DEEP SEA EXPLORATION
INDEX2010
Sangihe Talaud
Indonesia-USA

INDEX/SATAL 2010

Walk the Line

Image captions/credits on Page 2.

lesson plan

Focus
Biodiversity and biogeography around Wallace's Line

Grade Level
7-8 (Life Science)

Focus Question
Why are biodiversity and endemism unusually high in Wallacea?

Learning Objectives
- Students will be able to discuss the meaning of "biodiversity."
- Students will be able to describe at least three ways in which biodiversity in the deep ocean may be important to humans.
- Students will be able to locate and define Wallacea and Wallace's Line.
- Students will be able to offer at least two possible explanations for the high degree of biodiversity and endemism in Wallacea.

Materials
- ❑ Copies of *Indonesian Biodiversity Inquiry Guide*, one copy for each student or student group

Audio-Visual Materials
- ❑ None

Teaching Time
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
Biogeography
Wallace's Line
Endemism
Biodiversity
Wallacea

The NOAA Ship *Okeanos Explorer*
Formerly: USNS *Capable*
Launched: October 28, 1988
Transferred to NOAA: September 10, 2004
Commissioned: August 13, 2008
Class: T-AGOS
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46 (19 Mission/science)
Speed: 10 knots
Range: 9600 nm
Endurance: 40 days

Systems and Instumentation:
Kongsberg EM302 Multibeam rated to 7,000 m
SBE 911 Plus CTD
ROVs -
Little Hercules - 4,000 m depth rating; USBL tracking; depth, altitude, attitude/heading sensors; Seabird SBE 49 FastCat CTD; HD camera and HMI lights
Camera platform with depth/altitude/ heading sensors, HD cameraand HMI lights.
Telepresence

Operations:
Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation; Mission equipment operated by NOAA's Office of Ocean Exploration and Research

For more information, visit http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Images from Page 1 top to bottom:
The ROV Hercules being lowered into the water from the NOAA Ship *Okeanos Explorer*. Image credit: NOAA OER.

NOAA scientists examining live video feed from the ROV Hercules. Image credit: NOAA OER.

Mussels, shrimp, limpets, and crabs cover the slope of an underwater volcano near a hydro-thermal vent. Image credit NOAA http://www.photolib.noaa.gov/bigs/expl0071.jpg

Black smokers on the Kermadec Arc. Image courtesy of New Zealand American Submarine Ring of Fire 2007 Exploration, NOAA Vents Program, the Institute of Geological & Nuclear Sciences and NOAA-OE. http://oceanexplorer.noaa.gov/explorations/07fire/logs/july31/media/brothers_blacksmoker_600.jpg

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

During the summer of 2010, scientists from Indonesia and the United States will work together on an expedition to explore the deep ocean surrounding Indonesia. This mission is called INDEX/SATAL 2010, since the expedition is focussed on INDonesia, EXploration, and the Sangihe Talaud (SATAL) region. Working from the Indonesian Research Vessel *Baruna Jaya IV* and the NOAA Ship *Okeanos Explorer*, these ocean explorers expect to find new deep-sea ecosystems, undiscovered geological features, and living organisms that have never been seen before. New discoveries are always exciting to scientists; but information from ocean exploration is important to everyone, because:

- Biodiversity in deep-sea ecosystems includes new species that can provide important drugs and other useful products;
- Some deep-sea ecosystems include organisms that can be used for human food;
- Information from deep ocean exploration can help predict earthquakes and tsunamis; and
- Human benefits from deep ocean systems are being affected by changes in Earth's climate and atmosphere.

Indonesia is well-known as one of Earth's major centers of biodiversity (which means the variety of all forms of life). 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;
- 17 percent of the world's bird species;
- 15 percent of the world's coral reefs;
- the highest number of coral species in the world (more than 600 identified species); and
- more than 2000 species of near shore fishes.

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.

