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2007: Exploring the Inner Space of the Celebes Sea

The Census of Marine Life

Focus
The Census of Marine Life

Grade Level
9-12 (Biology)

Focus Question
How can scientists study life in Earth's ocean on a global scale, and understand what used to live in the ocean, what currently lives in the ocean, and what will live in the future ocean?

Learning Objectives
Students will be able to describe the Census of Marine Life (CoML).

Students will be able to explain in general terms the CoML strategy for assessing and explaining the changing diversity, distribution, and abundance of marine species from the past to the present, and for projecting future marine life.

Students will be able to use the Ocean Biogeographic Information System to retrieve information about ocean species from specific geographic areas.

Materials
- ❒ Copies of the "Census of Marine Life Worksheet," one copy for each student or student group
- ❒ Internet access for student research or copies of applicable reference materials (see Learning Procedure, Step 1)

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods plus time for student research

Seating Arrangement
Classroom style or groups of 3-4 students

Maximum Number of Students
30

Key Words
Celebes Sea
Census of Marine Life
Biodiversity
Biogeography
Climate change
Ocean Biogeographic Information System
Worksheet

Background Information
Indonesia is well-known as one of Earth's major centers of biodiversity. Although Indonesia covers only 1.3 percent of Earth's land surface, it includes:
- 10 percent of the world's flowering plant species;
- 12 percent of the world's mammal species;
- 16 percent of all reptile and amphibian species; and
- 17 percent of the world's bird species.

In addition, together with the Philippines and

Great Barrier Reef, this region has more species of fishes, corals, mollusks, and crustaceans than any other location on Earth.

What, exactly, is meant by biodiversity, and why is it important? The term "biodiversity" is usually understood to include variety at several levels:

- variety of ecosystems: high biodiversity suggests many different ecosystems in a given area;
- variety of species: high biodiversity suggests many different species in a given area;
- variety of interactions between species; and
- variety within species (genetic diversity): high biodiversity suggests a relatively high level of genetic variety among individuals of the same species.

A simple definition of biodiversity could be "The variety of all forms of life, ranging in scale from genes to species to ecosystems."

Biodiversity is important to humans because our survival depends upon many other species and ecosystems. Some examples of our dependence on biodiversity include:

- fresh air containing oxygen;
- clean water;
- productive soils;
- food, medicines and natural products;
- natural resources that provide the basis for human economies; and
- natural beauty that improves our quality of life.

(adapted from the Biodiversity Project, http://www.biodiversityproject.org/bdimportant.htm)

Quite a lot is known about Indonesia's terrestrial and shallow-water ecosystems. But scientific knowledge and understanding of midwater ocean communities is generally sketchy, and many midwater animals have not been studied at all—even though the midwater ocean environment is our planet's largest ecosystem. Midwater animals range from microscopic zooplankton to the largest animals on Earth, provide a major source of nutrition for benthic (bottom) communities, and are an important link in the transfer of energy and materials from the top to the bottom of the ocean. Note that the term "midwater" as used here includes the entire water column, but the same term has also been used to refer to only part of the water column. Scientists often divide the ocean water column into three zones: the "epipelagic zone" (also called the "sunlit" or "euphotic" zone) from the surface to a depth of about 200 m; the "mesopelagic zone" between 200 m and 1100 m; and the "bathypelagic zone," which is deeper than 1100 m.

The seas of Indonesia and the Philippines (including the Sulu, Banda, Celebes, Java, Molucca, and Halmahera Seas) are the only deep-water gap between the continental shelves of Australia and Southeast Asia. Water flowing from the Western Pacific Ocean into the Indian Ocean is channeled by numerous island chains to form a series of ocean currents known as the Indonesian Throughflow. The dominant Throughflow current passes off the southern Philippines into the Celebes Sea (which is partially enclosed by Borneo (Kalimantan) and the island of Celebes (Sulawesi), then flows through the Makassar Strait, around Java and the Lesser Sunda Islands, and eventually becomes part of the west-flowing South Equatorial Current.

