to locals because of its affect on local fish and bird populations. More recently, however, El Niño has been studied as part of a Pacific Basin-side phenomenon that may be linked to global climate aberrations. The underlying definition is unchanged; El Niño is marked by the presence of warm surface waters in the eastern Pacific. But this has been linked to unusually low pressure in the central Pacific (around Tahiti) and unusually high pressure in the western Pacific (around Darwin, Australia.) These pressure changes—known as the Southern Oscillation—together with the water and air currents of El Niño are considered to be responsible for abnormal weather in the Pacific basin—particularly droughts in Australia and India and flooding in South America. These cumulative events, however, may trigger global climate aberrations, and scientists are studying the effect of El Niño on weather conditions worldwide.

El Niño is a naturally occurring event which takes place at irregular intervals every few years, lasting months or a year each time. Scientists, however, are studying the impact of climate change on El Niño events. There is general consensus that climate change may make El Niño events more frequent and more intense, causing concern about the possibility of more extreme flooding, storms, and droughts in the future. The film quotes research that the frequency of El Niño events has increased from every six years to every two and a half years between the 1600s and today.

Conclusions: policies, predictions and actions

The topic of climate change tends to raise more questions than it provides answers. How much will the temperature of the Earth rise? What will the effect be on sea levels? How about on plant, animal, and human communities? Things tend to get more complex as you study them in greater depth. For example, if sea levels rise as a result of the melting of the polar ice caps and the expansion of warmer sea water, how will this affect low-lying islands, coastal areas, marine estuaries with a delicate balance of fresh and salt water, or the salinity of coastal agricultural land and drinking water reserves? While we understand these topics to some extent, there are still unanswered and unanswerable questions of interest to every person on earth.

Despite these uncertainties, however, a great deal has been generally agreed upon among scientists, and areas of consensus are important starting points for the formation of policy to address climate change issues. In recognition of the need for an international body dedicated to the topic of climate change, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988, and in 1990 it published its first scientific report. Among the IPCC's conclusions has been a "best estimate" predicted global average temperature rise of 4.5 degrees F over the next century. Considering that this is a global average, that it represents a rapid change in climate historically, that the pace may be faster than ecosystems are able to adapt to, and that temperature increases may be accompanied by an increase in the frequency and intensity of climate extremes such as flooding and drought, it is certainly a very significant number.

The 1990 IPCC report, with its climate change predictions, was drawn upon at the Rio Earth summit, at which over 160 countries signed the Framework Convention on climate change. This document attempts to form a basis for international

collaboration on achieving greenhouse gas emission reductions. Signatories to the convention recognized the pressing issue of climate change and accepted the need for demanding national and international target goals.

Today, we are in the difficult position of needing to take decisive action while many members of the public are still unconvinced about the seriousness of the potential ramifications of climate change. But nearly every year we see new records of climate extremes; the 1998 bleaching event was just one more urgent indication of the severe implications of global warming.

What can we do?

Faced with this sobering, disturbing and formidable issue, it sometimes seems easier to avoid the problem than to address it. There are, however, simple and important steps that we can each take to reducing human impact on climate change.

- Learn more about the issue, and support climate change research efforts.
- At the voting booth and through democratic participation, support policies which properly take the environment and climate change issues into account.
- Minimize your fossil fuel consumption.
    - How much electricity do you use, and where does it come from?
    - How do you meet your transport needs? Use public transport or fuel-efficient vehicles.
    - Maximize the efficiency of your energy use. Reduce consumption by using efficient appliances, light fixtures, etc, and ensuring that your house is well-insulated.
    - Consume less. Everything that we buy has a history of production and shipment which involves the use of fossil fuels. Minimize this impact.
- Do your part to help keep the world's forests intact. Buy products produced sustainably, and support policies to preserve our forests.
- Consult the resources section for more ideas on what you can do.

Glossary

Biodiversity, biological diversity Diversity of living things; includes not only variation of species on Earth, but also variation of ecosystems and genes

Coral bleaching The phenomenon of corals turning white as a result of the expulsion of the zooxanthellae (a type of dinoflagellate or single-celled algae) from their tissues; the loss of the zooxanthellae exposes the translucent corals and their limestone skeletons; corals often die as a result of the bleaching process.

El Niño Literally, the boy or the Christ Child, as a reference to the winter phenomenon off the coast of Peru of a warm current of ocean water. Today, El Niño refers to both the localized event of the current and the broader Pacific-wide event involving pressure fluctuations, and a change in air and water currents.

Global warming The process of a rise in earth's temperatures as a result of the greenhouse effect (below); global warming is feared to have far-reaching repercussions for people and ecosystems.

Greenhouse effect The trapping of the sun's heat in the earth's atmosphere by greenhouse gases (carbon dioxide, methane, CFC's, etc.) An increase in the concentration of these gases in the atmosphere in recent years has resulted in speculation of global warming (above.)