Indonesia's Research Vessel
Baruna Jaya IV

Port of Registry - Jakarta, Indonesia
Purpose - Oceanography, Fishery
Launched - 1995
Length - 60.4 m
Width - 12.10 m
Draft - 4.15 m
Draft mean - 4.15m
Cruising speed - 10 kts
BPPT Indonesia - owner
17 crew, 33 scientists, and engineers

Deck Gear:
6 ton A-Frame
3 ton Crane
2 - Gilson Winches
2 - Otter Trawl Winches
Hydrographic Winch

Oceanographic Equipment:
Seabeam ELAXC1050D Multibeam
Seabeam ELAC 1190 Multibeam
ELAC 4700
Acoustic Doppler Current Profiler RDI Broadband
Sea Bird SBE-911 CTD
Rosette
Aanderaa, MORS, RDI current meters
Gravity Core Sediment Sampler
Oretech 3000 Subbottom Profiler
Edge Tech 4200-MP Sidescan Sonar

Fishery Equipment:
Mid- and Deep-water Fisheries Trawl
Koden Fish Finder
Simrad EK 500
Plankton Net

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, through the strait between Bali and Lombok.

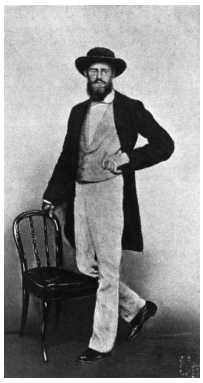
This junction of two great zoogeographic regions is sometimes referred to as "Wallacea," and is an area of particularly high biological diversity and endemism. Endemic species are species that are found nowhere else. The high number of endemic species in Wallacea is probably due to several factors:

- 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.

Very little is known about Indonesia's deep ocean, but explorers expect to find high biodiversity there as well, along with new ecosystems and many species that have never been seen before.

Conditions in the deep-sea environment include very high pressures, total darkness, extreme temperatures, and toxic chemicals. Hydrothermal vents, for example, are deep ocean habitats where hot fluids erupt from the seafloor. These habitats are found near mid-ocean ridges where Earth's tectonic plates are spreading apart. The ridges are formed by hot lava that erupts between spreading tectonic plates. Hydrothermal vents are produced when cold seawater seeps down



Alfred Russel Wallace. Image credit: Wikipedia.

Wallace and Darwin —
By 1858, Wallace had written "On the Tendency of Varieties to Depart Indefinitely From the Original Type," in which he outlined the idea of the origin of species by natural selection. Wallace sent his paper to Charles Darwin for comment, unaware that Darwin had independently formulated a very similar theory. Eventually, Wallace and Darwin made a joint public announcement of their ideas, but since Wallace was thousands of miles away in Indonesia, Darwin became much more widely associated with the concepts of natural selection and evolution.

Map of Wallacea; upper right corner facing North. The red line denotes the western border of Wallacea. The eastern border corresponds to the light Australia-New Guinea shelf. Image credit: Wikipedia.

into Earth's crust through cracks in the ocean floor near mid-ocean ridges. As the seawater moves deeper into the crust, it is heated by molten rock. As the temperature increases, sulfur and metals such as copper, zinc, and iron dissolve from the surrounding rock into the hot fluid. Eventually, the mineral-rich fluid rises again and erupts from openings in the seafloor. The temperature of the erupting fluid may be as high as 400°C, and contains hydrogen sulfide. When the hot hydrothermal fluid meets cold (nearly freezing) seawater, minerals in the fluid precipitate. The precipitated mineral particles give the fluid a smoke-like appearance, so these vents are often called black smokers or white smokers, depending upon the types of minerals in the fluid. Precipitated minerals may also form chimneys that can be several meters high.

The conditions around hydrothermal vents would be deadly to humans and many other species, but deep ocean explorers have found living organisms with special adaptations that allow them to thrive in the deep-sea environment. Some of these adaptations produce new drugs and other useful products. At present, almost all drugs produced from natural sources come from terrestrial plants, but marine organisms produce more drug-like substances than any group of organisms that live on land. Some chemicals from microorganisms found around hydrothermal vents (the exopolysaccharide HE 800 from *Vibrio diabolicus*) are promising for the treatment of bone injuries and diseases, while similar chemicals may be useful for treating cardiovascular disease. Other examples of useful products include *Thermus thermophylus*, a microorganism that is adapted to live under extremely high temperature conditions near hydrothermal vents. One of these adaptations is a protein (Tth DNA polymerase) that can be used to make billions of copies of DNA for scientific studies and crime scene investigations. Another microorganism (genus Thermococcus) produces a type of protein (an enzyme called pullulanase) that can be used to make sweeteners for food additives.