The path of the Indonesian Throughflow through the Celebes Sea coincides with an imaginary boundary known as "Wallace's Line." Alfred Russell Wallace was an English naturalist who spent eight years in Indonesia during the mid-1800's studying wildlife and collecting specimens for museums. During his travels, Wallace noticed that animals on the island of Bali seemed to be related to similar species found in Asia, while animals on the Island of Lombok (only 20 miles away to the southeast) were very different and more closely resembled species in Australia. The boundary between these two "zoogeographic regions" became known as "Wallace's Line," and extends from the middle of the Celebes Sea, through the Makassar Strait between Borneo and Celebes, and through the strait between Bali and Lombok.

This junction of two great zoogeographic regions is sometimes referred to as "Wallacea," and is an area of particularly high biological diversity and endemism. Endemic species are species that are found nowhere else. The high number of endemic species in Wallacea is probably due to several factors:

- High temperatures associated with the tropical climate are thought to increase rates of mutation, which in turn increase the opportunity for new species to arise;
- The presence of many islands creates habitats that are more or less isolated from each other, and such isolation favors the evolution of new species that are uniquely adapted to local conditions; and
- During past ice-ages, lower sea levels created land bridges between the islands of Java, Borneo, Sumatra and Bali and allowed species to spread among these islands, but deep ocean trenches prevented migrations to islands to the east.

These factors help explain the diversity of terrestrial organisms on either side of Wallace's Line; but what about marine organisms? Does Wallace's Line also exist in the ocean environment? Recent research on the genetics of some marine species suggests that populations in the seas of Indonesia may also be biologically isolated from each other, even though strong currents would be expected to spread larvae around the region and prevent this kind of isolation.

Why is this important? Because Earth's marine habitats are in serious trouble. In particular, coral reefs are in decline: 10% of reef environments have already been permanently lost, and this figure may increase to as much as 70% by the year 2020 (Wilkinson, 1992). Protected areas known as marine reserves are one way to deal with this problem; studies have shown that marine reserves can help restore biomass and diversity in over-exploited communities. To be effective, though, marine reserves must have a supply of new organisms to re-populate such communities, and for many marine species this means a supply of larval organisms.

So, decisions about the size and location of marine reserves require information on how much interaction or "connectivity" exists between populations in a given region. One way to predict connectivity is to examine the currents that flow between populations, and couple these data with information about the larval cycle of organisms of interest (organisms with long larval cycles would be expected to travel farther than those with shorter cycles). But this approach may not give an accurate picture if there are other factors that tend to keep populations isolated from each other.

The 2007: Exploring the Inner Space of the Celebes Sea Expedition is focused on exploring the variety of midwater organisms in the most biologically diverse region on Earth. Key expedition questions include:

- What animals are found in Indonesian midwater communities?
- How does the biodiversity of Indonesian midwater communities compare with other marine communities in this region, and with other midwater communities in other regions?
- What proportion of animal species in Indonesian midwater communities is endemic to this region (found nowhere else on Earth), and how does this degree of endemism compare with that of other regions?

The last two questions require information from all of Earth's ocean habitats, and some of the major concerns about these habitats are global in scale (overfishing, pollution and climate change, for example). To deal with these realities, scientists from over 80 countries are collaborating in a ten-year project known as the Census of Marine Life (CoML). Using historic databases (some of which are centuries-old), new ocean exploration technologies, and the communications power of the worldwide web, CoML's mission is to "assess and explain the changing diversity, distribution, and abundance of marine species from the past to the present, and project future marine life." This goal involves three basic questions:

- What did live in the oceans?
- What does live in the oceans?
- What will live in the oceans?

To answer these questions, CoML activities include:

- Preparing a History of Marine Animal Populations (HMAP) based on scientific archives to quantify how fishing and environmental fluctuations have affected life in Earth's ocean;
- Fourteen international Ocean Realm Field Projects as well as affiliated national efforts to explore the diversity, distribution, and abundance of Earth's ocean life
- Assembling a global geographically indexed database about marine species known as the Ocean Biogeographic Information System (OBIS), which is accessible on the worldwide web; and
- The Future of Marine Animal Populations (FMAP) network to analyze data generated by CoML to predict how environmental and human influences will change what will live in the oceans.

