NATURE LAB Educator Resources

FISHING FOR A FUTURE

Subject Area: Science – Biology, Fisheries, AP Environmental Science

Grade Levels: 9-12

Essential Questions:

- How do Earth systems influence biological productivity?
- How does the El Niño-Southern Oscillation affect the Humboldt Current ecosystem?
- How is a fishery stock assessment conducted?
- How can fisheries become more responsible and/or sustainable?

Artisanal Fishers in Ancón, Peru
Image credit: TNC

Purpose and Overview:

The activities in this teacher's guide explore sustainable fishing through a specific case study in Peru, which is home to one of the world's largest fisheries. The fishing activities that occur in the waters off of the coast of Peru represent a microcosm for the rest of the world. The need to protect the ecosystem and effectively manage its resources are important both for the health of the ecosystem and for the communities that depend on it.

- Part 1- Students gain an introduction to the work being conducted by The Nature Conservancy in Peru and learn how the Humboldt Current sets the stage for one of the world's most productive fishing grounds.
- Part 2 - Students learn more about the difference between industrial and artisanal fisheries while exploring the challenges of open access fishing. They play the role of a fisheries management specialist and use data on catch and catch per unit effort to determine the best management strategies for two important species.
- Part 3 - Students will extend and broaden their understanding of the conflicts around open access fishing, using a Socratic Seminar as a forum to discuss real issues faced by the fishing communities of Peru.
- Part 4 - Students learn about common seafood species that are threatened by overfishing and reflect on lifestyle choices they could change. Students are provided the tools to become educated consumers.

Time:

- Part 1 – one 45-minute class
- Part 2 – two 45-minute classes
- Part 3 – one 45-minute class with the reading given as homework the beforehand
- Part 4 – 30 minutes

Materials:

- Part 1
  - Computer, projector, Internet access for students and teacher
  - Graph of major producer countries to project, page 31
  - ***Fishing for a Future*** (7:34) https://vimeo.com/153951684
  - Humboldt Current Story Map http://arcg.is/1RTcru2
  - Humboldt Current Student Handout for each student
- Part 2
  - Computer, projector, Internet access for students and teacher
  - Fishing for a Future Story Map http://arcg.is/1I7wF5n
  - Fisheries Management Handout for each student
  - *Fisheries Economics & Policy: Intro to Fisheries Management* by Conservation Strategy Fund https://www.youtube.com/watch?v=Z4AXnZOsrK8
  - *Fisheries Economics & Policy: Maximum Economic Yield* by Conservation Strategy Fund https://www.youtube.com/watch?v=7DNhqtYf47E
- Part 3
  - Student copies of the article "Artisanal and Industrial Fishing of Anchoveta in Peru"
- Part 4
  - Computer, projector, Internet access for teacher
  - TED Talk ***The four fish we're overeating – and what to eat instead*** by Paul Greenberg. https://www.ted.com/talks/paul_greenberg_the_four_fish_we_re_overeating_and_what_to_eat_instead/transcript?language=en

Theme:

The Humboldt Current Ecosystem provides a wealth of food and other products for humans. It is only through careful management and conservation that we will sustain this crucial ecosystem that supports not only the people of Peru, but people around the world whose livelihoods and nutrition depend on the productivity of this ecosystem.

Objectives:
The student will…

- Define and describe the Humboldt Current.
- Identify the location of the Humboldt Current and describe how this Earth system impacts life in the ocean and land.
- Describe the Humboldt Current ecosystem and explain how humans benefit from it.
- Identify and describe the parts of the El Niño-Southern Oscillation (ENSO) and explain how this cycle impacts the organisms in the Humboldt Current Ecosystem.
- Define "fishery" and differentiate between and artisanal and industrial fishery.
- Detail some of the threats to fisheries around the world.
- Explain why Peru has one of the world's leading fisheries, describe the threats to fishing, and explore the ways that groups are working to make fishing more sustainable in Peru.
- Compare and contrast between two types of fisheries data (catch per unit effort and catch).
- Analyze fisheries data from Peru to determine the health of a fishery.
- Using data analysis, determine the impacts of El Niño on a fishery.
- Read and think critically about the evidence provided in a text on artisanal and industrial fisheries.
- Cite evidence from a text to support thinking.
- Engage in collegial discussion with other students regarding the ideas presented in a text.
- Use evidence from a text to evaluate a problem and brainstorm solutions without taking sides.
- Evaluate how lifestyle choices might impact fish populations around the world and identify changes to reduce human impact.

Next Generation Science Standards:

Disciplinary Core Ideas:

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS4.D: Biodiversity and Humans

Crosscutting Concepts:

- Patterns
- Cause and Effect
- Stability and Change

Science and Engineering Practices:

- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Engaging in argument from evidence

Performance Expectations:

High School

- HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity or ecosystems at different scales.

- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7 Design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

AP Environmental Science:

- The Living World (Ecosystem Diversity, Ecosystem Services)
- Population (Population Biology Concepts)
- Land and Water Use (Fishing, Global Economics)
- Global Change (Loss of Biodiversity)

Common Core Standards (11th and 12th Grade)

- CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- CCSS.ELA-LITERACY.RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- CCSS.ELA-LITERACY.RST.11-12.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.

Vocabulary:

Benthic: At the very bottom of the ocean, including sediment and subsurface layers

Bycatch: Also called incidental catch, this refers to the catch of non-fish species caught during fishing. Examples are seabirds, marine mammals, and sea turtles.

Catch: The total number and/or weight of fish caught by fishing operations. This number includes all fish killed by the act of fishing, not just those landed or brought to shore.

Demersal: A layer just above the benthic zone in the ocean.

El Niño-Southern Oscillation (ENSO): ENSO is composed of three phases: a warming phase (El Niño), a cooling phase (La Niña), and a neutral phase. During the El Niño phase, the warm water current results from a warming in the eastern Pacific during certain years, which is caused by weakened trade winds (winds that typically blow from east to west along the equator) and a movement of water from the west-equatorial warm pool toward the east. When there is an El Niño event, the ocean surface warms to above-average temperatures affecting the west coasts of North and South America. During this phase rainfall also increases over the tropical Pacific Ocean and weather conditions through the world can be more drastic with increased flooding in some areas and severe drought in others. During La Niña, the opposite happens – rainfall decreases over the tropical Pacific, sea-surface temperatures decrease from the average, and the easterly winds increase in intensity. When there is neither a La Niña nor an El Niño, the sea surface temperatures are close to average.

Fishmeal: A protein-rich animal feed product made of fish.

Fisher: Someone who captures fish or shellfish (also fisherman).

Fishery: The activities leading to and resulting in the harvesting of fish. A fishery is characterized by the species caught, the gear used, and the area of operation. See also http://www.fishwatch.gov/wild_seafood/what_is_a_fishery.htm.

Types of fisheries include:

- **Artisanal or small-scale**: These words are often used interchangeably but can have separate meanings. For our purposes, we will use the Food and Agriculture Organization of the United Nations definition "*traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption…Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. They are sometimes referred to as small-scale fisheries.*"
- **Commercial**: The act of fishing for profit; applies to both artisanal and industrial
- **Industrial**: The use of large vessels with increased fishing capacity; fleet may also include factory vessels that process fish while at sea.
- **Nearshore**: Fishing that occurs in the relatively shallow waters that do not extend beyond the continental shelf.
- **Recreational**: Also called sport fishing; fishing for pleasure of competition
- **Subsistence**: Fishing for survival; fishing to feed one's relatives or family; can imply fishing with low tech "artisanal" techniques

Gear: The equipment used by fishers when fishing. Simple gear can include hooks and lines, while larger scale gear includes trawls, seines, nets, etc. Examples can be found here http://www.fao.org/fishery/geartype/search/en and here http://sanctuaries.noaa.gov/education/voicesofthebay/pdfs/seinenets.pdf

Harvest: The number or weight of fish caught and kept from a defined area over a given period of time.

Humboldt Current: A cold current that flows north along the west coast of South America from Chile to Peru. This current is one of the major upwelling systems in the world and the nutrients provided by this current support a wide diversity of life as well as one of the world's largest fisheries.

Landing: The amount of fish caught AND brought to shore. This may be different than the actual catch, which might include discarded organisms or species.

Pelagic: Open sea – not close to the bottom or near the shore

Stock: Population of a particular species of fish.

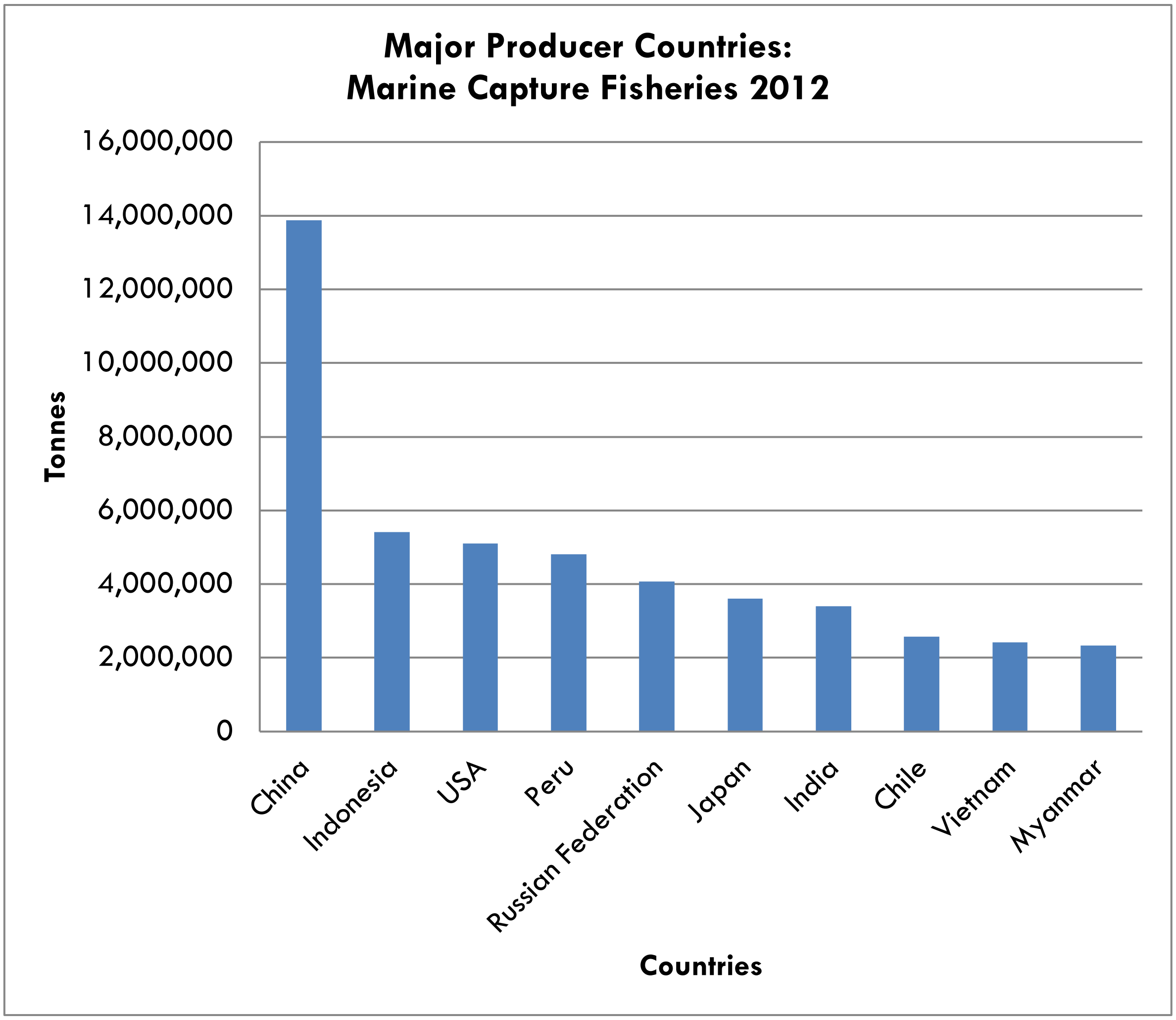
Upwelling: The process by which water, usually cold and nutrient-rich, rises from a deeper part of the ocean to a shallower depth.