This lesson guides student inquiries into the biogeography and biodiversity of Wallacea.

Learning Procedure

[NOTE: There is a wealth of information available on the geology and ecology of hydrothermal vent ecosystems. Several sources and potential activities are highlighted below, and educators are encouraged to investigate these, and select combinations that are most appropriate to their own students and specific curriculum needs.]

1. To prepare for this lesson:
   (a) Review introductory essays for the INDEX/SATAL 2010 Expedition at http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html

(b) Review questions on the *Indonesian Biodiversity Inquiry Guide*, and make copies of the Guide for each student or student group.

If students do not have Internet access for research, verify that available library resources have adequate information to answer questions on the *Indonesian Biodiversity Inquiry Guide*. Alternatively, suitable reference materials may be downloaded for student use. Keyword searches on worksheet topics will yield many sites that have sufficient information to answer the questions.

2. Briefly introduce the INDEX/SATAL 2010 Expedition, highlighting that this expedition is a joint effort between scientists from Indonesia and the United States to explore Indonesia's deep ocean. Show students a map of the Indonesian region and describe the general path of the Indonesian Throughflow.

3. Tell students that their assignment is to investigate some aspects of biodiversity in the vicinity of the Celebes Sea. Provide each student or student group with a copy of the *Indonesian Biodiversity Inquiry Guide*.

4. Lead a discussion of students' answers to questions on the *Inquiry Guide*. The following points should be included:
   - "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 among species; and
     – variety within species (genetic diversity): high biodiversity suggests a relatively high level of genetic variety among individuals of the same species.

   - Biogeographic provinces are regions that have distinct and different groups of species

   - Scientists recognize six major biogeographic provinces in Earth's deep ocean

   - In the simplest analysis, biodiversity is important to humans because our survival depends upon many other species and ecosystems. Examples 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.

- An endemic organism is found in only one area or location, and nowhere else. "Endemism" refers to the tendency for organisms in an area to be endemic to that area. So, a high degree of endemism means that there are a relatively high number of endemic organisms in an area.

- Wallace's Line is an imaginary boundary that separates the zoogeographic regions of Asia (species such as tigers and rhinoceros) and Australia (species such as kangaroos). The separation is particularly noticeable on some islands that are only a few miles apart. Wallace's Line extends from the middle of the Celebes Sea, through the Makassar Strait between Borneo and Celebes, through the strait between Bali and Lombok.

- Wallacea is the area surrounding Wallace's Line, which is characterized by particularly high biological diversity and endemism. Endemic species are species that are found nowhere else.

- Some explanations for the high number of endemic species in Wallacea include:
  – Some species (e.g., corals) may have originated in this area before they spread to other locations;
  - Fauna may have accumulated from both the Indian and Pacific Oceans; and
  - During past ice-ages, lower sea levels created land bridges between many of the islands that make up present-day Indonesia. This allowed species to spread among these islands, but deep ocean trenches prevented migrations to islands to the east, and there was no oceanic flow between the Pacific and Indian Oceans west of Borneo or south of New Guinea. Water in deep basins within Indonesia was virtually cut off from the surrounding oceans, and the animals and plants in these basins were isolated for thousands of years.

- The close proximity of the Celebes Sea, South China Sea, Tomini Bay, Flores Sea, Java Sea, as well as strong current flowing between these features, would seem to reduce the likelihood of endemism between these areas.

- The observations of Barber *et al*. are not consistent with the idea of low endemism between the areas listed in Question 12. Isolation due to ice-age sea levels might explain how populations in these areas became different from one another, but that still leaves the question of why there hasn't been more mixing since sea levels rose again. One possibility is that the organisms investigated in this study are abnormal and do not represent a larger trend among populations of other marine species in these areas. Another

possibility is that organisms may have developed specific defenses against larvae of very similar species that might compete for the same ecological niche. It is also possible that one or more factors may cause larvae to be retained near the area in which they are produced, rather than be dispersed into currents that could transport them away from suitable habitats. Students may suggest other possibilities, and since there are no definite explanations for these observations at this point, their suggestions may be correct!

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science Topics" in the menu on the left side of the page, then select "Biology," then click on "Biodiversity" for links to topics on biodiversity and evolution.