In this lesson, students will become familiar with the overall purpose of the Census of Marine Life and some CoML resources that are available to the public.

Learning Procedure

1. To prepare for this lesson, review the introductory essays for the 2007: Exploring the Inner Space of the Celebes Sea Expedition at http://oceanexplorer.noaa.gov/explorations/07philippines/. Review questions on the "Census of Marine Life Worksheet;" and if students do not have Internet access for research, download appropriate materials from the Web sites referenced in the Worksheet.

2. Briefly introduce the 2007: Exploring the Inner Space of the Celebes Sea Expedition, focusing on midwater animals as an example of potentially important marine life that has not been well-studied. Discuss the concept of biodiversity, highlighting why biodiversity is important to humans and that Indonesia is one of Earth's major biodiversity centers. List the key expedition questions described in "Background Information," and ask students how scientists working in a single location could go about comparing their results with relevant work from the rest of Earth's ocean? Discussing this question should lead students to recognize the need for a global inventory of scientific information about ocean life. Tell students that the need for such an inventory has led to the creation of the Census of Marine Life, and that their assignment is to learn more about CoML and some of the CoML resources that are available to the global scientific community (which includes students!).

3. Provide each student or student group with a copy of the "Census of Marine Life Worksheet."

4. When students have finished answering Worksheet questions, lead a discussion of their answers and reports. Answers to questions in Part I should include the following points:

   - CoML began in the year 2000.

   - All ocean habitats are included in CoML, "from icy polar to warm tropical waters, from tidal zones shared by humans to obscure trenches 10,000 meters deep, from microscopic plankton in the light and sea lions plunging into the dark to worms in abyssal sediments, from organisms shifting on the slopes of seamounts to ones tolerating fiery oceanic vents, the 5 percent of the ocean that is fairly regularly visited and the 95 percent of the ocean whose life is largely unexplored."

- HMAP stands for "History of Marine Animal Populations," a CoML activity to quantify "how fishing and environmental fluctuations changed what lived in the oceans."

- Information for the History of Marine Animal Populations is being assembled by "mining historical and environmental archives, typically since about the year 1500."

- Six ocean realms are included in CoML's Ocean Realm Field Projects:
  - Human Edges include the Nearshore and Coastal zones, coral reefs, regional ecosystems, and continental shelves;
  - Hidden Boundaries include Continental Margins and Abyssal Plains;
  - Central Waters include the Light (drifters and swimmers) and Dark (mid-water and bottom-water) zones, zooplankton, top predators, and mid-ocean ridges;
  - Active Geology includes Seamounts, Vents, and Seeps;
  - Ice Oceans include the polar zones of the Arctic and Antarctic; and
  - Microscopic Ocean includes microbes, which are present everywhere in Earth's ocean.

- FMAP stands for "Future of Marine Animal Populations," an activity to integrate CoML data with mathematical models that can predict how environmental and human influences will change what will live in Earth's ocean.

- "CoML works toward the following legacies beyond 2010:
  (1) a sustained, dynamic OBIS that serves the needs of the scientific community, as well as those of government, industry, and educators;
  (2) proven technologies and approaches to surveying marine biodiversity that can be replicated by researchers globally and implemented in monitoring programs and ocean and coastal observation systems;
  (3) increased public interest in the oceans and marine life and support for ongoing research;
  (4) centers of excellence in marine biodiversity to build capacity in the developing world; and
  (5) identification of a new generation of ocean biogeographers and ecologists."

Discuss students' experience with OBIS and CephBase. Students should realize that these exercises represent a very small sample of the kinds of information that can be retrieved via OBIS. Be sure students understand that most of this information was not readily available prior to the creation of OBIS, and that these tools make it possible for many people to investigate many kinds of questions about ocean life on a global scale.

The Bridge Connection

www.vims.edu/bridge/ – In the "Site Navigation" menu on the left, click on "Ocean Science Topics," then "Biology," then "Biodiversity for links to topics on biodiversity and evolution.