Part 1: LEARN - Providing Context

Part 1a: Introduction to Small-Scale and Artisanal Fishing in Peru

1. As a starter activity (entry task/do now), ask students where they think they will find the world's largest marine fisheries.

2. After they have recorded their answers, have a class discussion about the locations they chose and share this graph below (a large version can be found on page 31)



Data Source: The State of World Fisheries and Aquaculture 2014, FAO

3. Have students note that as of 2012, Peru ranked fourth in the world for major marine fisheries. Explain that the intent of this lesson is to explore the fisheries of Peru, the ecosystem that supports these fisheries, and the efforts to increase the sustainability of these fisheries. What is happening in Peru is a microcosm of what is happening around the world. Efforts to make fishing more sustainable are important on a worldwide scale. For further exploration of what happens when a fishery is not sustainable or well-managed,

the books A World Without Fish and Cod: A Biography of the Fish that Changed the World by Mark Kurlanksy are great reads.

4. Show students the video ***Fishing for a Future*** (7:34) (https://vimeo.com/153951684) to give them a brief introduction to small-scale fishing in Peru. The video is also available in Spanish (https://vimeo.com/153956366).

5. After the video, have students discuss the efforts described in the video to make small-scale fishing in Peru more sustainable/responsible.

Part 1b: Background on Humboldt Current Ecosystem

1. If you have access to computers at your school, students can explore an interactive story map about the Humboldt Current, El Niño-Southern Oscillation (ENSO), and the Humboldt Current ecosystem to provide context for the activities presented in this lesson. The story map can be found here: http://arcg.is/1RTcru2

2. Explain to students that any text in the story map that is underlined with dashes will open up different media (a map, video, image, etc.) in the viewing pane. Text underlined with a solid line is hyperlinked to more information on the internet. If a map is displayed in viewing pane, students can move throughout the map and zoom in/out to explore in detail.

3. While students are looking at the story map, you can have them answer the questions on the student handout located here: https://natureworkseverywhere.org/asset/resources/Humboldt_Current_Ecosystem_Handout.docx

4. The answer key for this handout is on the next page.

Part 1: Further Exploration:

- In this NASA visualization of the Earth's ocean surface currents, students can explore the unique patterns of surface currents around the world. The Humboldt Current, being a deep ocean current, doesn't show up on this visualization as profoundly as currents like the Gulf Stream in the Atlantic, but it will give students a sense of the global system. http://svs.gsfc.nasa.gov/vis/a010000/a010800/a010841/index.html

- NOAA's Data in the Classroom El Niño Module – in this module students can use real data sets to examine El Niño in more detail. http://dataintheclassroom.noaa.gov/SitePages/el-Niño_/index#.Vm3xJ0orKUk

- Earth's real-time wind patterns http://earth.nullschool.net/#current/wind/surface/level/orthographic=-91.54,-2.29,525

- Real-time sea surface temperature and ocean currents http://earth.nullschool.net/#current/ocean/surface/currents/orthographic=-97.25,4.46,525

- El Niño and the Galapagos Islands of Ecuador https://www.climate.gov/news-features/blogs/enso/el-ni%C3%B1o-and-gal%C3%A1pagos

The Humboldt Current Ecosystem: How Earth Systems Influence Ocean Productivity and Biodiversity

Student Handout Answer Key

Go to the story map located here http://arcg.is/1RTcru2 and answer the questions below.

1. What causes the productivity associated with the Humboldt Current?

   The Humboldt Current is a cold water upwelling that brings nutrients from the ocean floor. The nutrients nourish phytoplankton, which are the base of the food chain.

2. Draw and label a diagram that illustrates how an upwelling works.

   Student answers may be similar to the illustration below.

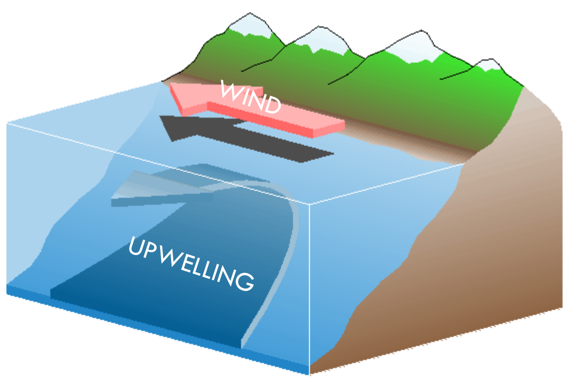


   Image credit: http://www.atmos.washington.edu/gcg/RTN/Figures/RTN13.html

3. Describe how the Humboldt Current impacts the ecosystem as a whole.

   Because of the rich nutrients brought by the current, phytoplankton can flourish, which in turn support a diverse ecosystem. The phytoplankton are food for fish like anchovy, the abundance of which makes for a successful marine fishery. Additionally, fish like anchovy are food for even larger fish, marine mammals like sea lions, and several species of sea birds.

4. How does the El Niño-Southern Oscillation or ENSO Cycle impact the Humboldt Current Ecosystem?

   During El Niño events, the water temperature increases, causing a decrease in phytoplankton, which can have a ripple effect through the food chain. Some species like sea lions and sea birds die-off and other species flourish in the warmer waters. Rainfall over the Pacific increases.

5. How does a La Niña event differ from an El Niño event?

   During La Niña sea surface temperatures decrease and easterly winds increase in intensity. Rainfall over the Pacific decreases.

Part 2: EXPLORE – Defining Management Strategies for a Small-Scale Fishery Based on Data and the Ecosystem Effects of El Niño

Teacher Background

To effectively manage a fishery, managers need to know how many fish are in a population at a given time. Fishery scientists use stock assessments to determine the abundance (number and size/age) of fish in a population. One of the simplest stock assessment methods requires almost no knowledge about the biology of the stock; however, good information about the fishery is required.

In this simple assessment, the fishery manager only needs to look at the history of catch for the stock and the effort expended to catch the seafood. The key word here is **effort**. Catch data (the amount of fish caught per year) alone are not very useful. Catch can fluctuate for a variety of reasons. Some of those reasons include:

- the amount of hours spent fishing
- the weather
- the number of fishers
- the type of fishing gear used by the fishers

A trend of decreased catch may be a cause for concern, but the amount of effort made by fishermen to catch the stock helps tell the real story.

In order to account for effort, fishery scientists use the terminology catch-per-unit-effort (CPUE). To determine the CPUE, the catch is divided by the amount of effort expended to make the catch.

The catch-per-unit-effort is directly related to the amount of fish in the stock. While CPUE doesn't tell you how many fish are in the stock, it provides an index of abundance that can be easily compared from one year to the next. A decline in CPUE usually indicates a decline in the stock. A decline in both CPUE and catch provides even more evidence for a decline in the stock. Decreasing CPUE indicates less efficiency – or that more effort is needed relative to the quantity of catch. In contrast, a higher CPUE corresponds to greater efficiency.

In this part of the activity, students will learn the difference between catch and catch-per-unit-effort data and will use the data to make a determination about the health the stock in a coastal area of Peru.

Procedure:

1. For context on the location, types of fisheries, and challenges facing the fishers of Peru, have students view this story map online: http://arcg.is/1I7wF5n. This story map will provide important background information for students completing the data exercise to follow. If you have access to computers at school, this can be part of an in class activity or you can have students do it as homework. Explain that any text in the story map that is underlined with dashes will open up different media (a map, video, image, etc.) in the main viewing pane. Text underlined with a solid line is hyperlinked to more information on the internet. If a map is displayed in viewing pane, students can move throughout the map and zoom in/out to explore in detail.

2. To give students context for this exercise, show the portions of the following videos as noted below. There are corresponding questions on the student worksheet and the answer key for this worksheet is on the next page.

    - Show the entire video (4:44) *Fisheries Economics & Policy: Intro to Fisheries Management* by Conservation Strategy Fund https://www.youtube.com/watch?v=Z4AXnZOsrK8

    - Show from 0:00 to 3:05 of the video *Fisheries Economics & Policy: Maximum Economic Yield* by Conservation Strategy Fund https://www.youtube.com/watch?v=7DNhqtYf47E

3. It may be useful for teacher background for you to watch the entire Maximum Economic Yield video (15:40).

Part 2: Further Exploration

- If you are teaching about Marine Protected Areas, the video *Fisheries Economics & Policy: Marine Protected Areas* by Conservation Strategy Fund provides a great background on marine protected areas and the costs and benefits of establishing them. https://www.youtube.com/watch?v=n6_JLZnQe6Y&list=PLBfu1mD9hk66c1Q23AOAAhCvkVLC2XZKm&index=6

Fisheries Management:

How Catch-Per-Unit-Effort Data Can Help a Community Conserve its Resources

Student Handout Answer Key

To understand how to create a more sustainable fishery, you must first understand the population dynamics of the resource and the way in which the fishery functions in the first place.

The two videos below will help provide this context. Watch the short clips from each video and answer the questions below.

Fisher in Ancón Harbor
Image Credit: TNC

Watch the video "Fisheries Economics & Policy: Intro to Fisheries Management" (4:44)
https://www.youtube.com/watch?v=Z4AXnZOsrK8

1. Describe the potential problems with common pool resources.

   An individual working alone has an incentive to protect their fishing stock, but in a group, there is less incentive because whatever that individual leaves behind might be fished by another individual.

2. What does "open access" mean?

   Open access means that the right to catch fish is free and open to all. There are no restrictions on the number of fishers that can enter the fishery.

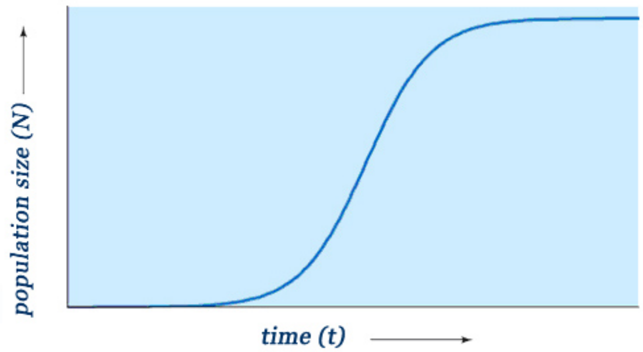
Watch from 0:00-3:05 of the video "Fisheries Economics & Policy: Maximum Economic Yield"
https://www.youtube.com/watch?v=7DNhqtYf47E

3. Explain the ways that fishing effort can increase.

   The number of boats can increase, the size of the boats can increase, and the technology or fishing gear can be improved.

4. If fishing effort increases, but the catch stays the same, what does that indicate about the fish population?

   This indicates that the population is declining. Increasing effort without increasing catches can signal an unhealthy population.



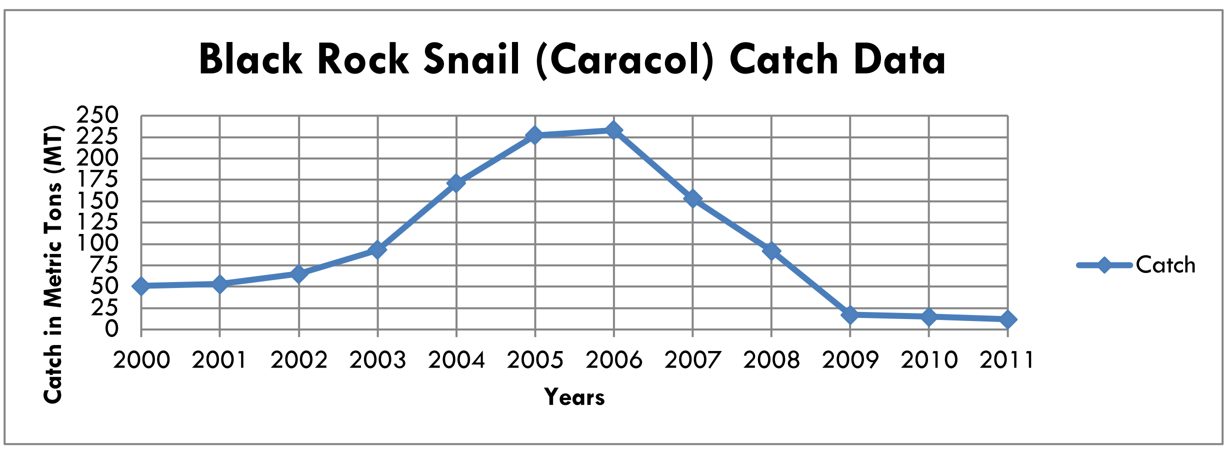
Population Growth Over Time
Image Credit: Licensed under Public Domain via Wikipedia

5. Using the graph above for reference, give a basic description of how fish populations behave and include in your explanation how population size relates to the growth rate.