The "Me" Connection

Have students write a short essay exploring at least three ways in which global biodiversity is of personal importance.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Students' answers to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. Visit http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html for the latest activities and discoveries by the INDEX/SATAL 2010 Expedition.

2. For another activity involving biogeography and speciation, see: http://www.ucmp.berkeley.edu/fosrec/Filson.html

3. For an activity about the concept of a "species," see http://www.actionbioscience.org/biodiversity/lessons/pagelessons.pdf

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 6 and 12 for interactive multimedia presentations and Learning Activities on Deep-Sea Benthos and Food, Water, and Medicine from the Sea.

Other 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/okeanos/explorations/10index/welcome.html – Web site for the INDEX SATAL 2010 Expedition, with links to lesson plans, career connections, and other resources

http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html – Web page for the NOAA Ship *Okeanos Explorer* Education Materials Collection

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://www.pmel.noaa.gov/vents/nemo/index.html – Web site for NOAA's New Millennium Observatory (NeMO), a seafloor observatory at an active underwater volcano near the spreading center between the Juan de Fuca and Pacific tectonic plates

http://www.nationalgeographic.com/xpeditions/lessons/07/g35/seasvents.html – National Geographic Xpeditions lesson plan, "We're in Hot Water Now: Hydrothermal Vents," includes links to *National Geographic* magazine articles and video with an emphasis on geography and geographic skills.

Barber, P. H., S.R. Palumbi, M.V. Erdmann, and M. K. Moosa. 2000. A marine Wallace's Line? Nature 406:692-693. Available online at http://www.stanford.edu/group/Palumbi/manuscripts/BARBER_ET._AL_2000.PDF_copy.pdf

http://www.actionbioscience.org/biodiversity/wilson.html – "Speciation and Biodiversity," an interview with Edward O. Wilson

http://www.pbs.org/wgbh/evolution/library/glossary/ – A glossary from PBS of terms related to evolution

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Corals_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about coral reefs

http://explore.noaa.gov/special-projects/indonesia-u-s-scientific-and-technical-cooperation-in-ocean-exploration/files/Okeanos_Explorer_for_WOC_-_FINAL.pdf – NOAA Fact Sheet about the NOAA Ship *Okeanos Explorer*

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

- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments

Content Standard G: History and Nature of Science

- History of science

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 c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation.

Fundamental Concept d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

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

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.

Fundamental Concept b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.

Fundamental Concept e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

Essential Principle 4.
The ocean makes Earth habitable.
Fundamental Concept b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
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.

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 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 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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Walk the Line
Indonesian Biodiversity Inquiry Guide

Read the essays on biodiversity, biogeography, and microbes at http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html, and the essay on speciation at http://oceanexplorer.noaa.gov/explorations/07philippines/background/speciation/speciation.html. Using information from these essays, as well as other Web sites and/or library resources, answer the following questions:

1. What is "biodiversity?"

2. What is a "biogeographic province?"

3. How many major biogeographic provinces do scientists recognize in Earth's deep ocean?

4. What are at least three ways that biodiversity in the deep ocean may be important to humans?

5. What is endemism?

6. What is Wallace's Line?

7. What is Wallacea?

8. What are some of the possible explanations for the unusually high biodiversity and large number of endemic species in Wallacea?

9. Refer to a map of the Celebes Sea and adjacent islands and waterbodies. Locate:
   - South China Sea
   - Tomini Bay
   - Flores Sea
   - Java Sea

Walk the Line
Indonesian Biodiversity Inquiry Guide – pg 2

10. Recall your teacher's description of the Indonesian Throughflow (or look it up if you don't remember the discussion). Look at the map of the Celebes Sea and think about what you know of the currents flowing through the area. How much endemism would you expect between the areas named in Question 9 (that is, how different would you expect the plants and animals to be between these areas)? Why?

11. In the August 17, 2000 issue of the journal *Nature*, Barber, *et al.* report significant differences in the genetic structure of stomatopod populations in the Celebes Sea, South China Sea, Tomini Bay, Flores Sea, and Java Sea (stomatopods are a type of crustacean found around coral reefs). Do these observations confirm your ideas about endemism between these areas? What might account for these observations?