The "Me" Connection

Have students write a short essay on how CoML could be of personal importance.

Connections to Other Subjects

Geography, Earth Science, Language Arts

Assessment

Worksheets and discussions provide opportunities for assessment.

Extensions

1. Visit oceanexplorer.noaa.gov to keep up to date with the latest 2007: Exploring the Inner Space of the Celebes Sea Expedition discoveries, and to find out what researchers are learning.

2. Visit the Marine Biodiversity and Ecosystem Functioning outreach Web page (http://www.marbef.org/outreach/) for links to additional education activities related to CoML.

Multimedia Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 8 and 12 for interactive multimedia presentations and Learning Activities on Ocean Currents and Food, Water, and Medicine from the Sea.

Other Relevant Lesson Plans from the Ocean Exploration Program

Blinded By the Light!! [http://www.oceanexplorer.noaa.gov/explorations/02sab/background/edu/media/sab_blinded.pdf] (6 pages, 460k) (from the Islands in the Stream 2002: Exploring Underwater Oases Expedition)

Focus: Physical Science – Absorption, Scattering, and Reflection of Light in the Deep Sea

In this activity, students will recognize that the colors they see are a result of the reflection of light and that other colors of light are absorbed; predict what color an object will appear when light of different colors is shined upon it; predict what color(s) will be produced when different colors of light are mixed; and identify the three primary colors and three secondary colors of light.

Drifting Downward [http://www.oceanexplorer.noaa.gov/explorations/02sab/background/edu/media/sab_drifting.pdf] (6 pages, 464k) (from the Islands in the Stream 2002: Exploring Underwater Oases Expedition)

Focus: Biology – Adaptations of planktonic organisms in the ocean

In this activity, students will describe the characteristics of plankton; develop abilities necessary to do scientific inquiry; test the effects of different salinity and temperature on the vertical movement of a model of a planktonic organism; and calculate the velocity of the plankton model.

How Diverse is That? [http://www.oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_hdiverse.pdf] (6 pages, 552k) (from the 2003 Windows to the Deep Expedition)

Focus: Quantifying biological diversity (Life Science)

In this activity, students will be able to discuss the meaning of "biological diversity" and will be able to compare and contrast the concepts of "variety" and "relative abundance" as they relate to biological diversity. Given abundance and distribution data of species in two communities, students will be able to calculate an appropriate numeric indicator that describes the biological diversity of these communities.

Where Is That Light Coming From? [http://www.oceanexplorer.noaa.gov/explorations/04deepscope/background/edu/media/WhereisLight.pdf] (PDF, 208Kb) (from the 2004 Operation Deep Scope Expedition)

Focus: Bioluminescence

In this activity, students explain the role of luciferins, luciferases, and co-factors in bioluminescence and the general sequence of the light-emitting process. Additionally, students discuss the major types of luciferins found in marine organisms, define the lux operon and discuss at least three ways that bioluminescence may benefit deep-sea organisms. Students give an example of at least one organism that actually receives each of the benefits discussed.

Other Links and Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration program

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery

http://www.comlsecretariat.org/ – Home page for the Census of Marine Life

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

- Biological evolution
- Interdependence of organisms

Content Standard E: Science and Technology

- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives

- Personal and community health
- Population growth
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science

- Nature of scientific knowledge
- Historical perspectives

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept a. The ocean is the dominant physical feature on our planet Earth— covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

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

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

Fundamental Concept b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

Fundamental Concept c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater in the ocean than on land.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy." Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

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

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.

Fundamental Concept d. Much of the world's population lives in coastal areas.

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.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

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 e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

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.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
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Census of Marine Life Worksheet

You are about to discover how scientists around the world are working together to understand what is happening to life in Earth's ocean. The Census of Marine Life (CoML) is creating information resources about marine life in every part of the ocean, and these resources are available to anyone with access to the Internet. The following questions are intended to introduce you to CoML and some of these resources.