   As fish reproduce, the population doesn't grow that fast. After some time, when more fish are present, there are more fish to reproduce and the population will grow faster. However, the population will eventually be limited by resources and will reach a carrying capacity, which is the highest population that a particular environment can sustain. It is when the death rate is equal to the birth rate. When the population size is low, the growth rate is low and when the population size is high, the growth rate is also low.

6. Describe how a population's carrying capacity can shift over time.

   Changes in the environment can cause resources to be depleted, which would cause the carrying capacity to decrease. Likewise the environment can change in ways that increase the resources available to fish needed to survive, such as food or habitat, which in turn would increase the carrying capacity.



7. The graph above shows catch data for Black Rock Snails, which are harvested by benthic divers. Based on the amount of snails caught every year, describe what you think might be happening with the population.

   The catch increases to around 225 MT in 2005 and then levels off between 2005-2006. After 2006 it begins a period of decline. By 2009 the catch has decreased to less than 25 MT and continues to decrease slightly through 2011. This could indicate that the population is crashing.

8. What factors might influence the "catchability" of the snails? Do you think that the amount of snails caught directly correlates with the size of the population or might there be other factors and if so what are they?

   The amount of snails caught isn't a great assessment of the population size. We don't know how many fishers are out catching snails. It might be that the population is fine but fishers aren't catching snails because they aren't profitable anymore and they've switched to another species. As a result, the catch has decreased, but that's not because there are fewer snails, just fewer fishers harvesting them.

9. What more do we need to know in order to truly assess the snail population?

   We need to know how many fishers are working, how many trips they take, how long they dive. We need to know how much effort they are putting into harvesting and we need to take a more scientific approach to evaluate all of these factors.

Catch vs. Catch Per Unit Effort (CPUE)

When you observed the trend in Black Rock Snail catch in question 7, you may have realized that you need more information than the amount of catch to truly understand the population, especially when the goal is to manage the fishery. The amount of a resource caught does not accurately reflect the population size.

To effectively manage a fishery, managers need to know how many fish are in a population at a given time. Fishery scientists use stock assessments to determine the abundance (number and size/age) of fish in a population. One of the simplest stock assessment methods requires almost no knowledge about the biology of the stock. However, good information about the fishery is required.

In this simple assessment, the fishery manager only needs to look at the **history of catch** for the stock and the **effort expended** to catch the seafood. The key word here is **effort**.

Catch data (the amount of fish caught per year) alone are not very useful. Catch can fluctuate for a variety of reasons. Some of those reasons include:

- the amount of hours spent fishing
- the weather
- the number of fishers
- the type of fishing gear used by the fishers

A trend of decreased catch may be a cause for concern, but the amount of effort made by fishermen to catch the stock helps tell the real story.

In order to account for effort, fishery biologists use the terminology catch-per-unit-effort (CPUE). To determine the CPUE, the catch is divided by the amount of effort expended to make the catch.

For example, if a fisher goes out on a boat for 2 hours and catches 10 chinook salmon weighing a total of 200 pounds, then the fisher's CPUE could be expressed as either 5 fish per hour (10 fish caught in 2 hours) or as 100 pounds per hour (200 pounds caught in 2 hours of fishing).

The catch-per-unit-effort is directly related to the amount of fish in the stock. While CPUE doesn't tell you how many fish are in the stock, it provides an index of abundance that can be easily compared from one year to the next. **A decline in CPUE usually indicates a decline in the stock. A decline in both CPUE and catch provides even more evidence for a decline in the stock.** Decreasing CPUE indicates less efficiency – or that more effort is needed relative to the quantity of catch. In contrast, a higher CPUE corresponds to greater efficiency.

A number of fisheries have followed a pattern in relation to the catch-per-unit effort. The following statements describe trends that occur over time **after a new fishery is established**:

- At the beginning of a new fishery, the catch-per-unit effort is high and the effort is low.
- As interest in catching fish grows, the effort increases, the catch increases and the catch-per unit effort usually levels off or declines.
- Finally, as more effort is applied, the catch declines and the catch-per-unit effort declines even more. When both the catch and the catch-per-unit effort decline, it is an indication that the stock is probably overfished. This means that too many fish are being removed before having the chance to reproduce. Catches decline despite increasing effort.

Additional factors that might increase or decrease catchability are as follows:

- Catchability often increases over time as the fishers improve their fishing gear and boats.
- The catchability of a species can be greatly affected when fishers change their targeting practice from one species to another. In general, catchability increases for the new target species, and decreases for the previous target species. However, if the new target species is the predator of the original target species, this could later have a positive effect on population size of the original target species (the prey) as the predator is removed by fishing.
- The environment can have a large influence on catchability. For example, El Niño/La Niña conditions can impact the availability of nutrients and food for fish stock. Additionally, warmer water temperatures caused by El Niño could push the fish stock into deeper, less accessible waters, making it harder to catch.
- The dynamics of a fish stock can also influence how catchability changes over time For example, fish that swim in large groups are fairly easy to catch, so CPUE might not necessarily decline until the population has totally crashed. Other fish that don't aggregate together will become scarcer and more difficult to catch.

10. What is CPUE? Why isn't information on catch alone enough to know the health of a fish stock?

CPUE stands for catch-per-unit-effort. It represents a ratio of fish caught to the amount of effort applied. A higher CPUE number indicates greater efficiency and a lower CPUE number represents lower efficiency. In other words, high CPUE indicates that lower effort is being applied to catch a relative number of fish. Low CPUE can indicate that a lot of effort has been applied to catch a relative number of fish. Catch data alone doesn't provide enough information about the abundance of fish in the ocean. Catch can fluctuate for a variety of reasons, including the amount of time spent fishing, the weather conditions, the number of fishers, the type of fishing gear used by the fishers, and others.

11. Consider the information in the reading above and the equation for calculating CPUE. Describe some scenarios that might cause an increase or decrease in CPUE.

Increase –

- *The fish population is increasing faster than they are being caught (birth rate is higher than death rate) and the population overall is growing.*
- *Environmental conditions increase productivity, food available, and number of fish in ocean.*
- *Other fishing dynamics have resulted in the stocks of the predators to decline and the prey (the catch in this case) to grow, resulting in a population boom of the target species.*
- *When fishing technology improves, there can be a boost on CPUE, at least at the beginning, as fishers are able to find the fish faster and catch it easier. For example, fishers could develop a new net that is twice the size and allows them catch twice as many fish on each trip.*
- *The number of fishers declines as more people decide to play soccer instead, which reduces the overall effort of the fleet.*

Decrease –

- *The fishers catch too many fish (death rate is higher than birth rate) and the population is declining.*
- *El Niño conditions decrease productivity, food available, and number of fish in ocean.*
- *Other fishing dynamics have resulted in the stocks of the predators to grow and the prey (the catch in this case) to decline, resulting in a dwindling population of the target species.*
- *The number of fishers increases as more people see how lucrative fishing is, which increases the overall effort of the fleet.*

In this remainder of this activity, you will examine catch and CPUE data for the two species in the table below. The Lorna Drum is a demersal fish – in other words it lives in the water column close to the ocean floor. The Black Rock Snail is a benthic species – one that lives on the rocky bottoms of the ocean floor. The characteristics of these two organisms will be useful in answering the questions that follow.

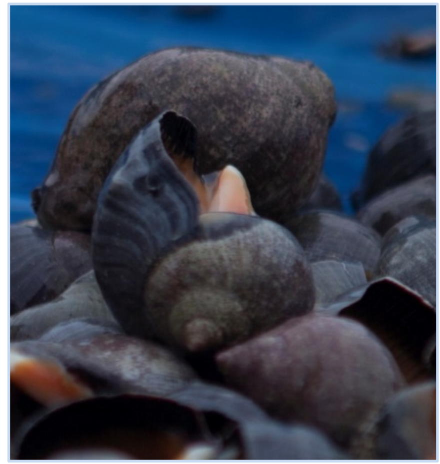
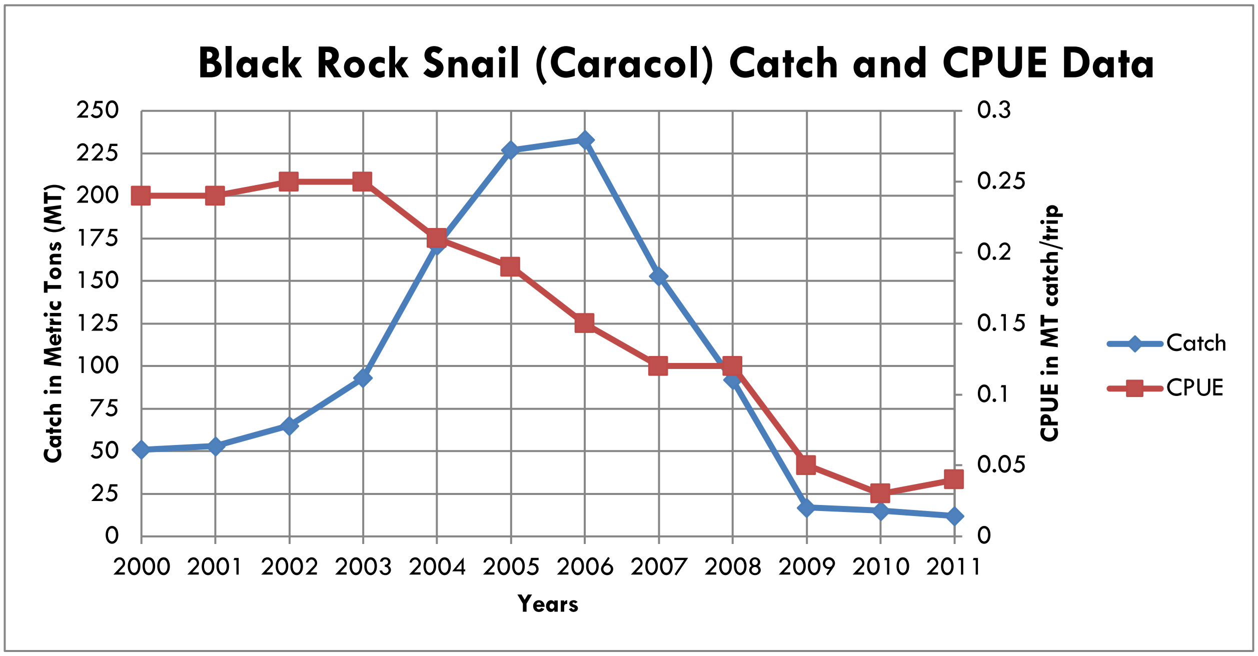


Image credits: Drum - Matias Caillaux and Snail - TNC

Common Name	**Lorna Drum**	**Black Rock Snail**
Latin Name	*Sciaena deliciosa*	*Thais chocolata*
Spanish Name	Lorna	Caracol
Habitat	Demersal, moves along the water column close to the ocean floor	Live on the ocean floor, mainly on rocky bottoms, does not move around a lot
Food	Feeds on benthic worms, gastropods, bivalves, and crustaceans (which eat phytoplankton)	Carnivorous snail - feeds on mussels, limpets, bivalves and other crustaceans
Fishing Gears Used	Purse seines, gill nets, hook and line	Compressor Diving (Huka), Free Diving



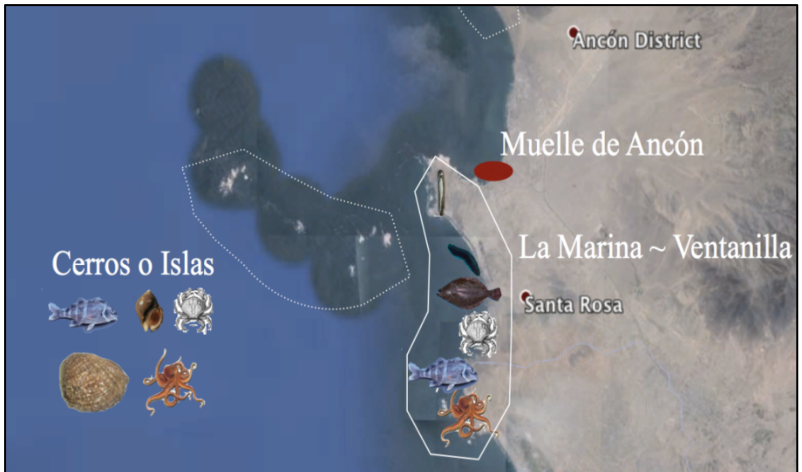
12. The graph above combines the catch data from question 7 with CPUE data for the same time period for the Black Rock Snail. Using the information in the graph above, describe the trend in **CPUE** for the black rock snail.