Polyp A single coral animal; a polyp is an immobile animal which receives much of its energy from algae living in its tissue which photosynthesize light. (see zooxanthellae, below)

Sentinel One posted to keep guard.

Symbiotic relationship A close association between the individuals of different species which brings mutual benefits.

Thermal tolerance The temperature comfort range which a species can tolerate without demonstrating signs of stress.

Zooxanthellae A type of dinoflagellate; a singe-celled algae which live within the tissue of corals and provide energy from photosynthesis in exchange for receiving carbon dioxide and a secure habitat. They provide the coral with much of its color and nutrition. Zooxanthellae have a narrow thermal tolerance which results in coral bleaching during periods of abnormally high water temperatures.

Resources

<u>Books and printed material</u>

Coral bleaching, coral mortality, and global climate change. Report to the U.S. Coral Reef Task Force. U.S. Department of State Pomerance, R., J.K. Reaser, P.O. Thomas. 1999

Coral Reefs and Climate Change: Last Straw for a Threatened Ecosystem. Patricia Glick. Washington: National Wildlife Federation, 1999. (see NWF, below)

Currents of Change: El Nino's Impact on Climate and Society. Michael H Glantz. Cambridge: Cambridge University Press, 1996.

Global Warming: The Complete Briefing. John Houghton. Oxford: Lion Publishing, 1994.

A Natural History of the Coral Reef. Charles Sheppard. Dorset, England: Blandford Press, 1983.

The End of Nature. Bill McKibben.

-and many others. Keywords: Coral, Coral reefs, Climate change, Global warming.

Organizations and Websites

Coral Reef Alliance
2014 Shattuck Ave; Berkeley, CA; 94704
(510) 848-0110 or 1 888 CORAL REEF
http://www.coral.org useful link: directory of coral reef NGO's
http://www.coral.org/NGO/index.html

EPA Office of Water
-Coral website at http://www.epa.gov/owow/oceans/coral

EPA – Climate issues
http://www.epa.gov/globalwarming/index.html

Greenpeace
-Report on coral bleaching at
http://www.greenpeace.org/~climate/science/coralbleach.html

Intergovernmental Panel on Climate Change
http://www.ipcc.ch

National Oceanographic and Atmospheric Administration—Atlantic Oceanographic and Meteorological Laboratory
4301 Rickenbacker Causeway; Miami, FL; 33149
Coral Health and Monitoring Program (CHAMP)
http://www.coral.noaa.gov
satellite imagery of hotspots at http://www.coral.noaa.gov/images/images.html

National Wildlife Federation: Climate Change and Wildlife Program
1400 16th St NW; Suite 501; Washington, DC; 20036
(202) 797-6898
http://www.nwf.org/nwf/climate/coral/index.html
http://www.nwf.org/nwf/climate/

REEF – Reef Environmental Education Foundation
(305) 451-0312
http://www.reef.org

Waikiki Aquarium
Webcam of corals growing at
http://www.mic.hawaii.edu/aquarium/research/index.html

World Wildlife Foundation Climate Change Campaign
1250 24th St NW; PO Box 97180; Washington, DC; 20077-7180
(800) CALL WWF
http://www.worldwildlife.org/climate/index.cfm

Related Bullfrog Films

THE PERILS OF PLECTROPOMUS (56 mins, 1999) – A companion film to, and produced by the same team as, **SILENT SENTINELS**, it looks at the dangers the coral reef trout faces from cyanide fishing.

RISING WATERS: Global Warming and the Fate of the Pacific Islanders (57 mins, 2000) – Pacific Islanders are the canaries in the coal mine of global warming.

TURNING DOWN THE HEAT (46 mins, 1999) – Shows the latest advances in renewable energy technology as at least a partial answer to global warming.

BIG SPUDS, LITTLE SPUDS (52 mins, 1999) – Takes a close look at the potato to examine the effects of climate change and monoculture on one of the world's staple food crops. In 1997 El Niño had a dramatic impact on two centers of the world's potato industry, Idaho and Peru.

GLOBAL WARMING: Turning Up the Heat (46 mins, 1996) – At the 1992 Earth Summit in Rio there was a broad consensus to do something about global warming. Why has nothing happened?

GAIA: THE LIVING PLANET (45 mins, 1989) – James Lovelock, an atmosphere scientist, was the author of the Gaia Hypothesis that says that the Earth is a living organism. In this portrait of his life and work, particular emphasis is placed on the role that phytoplankton plays in regulating the planet's atmosphere and environment.

ONCE AND FUTURE PLANET (23 mins, 1990) – A balanced and concise look at global warming and the effect that our industries and lifestyles have on the earth's atmosphere.