Part I

To get started, visit CoML's home page at http://www.comlsecretariat.org/. After you have read that page, click on the "Program Summary" link on the left side. Feel free to cut and paste appropriate text from CoML's Web pages to answer these questions:

1. When did CoML begin?

2. What ocean habitats are included in CoML?

3. What is HMAP?

4. How are scientists collaborating with CoML obtaining information for HMAP?

5. How many "ocean realms" are included in CoML's Ocean Realm Field Projects? What are these realms, and what do they include?

6. What is FMAP?

7. What does CoML expect to accomplish after the year 2010?

Part II

Now, let's put some of CoML's resources to work! From the CoML home page (http://www.comlsecretariat.org), click on the link to "Research Activities" on the left side, then "Ocean Biogeographic Information System." Now you should see the opening page for the Ocean Biogeographic Information System (OBIS), one of CoML's most powerful tools, containing 13.6 million records of 80,000 species from 232 databases.

1. Click on the link to the OBIS portal site (www.iobis.org). Be patient, this page may take a minute or so to load. When the page is fully loaded, you should see a "Search by Name" box and a "Search by Geography" box. If you are looking for information about a particular species or group of species you would use the "Search by Name" box. Since we are interested in the Celebes Sea, we'll use the "Search by Geography" box.

2. Use the map tools to drag and zoom into the area that includes Indonesia (Not sure where that is? It's between the northwest coast of Australia and southeast Asia). Continue to drag and zoom until the scale bar in the lower left corner of the map reads about 500 km. Click in the middle of the map and a red rectangle will appear. When you click the "Search>>" button, OBIS will build a list of all records for species found in the area bounded by the rectangle. You can change the size of the rectangle by clicking in the "search area" box, and change the location of the rectangle by clicking on different areas of the map. The latitude and longitude of the area to be searched

are shown next to the "search area" box. For now, be sure the "search area" box is set to 5°, the Search latitude is 0-5 N, and the Search longitude is 120-125 E, then click on the "Search>>" button. Soon, you should see a list of all species in OBIS that are recorded for this area. The species are listed in alphabetic order, but you can have them grouped in other ways by clicking the buttons near the top of the window. Suppose we are interested in fishes; click on "Higher Taxon" and the list will re-sort so that all fishes (and all other major groups) are listed together.

3. Now let's look at some of these fishes. Clicking on one of the species names will open a new window for that species, including links to images, a map showing the locations for records in OBIS, and the specific database that contains these records. Select five species found in this search area and prepare a one-page report that shows an image of each species, the common name (if any) and the scientific name.

4. Click on "Advanced Search" at the top of the window. Now you have lots of other ways to look for data, including Genus and Species names, Report Dates, Depth, Geographic Region, and Data Sources. Let's explore one of these data sources named "CephBase." Scroll down the list of "Data Sources," click on the box next to "CephBase," then click the "Advanced Search>>" button. Soon, you should see a map that shows the location of all records from CephBase. Click on the link to CephBase at the bottom of the map page. A new page will open with information about CephBase. Click on the link to the CephBase Web site.

5. From the CephBase welcome page, click on the "Biogeography" button. Now you should see a search page that allows you to search CephBase by species name, FAO Statistical Area, Large Marine Ecosystem, or Exclusive Economic Zone. Scroll down the window in the "Large Marine Ecosystem" window, select "37-Sulu-Celebes Seas," then click the "Search" button.

6. A new window should open with a map showing the location of the Sulu-Celebes Seas, and a list of all cephalopod species reported from this area. Click on a species name to open a window with information about classification, common names, size, and geographic distribution.

   Click on the "Image Database" button to open a search window that allows you to look at images for some cephalopod species. Not all of these images are photographs of actual animals. Searching images for *Argonauta argo*, for example, retrieves a photograph of a Yugoslavian stamp issued in 1956 that featured this species.

   Click on the "Prey Database" or "Predators Database" buttons to open search windows that allow you to find out what a particular cephalopod species eats, and what eats that species.

   Use CephBase to prepare a one-page report that shows images of three cephalopod species found in the Celebes Sea with information on predators and prey of each species.