CPUE is stable between 2001-2003. After 2003, CPUE begins to decrease nearly every year through 2011.

13. Based on what you know about the relationship between catch and CPUE, describe what you think is happening to this fishery and the health of the snail population.

Because the catch in increasing steadily through 2005, based on this data alone you could imagine that the population of snails is healthy though this time. However, because CPUE starts to decrease around 2003 – this indicates that while the catch is high, it's taking more and more effort to get the snails. When CPUE and catch are both declining from 2006 onward, this is clear indication that the stock is becoming overfished as its taking more effort to catch the resource.

Case Study: Ancón, Peru



The circled areas represent the fishing grounds around Ancón District. Symbols indicate types of organisms caught in each area. Credit: TNC

The town of Ancón, located just north of Lima, Peru is home to approximately 300 fishers. Artisanal and small-scale fisheries are an important economic engine for coastal communities. They provide almost 80% of the seafood consumed in the country. More than 44,000 fishers are directly employed in this sector.

Despite the importance of the small-scale fisheries sector to the economy, very little information on the condition of stocks, levels of fishing effort, efficacy of management, or performance of the fishery is available. Other impediments to sustainability include weak governance, limited market access, and very low capacity for producing value-added products. These obstacles have led, in many instances, to overharvesting stocks and destructive fishing practices, resulting in poor outcomes for fishers and the environment.

For background on artisanal and small-scale fishing in Peru, view the short story map on the fishing community of the Ancón District found here: http://arcg.is/1I7wF5n and answer the question below.

14. Based on the information in the story map, describe the artisanal fishing sector and contrast it with the industrial sector.

    Artisanal fishers use small vessels with less fishing capacity. These fishers have the rights to fish within 10 nautical miles of the shore, whereas industrial fishers are restricted from this area. Industrial boats are larger in size and have a greater fishing capacity. Artisanal fishers catch food for direct human consumption while the catch from industrial vessels is mostly for export or for processing into fish oil and fish meal. Artisanal fishers are among the 54% of Peruvians living below the poverty line.

In the activity that follows, you will play the role of a fisheries management specialist from a conservation organization. You are working with local fishers to combine their expertise with scientific data to determine how to make their fishery more sustainable. You will examine the population change over time of two species, the Lorna Drum and Black Rock Snail, which are important to the small-scale fishing community of Ancón.

From 2000-2011, you and the fishers have been collecting data on their fishing grounds. Your aim is to help them to make choices on how to collectively manage their fishing grounds so that they can continue to fish without their resources being depleted. Using your knowledge of catch and catch-per-unit-effort you will conduct a stock assessment and provide management suggestions. The two types of management strategies that the fishers are willing to experiment with are seasonal closure and catch limits.

The Effect of El Niño on a Fishery

There is one more factor that you must consider when making a stock assessment in this area. The waters off the coast are affected by El Niño, an abnormal weather pattern that is caused by the warming of the Pacific Ocean near the equator, off the coast of South America. Throughout the year, a northward cool current prevails because of southeast trade winds, causing upwelling of cool, nutrient-rich water. However, during late December the upwelling relaxes, causing warmer and nutrient-poor water to appear. The nutrient poor water leads to a reduction in phytoplankton, which is the base of the food chain in the Humboldt Current Ecosystem. An El Niño event may lead to fewer fish in the area, either because they die-off from lack of food or move to cooler waters out of the fishing area. In order to understand if an El Niño event is responsible for the population changes of the target species, you must first identify the years during our study period in which an El Niño occurred.

Scientists use the Oceanic Niño Index (ONI) to measure anomalies or deviations from normal sea surface temperatures. When sea surface temperature in the Pacific Ocean deviates by more than 0.9 degrees Fahrenheit (0.5 degrees Celsius) above normal for at five successive three-month periods or more, this indicates an El Niño event. Likewise, when SST deviates by 0.9 degrees Fahrenheit below normal over five successive three month periods, this indicates a La Niña event.

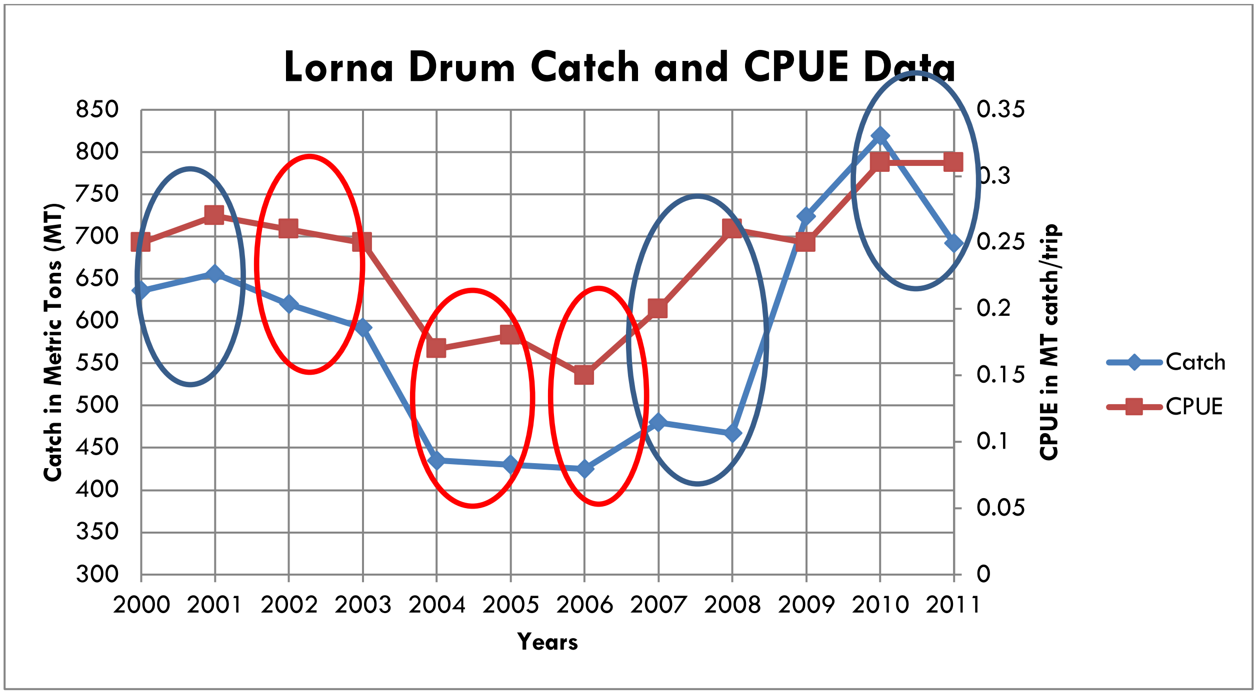
The top row of the chart below shows the abbreviations for months in three-month groupings. "DJF" indicates the three-month period from December to January to February. The chart below shows temperature deviations for the same period as the fisheries data in this exercise.

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	**-1.6**	**-1.4**	**-1.1**	**-0.9**	**-0.7**	**-0.7**	**-0.6**	**-0.5**	**-0.6**	**-0.7**	**-0.8**	**-0.8**
2001	**-0.7**	**-0.6**	**-0.5**	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
2002	-0.2	-0.1	0.1	0.2	0.4	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.3**	**1.1**
2003	**0.9**	**0.6**	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	**0.5**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
2005	**0.6**	**0.6**	**0.5**	**0.5**	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	**0.5**	**0.8**	**0.9**	**1.0**
2007	**0.7**	0.3	0	-0.1	-0.2	-0.2	-0.3	**-0.6**	**-0.8**	**-1.1**	**-1.2**	**-1.3**
2008	**-1.4**	**-1.3**	**-1.1**	**-0.9**	**-0.7**	**-0.5**	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	**0.5**	**0.6**	**0.7**	**1.0**	**1.2**	**1.3**
2010	**1.3**	**1.1**	**0.8**	**0.5**	0	-0.4	**-0.8**	**-1.1**	**-1.3**	**-1.4**	**-1.3**	**-1.4**
2011	**-1.3**	**-1.1**	**-0.8**	**-0.6**	-0.3	-0.2	-0.3	**-0.5**	**-0.7**	**-0.9**	**-0.9**	**-0.8**

Data from NOAA's Climate Prediction Center, full data table here:
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

15. Using the chart above, identify the years in which La Niña and El Niño events occurred.

La Niña	***El Niño***
2000-2001	*2002*
2007-2008	*2004-2005*
2010-2011	*2006-2007*
2011-?	*2009-2010*



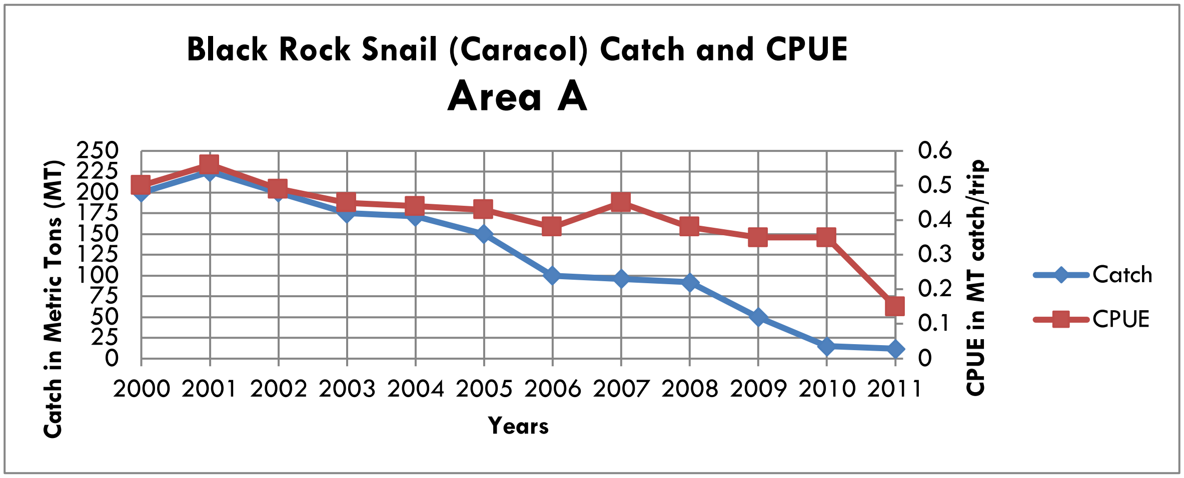
16. In the graph above, circle the El Niño periods with a red pen and circle the La Niña periods with a blue pen.

    See graph as marked above.

17. Using the graph above, your knowledge of El Niño and La Niña periods, and the feeding habits of the Lorna Drum to describe how these climactic events might have impacted the Lorna Drum population. What kind of management strategies might you suggest for this species of fish based on these data?

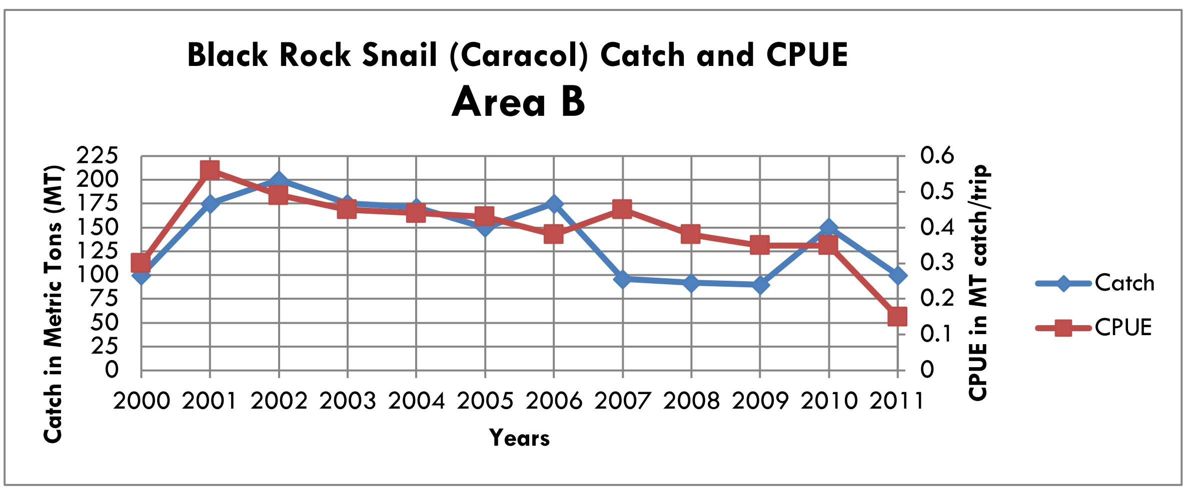
    The years 2004-5 and 2006-7 were El Niño periods. These periods correspond with a decrease in both catch and CPUE on the graph. It appears that the Lorna Drum population must be affected by El Niño. The Lorna Drum eats organisms that eat phytoplankton. If phytoplankton decrease in population as a result of the influx of warm, nutrient-poor water, one can infer that the stocks of these fish will also decrease. That being said, the best management strategy might be to impose stricter catch limits on Lorna Drum during El Niño periods. Perhaps fishers could also switch to a species not impacted by El Niño during times of Lorna Drum decrease. The stricter limits could be lifted once the CPUE starts to increase.

18. There are three areas (A, B, and C) where you and the fishers have been collecting data on the Black Rock Snail. Based on your knowledge of CPUE and catch, below each graph describe what you think is happening to the snail population in that area and describe whether or not you feel the area should be closed to allow the population to rebuild.



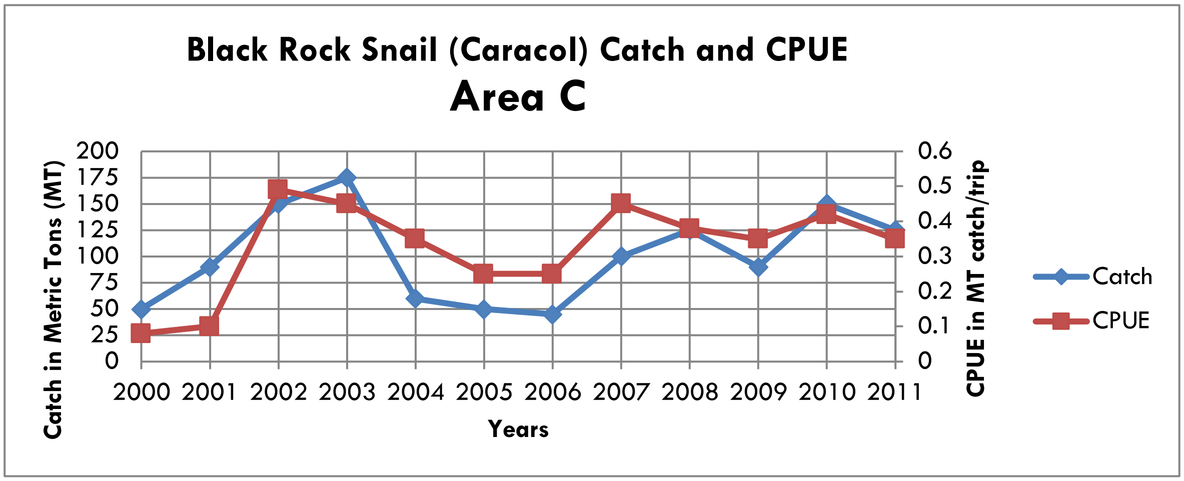
Area A Assessment:

The catch and CPUE in Area A have both been declining for several years, which indicate that the population of Black Rock Snail is overfished. Rock Snails are benthic species and don't move around too much in their lives, so closing this area to fishing would be strategy to allowing the population to rebuild.



Area B Assessment:

In Area B, the catch and CPUE increased in the first few years, but then have slowly decreased since. The trend continues longer than a typical El Niño cycle, suggesting that the decline is due to overfishing rather than environmental variability. It should probably be closed to allow the population to rebuild.

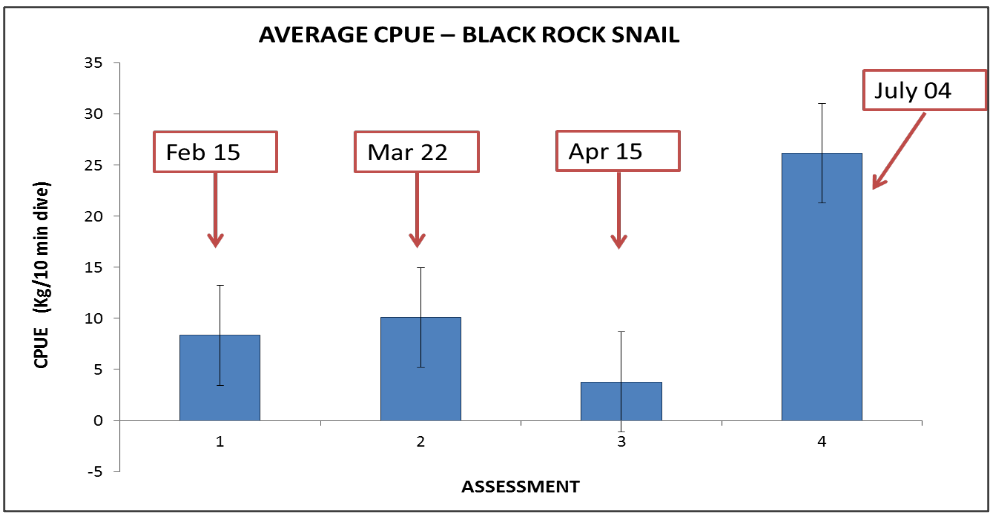


<u>Area C Assessment:</u>

There are fluctuations in catch and CPUE in area C, but these last only a few years at most, suggesting they are results of environmental variation. Additionally, the trend of both catch and CPUE are increasing. Area C does not need to be closed to fishing.

19. The fishers you are working with decided to close off The Isleta, a small island with a perimeter of 1.4 km near Ancón. So far they have closed it to fishing for 5 months. During this time, you've worked with the divers to collect scientific data on the CPUE for Black Rock Snail. Here the CPUE is measured in kilograms of snails collected during a 10 minute dive. Based on the graph below, describe the effect of the closure on CPUE.

The Isleta near Ancón, Peru where a snail fishing area has been closed
Image credit: TNC



CPUE of Black Rock Snail at the Isleta after 5 months of closure. Note that monitoring was not performed in May and June due to poor weather conditions.

Initially, through the first three months of data collection, the CPUE remained low. Data was not collected for two months in May and June, but subsequent data collected in July shows a huge increase (approximately 5 times the CPUE in April). This could indicate a rebound in the population.

20. Now that you have these data, what more do you need to know? Will you continue the closure? For how long? Do you feel that 5 months of investigation is long enough to understand all of the factors involved in the population dynamics of the snail? What further investigations might you propose in order to develop a management strategy for the Black Rock Snail in this area?

If the fishers agree, the closure should be continued at least throughout the rest of the year so that all yearly environmental conditions can be taken into account. It seems we might need to know more about the snail's reproductive cycle as well. For further investigation, it might be useful to know how many snails can be removed to get the maximum yield without depleting the resource. One possibility would be to increase the amount of diving time (effort) and then see how the CPUE is affected.

Part 3: EXPLORE - Socratic Seminar on Artisanal and Industrial Fisheries

Teacher Background:

The purpose of this activity is to extend and broaden your students' understanding of conflicts around open access fishing, using a Socratic Seminar as a forum to discuss real issues faced by the fishing communities of Peru.

A Socratic Seminar is a way to foster active learning, inquiry, and critical thinking skills in students. The teacher's role in a Socratic Seminar is as a guide and coach. The ideal room set-up is for students to sit in a circle with the teacher as part of the circle and at the same height as the students. It's important that the teacher relinquish a little bit of control during the discussion. It's also important to accept that there will be periods of uncomfortable wait time while students think about the text and the discussion.

To begin the seminar, use an opening prompt (provided below). During the seminar, if the discussion totally stalls, move the discussion along using prepared prompts like those provided below. If the discussion goes off track, you can restate the opening question. If there are students who have not spoken during the seminar, you may ask "who hasn't had a chance to speak?" If appropriate, you might also ask students to cite evidence from the text or ask them to relate their statements to what someone else has said. It will be very helpful if during the seminar, you are taking notes about the main points of discussion.

At the end of the seminar ask students to summarize the main points that were made in the discussion. To close the seminar, debrief with students about the process and share your own observations about the experience.

With respect to grading and assessment, some teachers offer points for participation in the seminar. At the end of the seminar, you could also have students write a reflection on the process and have them detail their initial perspective about the article and then have them comment on how the discussion may have shaped their ideas.

To learn more about Socratic Seminars, check out the following resources:

- National Paideia Center website: http://www.paideia.org/
- NSTA article on Socratic Seminars by Jeanne Ting Chowning: http://learningcenter.nsta.org/product_detail.aspx?id=10.2505/4/tst09_076_07_36
- To see a Socratic Seminar in action in the science classroom and hear advice from a teacher, check out this video by Northwest Association for Biomedical Research (NWABR): https://www.youtube.com/watch?v=9TckVI4e3Y0

Suggested Flow:

1. Give students the article (found on pages 27-28 for your reference, a printable copy for students can be found below to read as homework before the Socratic Seminar. In order to participate in the seminar they MUST have read the article. The article is pre-numbered

for student use in citing evidence. It is much easier to cite evidence from the text when students can refer to a numbered paragraph.

2. Before you begin the seminar, share the purpose of the discussion and the rules with the students.
   a. The purpose: To understand the framework and evidence in the "Artisanal and Industrial Fishing of Anchoveta in Peru" text through shared discussion and to form conclusions based on evidence from the text.
   b. The rules for students are:
      - No hand-raising. Focus on the speaker and wait until it's their turn to talk.
      - Only one person can speak at a time.
      - Be courteous to each other, even when disagreeing.
      - Respond to each other by name.
      - Listen carefully.
      - Monitor your air time.
      - Reference the text to cite evidence for your statements.
      - Keep an open mind and be willing to be flexible in light of new information.

3. Read aloud the Socratic Seminar opening question to students:

   The article you have read highlights some of the differences between two anchoveta fisheries in Peru: the artisanal and industrial. Summarize the differences between these two fleets and using evidence from the text; suggest possible consequences that might arise from the differences in the ways they operate.

4. Below are **possible prompts** that you can use during the discussion if students need to be redirected or refocused.
   a. Use evidence from the text to support where you think there might be a source of conflict between the two fleets.
   b. What might be the unintended consequences of some of the policies (or lack thereof) presented in this text?
      - What might be some of the ecological consequences?
      - What might be some of the economic consequences?
   c. Do you see any issues with the area (consider the 10 NM from the coast exclusive zone) that the fleets are allowed to fish?
   d. Is there a "tragedy of the commons" scenario at play here? Cite evidence from the text that might allude to this.
   e. Suggest practical approaches that could be used to create different management solutions for the artisanal or industrial sector.

5. To **close the seminar**, you might read this statement to students and have them reflect on it:

   In an article entitled "When Fishery Rhymes with Poverty: A First Step Beyond the Old Paradigm on Poverty in Small-Scale Fisheries" by Christophe Béné, the author writes "Different socio-institutional mechanisms which govern the command of fishery resources (essentially social positions and the institutional arrangements controlling the access to, and the use of, these resources) play a more critical role in determining poverty than pure economic or biological considerations." (Béné 968)

   Reflect on this statement and describe how it might apply to the artisanal fishery described in the text.

6. Have a student or students summarize some of the main points of the seminar.

7. Before the end of class, be sure debrief the seminar with students. You could ask them if the norms were followed and if they felt like there was enough participation. You could ask them how their viewpoints changed during the course of the discussion.

8. As mentioned previously, as a final assessment of the activity, you could have students write a reflection on the seminar process and their final thoughts on the topic.

Artisanal and Industrial Fishing of Anchoveta in Peru

Peru is one of the world's top producers of ground fishmeal, which is used as animal feed around the world. Fish oil is a by-product of the production of fishmeal, and is used for animal feed and as a supplementary source of Omega3 oils for human consumption. The fishmeal and fish oil is made from anchoveta (anchovy), a fast-growing species of fish found in the cold waters off the coast of Peru. These fish thrive on the multitudes of plankton found in this ecosystem, nourished by the upwelling of nutrients from the Humboldt Current. In addition to being a main fisheries target, anchoveta are also eaten by larger fish, marine mammals, and seabirds. Anchoveta are a main food source for sea lions and off the coast of Peru, you will find one of the world's largest sea lion colonies. Anchoveta and other small pelagic species like them are also suitable for human consumption; however, more than 95% of the pelagic fish landed in Peru are ground into fishmeal for export.

In Peru, there are a wide variety of fisheries, but for the purposes of this article, we will focus on two: the industrial anchoveta fishery and the artisanal or small-scale anchoveta fishery. The industrial anchoveta fleet is highly regulated and enforced with three main management measures including: total allowable catch, minimum harvesting size, and closed seasons during anchoveta reproduction. Additionally, the industrial fleet is not permitted to fish within 10 nautical miles from the coast. The industrial fleet sells 100% of their catch for fishmeal production.

The artisanal sector has one major regulation and it is that they are only allowed to fish for direct human consumption (DHC) and not for fishmeal production. With 30% of malnutrition in the country, this regulation was aimed at improving the protein supply for poor communities and promoting the consolidation of the DHC industry for Anchoveta products. The reader should note that fish sold for fishmeal garners higher market prices than fish sold for direct human consumption, as the overall profits of fishmeal are significantly higher due to the large international demand. Additionally, local demand for anchoveta products for human consumption has remains low.

The artisanal fishermen have exclusive fishing rights to the area from the coast to 10 nautical miles out, as the industrial fleet is excluded from this zone; however, the artisanal fishermen are not limited to this area and can fish beyond 10 nautical miles. Otherwise, unless self-imposed, there are no quotas or other regulations on this sector.

To give a sense of scale between the two fisheries, approximately 5 million tons of anchoveta per year are landed by the artisanal sector fishing within 10 nautical miles for direct human consumption. In contrast, the industrial fleet fishing beyond 10 nautical miles catches/lands anywhere between 10-200 million tons of anchoveta per year.

As mentioned previously, the artisanal sector also has unregulated access to the same area as the industrial fleet (beyond 10 nautical miles) and from this area, they report up to 200,000 anchoveta caught/landed per year, however, in some years, they have caught up to 1 million tons per year from this area.

The anchoveta (*Engraulis ringens*) is a mostly coastal, pelagic species. They are generally found within 50 nautical miles of the coast and occasionally, especially during the winter, they can be found beyond 100 nautical miles. The fish are sexually mature upon reaching a length of 9-10 cm, which happens around one year in age. The minimum allowable catch size (for the industrial fleet) is 12 cm. This ensures that young fish are not caught and removed from the population.

Anchoveta spawn two times per year. The primary spawning season is in spring between August-October and the secondary season is in summer between February-March. During spawning, the anchoveta move closer to the coast and can get as close as to half of a nautical mile from the coast. Anchoveta fishing seasons for the industrial fleet happen twice a year, the first season happens in the months of April through the end of July, while the second season (the shorter one) runs from November to January – and thus the industrial fleet is not allowed to fish anchoveta when they are spawning. For the most part, the artisanal fleet does not have seasonal restrictions and can fish for anchoveta all year long, with the exception of short “temporary bans” due to a high presence of juveniles in the stock.

Anchoveta populations can be affected by temperature changes in the water like when ocean water warms due to El Niño. During the first phase of an El Niño, the anchoveta might move closer to the coast where some colder water remains, later on the event they might also go southward toward Chile or into waters deeper than 70 meters where they are not accessible to fishermen.

The success of the anchoveta fishery in general is heavily linked to these climactic changes. During El Niño years the amount of anchoveta landings can decrease significantly for both the artisanal and industrial sectors, which can have staggering effects on Peru’s economy and the livelihoods of the fishermen. To deal with fluctuations in the anchoveta stock and to create a buffer to ensure that anchoveta supply will not be exhausted or overfished, the Marine Institute of Peru (IMARPE) assesses the stock before each fishing season and sets catch limits. Remember, however, that these limits only apply to the industrial fleets.

Part 4: ACT - What You Can do to Make an Impact

1. Show students the TED Talk "The four fish we're overeating – and what to eat instead" by Paul Greenberg. In this TED Talk Paul Greenberg describes how popular seafood choices like salmon, shrimp, and tuna are threatening our oceans. https://www.ted.com/talks/paul_greenberg_the_four_fish_we_re_overeating_and_what_to_eat_instead/transcript?language=en

2. Have students discuss the impacts he describes as well as his solutions. Have them write a short reflection about changes they think they might make with their own diets.

3. Share with students the following websites as resources to learn more about seafood recommendations, ocean impacts, and other issues surround the sustainability of the world's fisheries.

    - NOAA's Fishwatch: http://www.fishwatch.gov/
    - Monterey Bay Aquarium Seafood Watch: http://www.seafoodwatch.org/

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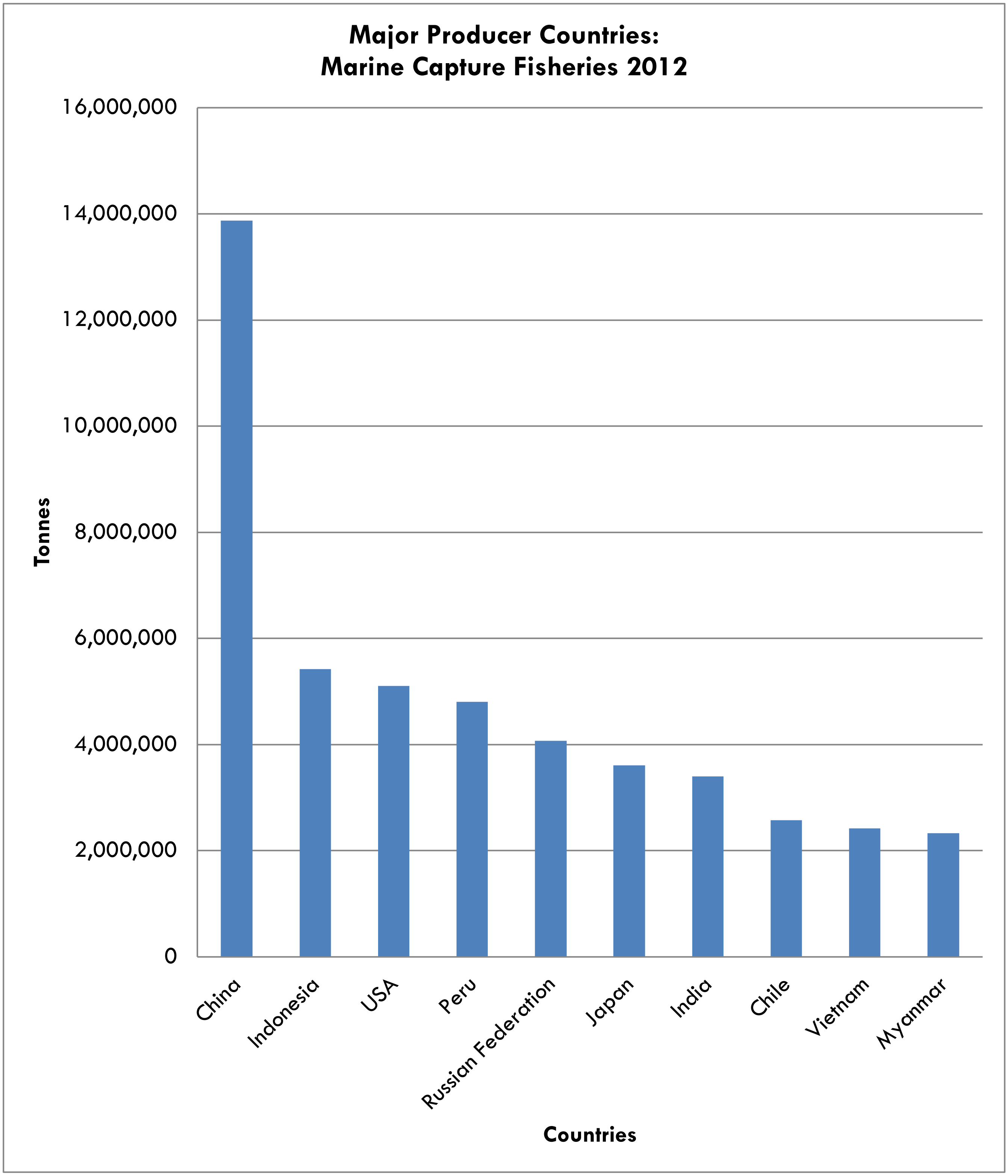

Major Producer Countries:
Marine Capture Fisheries 2012
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
Tonnes
China
Indonesia
USA
Peru
Russian Federation
Japan
India
Chile
Vietnam
Myanmar
Countries

The Humboldt Current Ecosystem:

How Earth Systems Influence Ocean Productivity and Biodiversity

Student Handout

Go to the story map located here http://arcg.is/1RTcru2 and answer the questions below.

1. What causes the productivity associated with the Humboldt Current?

2. Draw and label a diagram that illustrates how an upwelling works.

3. Describe how the Humboldt Current impacts the ecosystem as a whole.

4. How does the El Niño-Southern Oscillation or ENSO Cycle impact the Humboldt Current Ecosystem?

5. How does a La Niña event differ from an El Niño event?

Fisheries Management:

How Catch-Per-Unit-Effort Data Can Help a Community Conserve its Resources

Student Handout

To understand how to create a more sustainable fishery, you must first understand the population dynamics of the resource and the way in which the fishery functions in the first place.

The two videos below will help provide this context. Watch the short clips from each video and answer the questions below.

Fisher in Ancón Harbor
Image Credit: TNC

Watch the video "Fisheries Economics & Policy: Intro to Fisheries Management" (4:44)
https://www.youtube.com/watch?v=Z4AXnZOsrK8

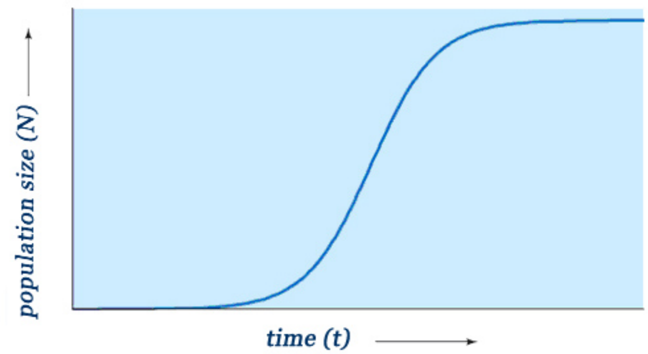
1. Describe the potential problems with common pool resources.

2. What does "open access" mean?

Watch from 0:00-3:05 of the video "Fisheries Economics & Policy: Maximum Economic Yield"
https://www.youtube.com/watch?v=7DNhqtYf47E

3. Explain the ways that fishing effort can increase.

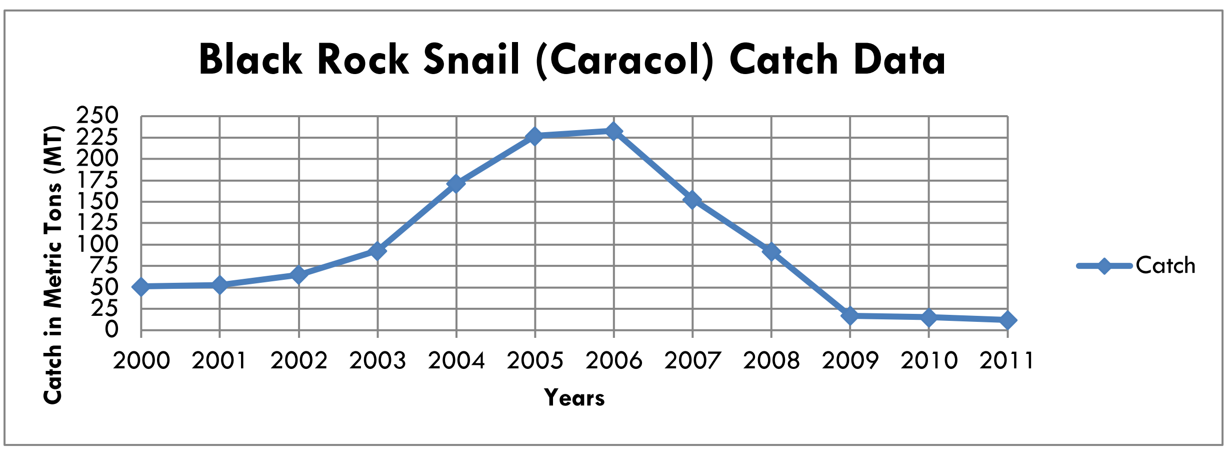
4. If fishing effort increases, but the catch stays the same, what does that indicate about the fish population?



Population Growth Over Time
Image Credit: Licensed under Public Domain via Wikipedia

5. Using the graph above for reference, give a basic description of how fish populations behave and include in your explanation how population size relates to the growth rate.

6. Describe how a population's carrying capacity can shift over time.



7. The graph above shows catch data for Black Rock Snails, which are harvested by benthic divers. Based on the amount of snails caught every year, describe what you think might be happening with the population.

8. What factors might influence the “catchability” of the snails? Do you think that the amount of snails caught directly correlates with the size of the population or might there be other factors and so what are they?

9. What more do we need to know in order to truly assess the snail population?

Catch vs. Catch Per Unit Effort (CPUE)

When you observed the trend in Black Rock Snail catch in question 7, you may have realized that you need more information than the amount of catch to truly understand the population, especially when the goal is to manage the fishery. The amount of a resource caught does not accurately reflect the population size.

To effectively manage a fishery, managers need to know how many fish are in a population at a given time. Fishery scientists use stock assessments to determine the abundance (number and size/age) of fish in a population. One of the simplest stock assessment methods requires almost no knowledge about the biology of the stock. However, good information about the fishery is required.

In this simple assessment, the fishery manager only needs to look at the **history of catch** for the stock and the **effort expended** to catch the seafood. The key word here is **effort**.

Catch data (the amount of fish caught per year) alone are not very useful. Catch can fluctuate for a variety of reasons. Some of those reasons include:

- the amount of hours spent fishing
- the weather
- the number of fishers
- the type of fishing gear used by the fishers

A trend of decreased catch may be a cause for concern, but the amount of effort made by fishermen to catch the stock helps tell the real story.

In order to account for effort, fishery biologists use the terminology catch-per-unit-effort (CPUE). To determine the CPUE, the catch is divided by the amount of effort expended to make the catch.

For example, if a fisher goes out on a boat for 2 hours and catches 10 chinook salmon weighing a total of 200 pounds, then the fisher's CPUE could be expressed as either 5 fish per hour (10 fish caught in 2 hours) or as 100 pounds per hour (200 pounds caught in 2 hours of fishing).

The catch-per-unit-effort is directly related to the amount of fish in the stock. While CPUE doesn't tell you how many fish are in the stock, it provides an index of abundance that can be easily compared from one year to the next. **A decline in CPUE usually indicates a decline in the stock. A decline in both CPUE and catch provides even more evidence for a decline in the stock.** Decreasing CPUE indicates less efficiency – or that more effort is needed relative to the quantity of catch. In contrast, a higher CPUE corresponds to greater efficiency.

A number of fisheries have followed a pattern in relation to the catch-per-unit effort. The following statements describe trends that occur over time **after a new fishery is established**:

- At the beginning of a new fishery, the catch-per-unit effort is high and the effort is low.
- As interest in catching fish grows, the effort increases, the catch increases and the catch-per unit effort usually levels off or declines.
- Finally, as more effort is applied, the catch declines and the catch-per-unit effort declines even more. When both the catch and the catch-per-unit effort decline, it is an indication that the stock is probably overfished. This means that too many fish are being removed before having the chance to reproduce. Catches decline despite increasing effort.

Additional factors that might increase or decrease catchability are as follows:

- Catchability often increases over time as the fishers improve their fishing gear and boats.
- The catchability of a species can be greatly affected when fishers change their targeting practice from one species to another. In general, catchability increases for the new target species, and decreases for the previous target species. However, if the new target species is the predator of the original target species, this could later have a positive effect on population size of the original target species (the prey) as the predator is removed by fishing.
- The environment can have a large influence on catchability. For example, El Niño/La Niña conditions can impact the availability of nutrients and food for fish stock. Additionally, warmer water temperatures caused by El Niño could push the fish stock into deeper, less accessible waters, making it harder to catch.
- The dynamics of a fish stock can also influence how catchability changes over time For example, fish that swim in large groups are fairly easy to catch, so CPUE might not necessarily decline until the population has totally crashed. Other fish that don't aggregate together will become scarcer and more difficult to catch.

10. What is CPUE? Why isn't information on catch alone enough to know the health of a fish stock?

11. Consider the information in the reading above and the equation for calculating CPUE. Describe some scenarios that might cause an increase or decrease in CPUE.

In this remainder of this activity, you will examine catch and CPUE data for the two species in the table below. The Lorna Drum is a demersal fish – in other words it lives in the water column close to the ocean floor. The Black Rock Snail is a benthic species – one that lives on the rocky bottoms of the ocean floor. The characteristics of these two organisms will be useful in answering the questions that follow.

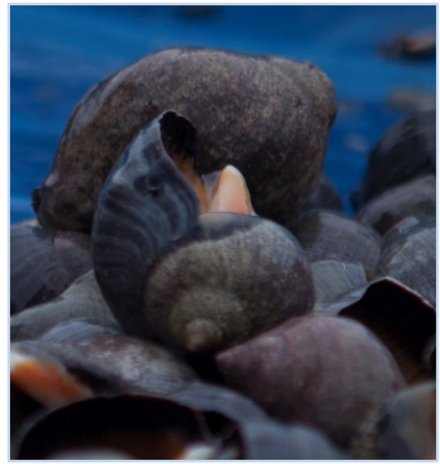
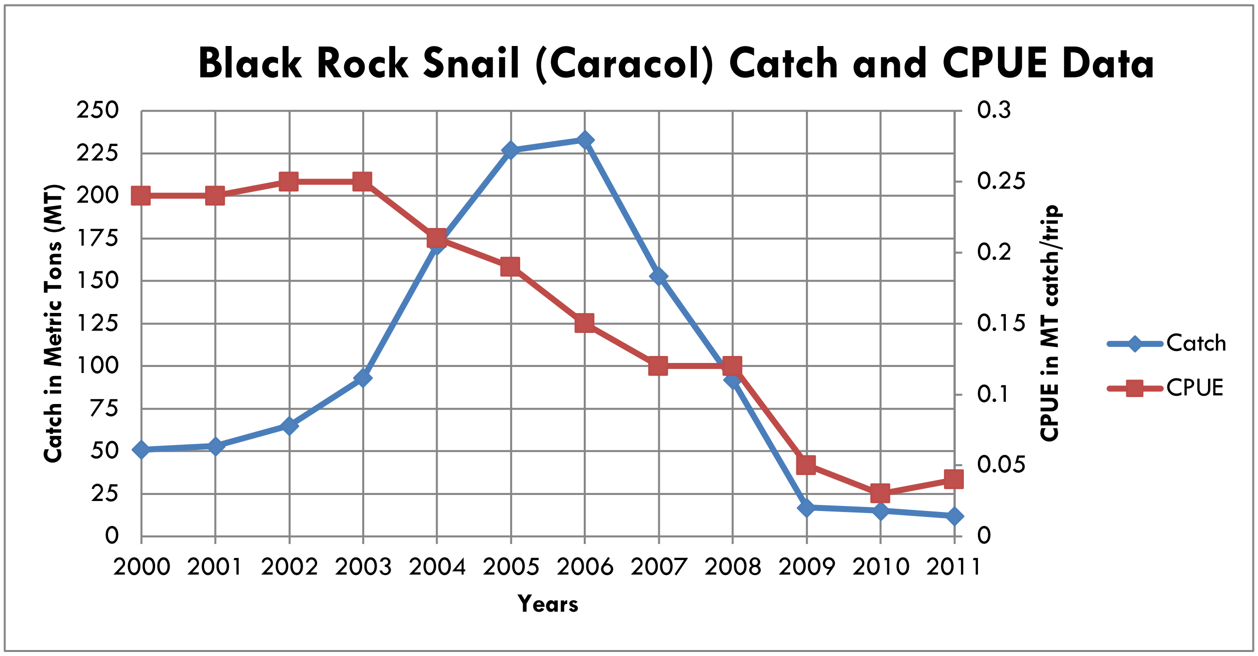


Image credits: Drum - Matias Caillaux and Snail - TNC

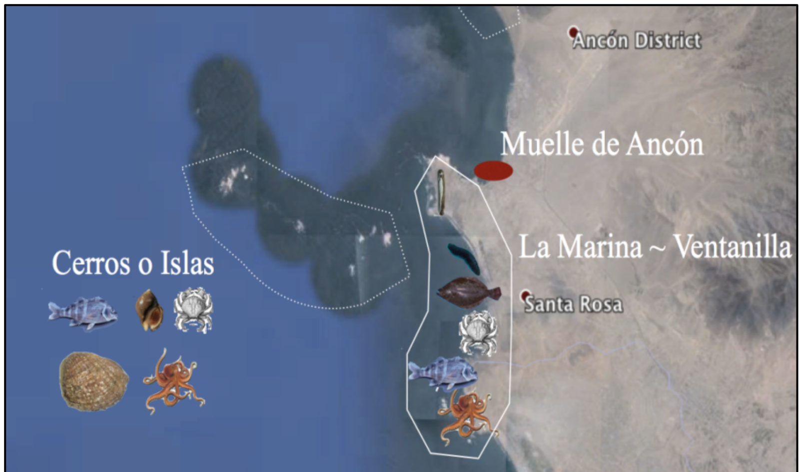
Common Name	**Lorna Drum**	**Black Rock Snail**
Latin Name	*Sciaena deliciosa*	*Thais chocolata*
Spanish Name	Lorna	Caracol
Habitat	Demersal, moves along the water column close to the ocean floor	Live on the ocean floor, mainly on rocky bottoms, does not move around a lot
Food	Feeds on benthic worms, gastropods, bivalves, and crustaceans (which eat phytoplankton)	Carnivorous snail - feeds on mussels, limpets, bivalves and other crustaceans
Fishing Gears Used	Purse seines, gill nets, hook and line	Compressor Diving (Huka), Free Diving



12. The graph above combines the catch data from question 7 with CPUE data for the same time period for the Black Rock Snail. Using the information in the graph above, describe the trend in **CPUE** for the black rock snail.

13. Based on what you know about the relationship between catch and CPUE, describe what you think is happening to this fishery and the health of the snail population.

Case Study: Ancón, Peru



The circled areas represent the fishing grounds around Ancón District Symbols indicate types of organisms caught in each area. Credit: TNC

The town of Ancón, located just north of Lima, Peru is home to approximately 300 fishers. Artisanal and small-scale fisheries are an important economic engine for coastal communities. They provide almost 80% of the seafood consumed in the country. More than 44,000 fishers are directly employed in this sector.

Despite the importance of the small-scale fisheries sector to the economy, very little information on the condition of stocks, levels of fishing effort, efficacy of management, or performance of the fishery is available. Other impediments to sustainability include weak governance, limited market access, and very low capacity for producing value-added products. These obstacles have led, in many instances, to overharvesting stocks and destructive fishing practices, resulting in poor outcomes for fishers and the environment.

For background on artisanal and small-scale fishing in Peru, view the short story map on the fishing community of the Ancón District found here: http://arcg.is/1I7wF5n and answer the question below.

14. Based on the information in the story map, describe the artisanal fishing sector and contrast it with the industrial sector.

In the activity that follows, you will play the role of a fisheries management specialist from a conservation organization. You are working with local fishers to combine their expertise with scientific data to determine how to make their fishery more sustainable. You will examine the population change over time of two species, the Lorna Drum and Black Rock Snail, which are important to the small-scale fishing community of Ancón.

From 2000-2011, you and the fishers have been collecting data on their fishing grounds. Your aim is to help them to make choices on how to collectively manage their fishing grounds so that they can continue to fish without their resources being depleted. Using your knowledge of catch and catch-per-unit-effort you will conduct a stock assessment and provide management suggestions. The two types of management strategies that the fishers are willing to experiment with are seasonal closure and catch limits.

The Effect of El Niño on a Fishery

There is one more factor that you must consider when making a stock assessment in this area. The waters off the coast are affected by El Niño, an abnormal weather pattern that is caused by the warming of the Pacific Ocean near the equator, off the coast of South America. Throughout the year, a northward cool current prevails because of southeast trade winds, causing upwelling of cool, nutrient-rich water. However, during late December the upwelling relaxes, causing warmer and nutrient-poor water to appear. The nutrient poor water leads to a reduction in phytoplankton, which is the base of the food chain in the Humboldt Current Ecosystem. An El Niño event may lead to fewer fish in the area, either because they die-off from lack of food or move to cooler waters out of the fishing area. In order to understand if an El Niño event is responsible for the population changes of the target species, you must first identify the years during our study period in which an El Niño occurred.

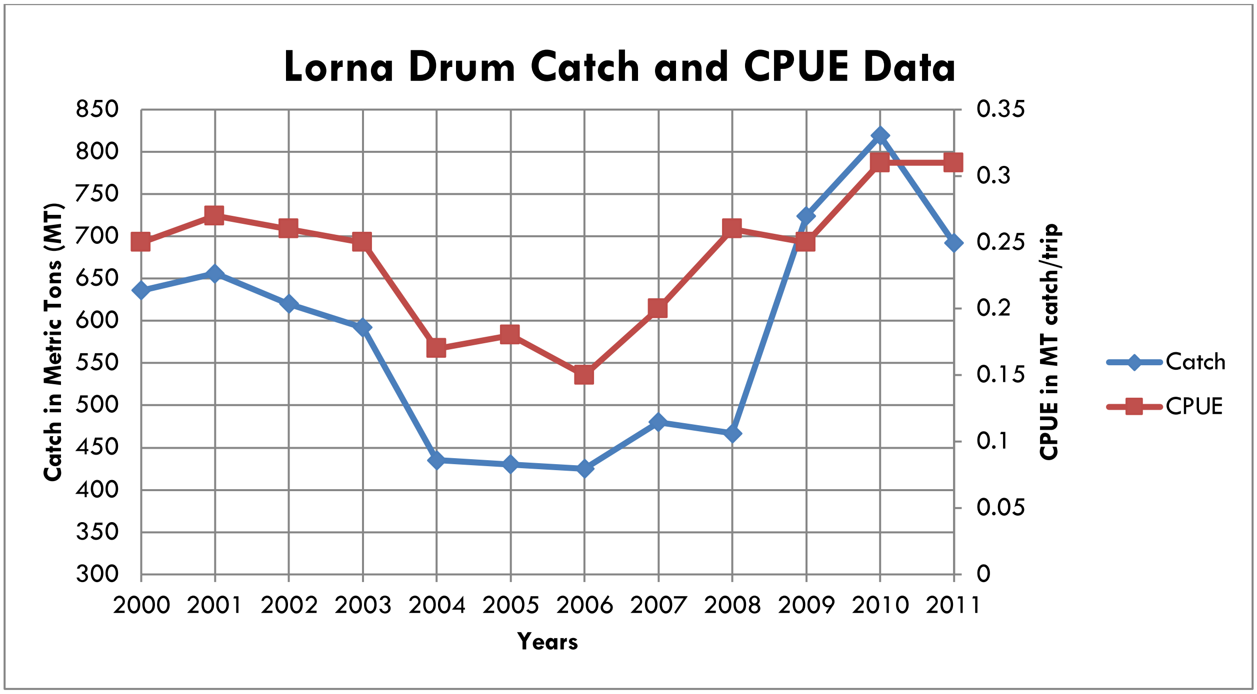
Scientists use the Oceanic Niño Index (ONI) to measure anomalies or deviations from normal sea surface temperatures. When sea surface temperature in the Pacific Ocean deviates by more than 0.9 degrees Fahrenheit (0.5 degrees Celsius) above normal for at five successive three-month periods or more, this indicates an El Niño event. Likewise, when SST deviates by 0.9 degrees Fahrenheit below normal over five successive three month periods, this indicates a La Niña event.

The top row of the chart below shows the abbreviations for months in three-month groupings. "DJF" indicates the three-month period from December to January to February. The chart below shows temperature deviations for the same period as the fisheries data in this exercise.

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	**-1.6**	**-1.4**	**-1.1**	**-0.9**	**-0.7**	**-0.7**	**-0.6**	**-0.5**	**-0.6**	**-0.7**	**-0.8**	**-0.8**
2001	**-0.7**	**-0.6**	**-0.5**	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
2002	-0.2	-0.1	0.1	0.2	0.4	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.3**	**1.1**
2003	**0.9**	**0.6**	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	**0.5**	**0.7**	**0.7**	**0.7**	**0.7**	**0.7**
2005	**0.6**	**0.6**	**0.5**	**0.5**	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	**0.5**	**0.8**	**0.9**	**1.0**
2007	**0.7**	0.3	0	-0.1	-0.2	-0.2	-0.3	**-0.6**	**-0.8**	**-1.1**	**-1.2**	**-1.3**
2008	**-1.4**	**-1.3**	**-1.1**	**-0.9**	**-0.7**	**-0.5**	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	**0.5**	**0.6**	**0.7**	**1.0**	**1.2**	**1.3**
2010	**1.3**	**1.1**	**0.8**	**0.5**	0	-0.4	**-0.8**	**-1.1**	**-1.3**	**-1.4**	**-1.3**	**-1.4**
2011	**-1.3**	**-1.1**	**-0.8**	**-0.6**	-0.3	-0.2	-0.3	**-0.5**	**-0.7**	**-0.9**	**-0.9**	**-0.8**

Data from NOAA's Climate Prediction Center, full data table here:
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

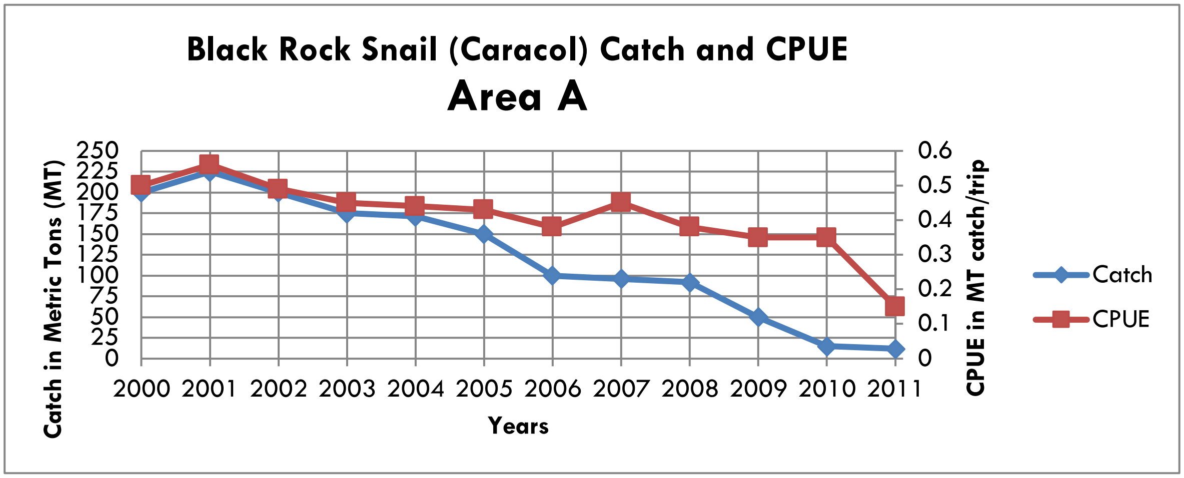
15. Using the chart above, identify the years in which La Niña and El Niño events occurred.



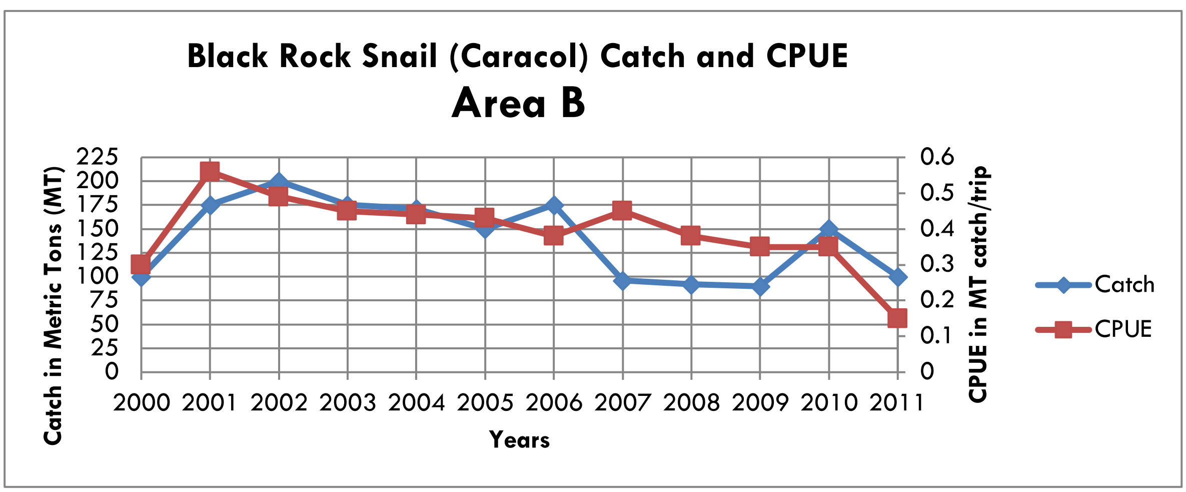
16. In the graph above, circle the El Niño periods with a red pen and circle the La Niña periods with a blue pen.

17. Using the graph above, your knowledge of El Niño and La Niña periods, and the feeding habits of the Lorna Drum to describe how these climactic events might have impacted the Lorna Drum population. What kind of management strategies might you suggest for this species of fish based on these data?

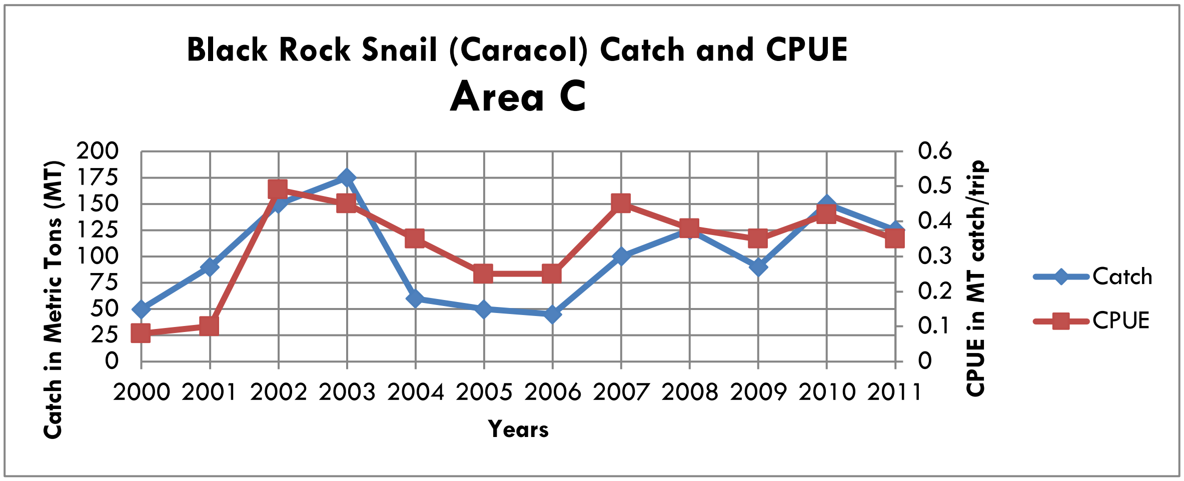
18. There are three areas (A, B, and C) where you and the fishers have been collecting data on the Black Rock Snail. Based on your knowledge of CPUE and catch, below each graph describe what you think is happening to the snail population in that area and describe whether or not you feel the area should be closed to allow the population to rebuild.



Area A Assessment:



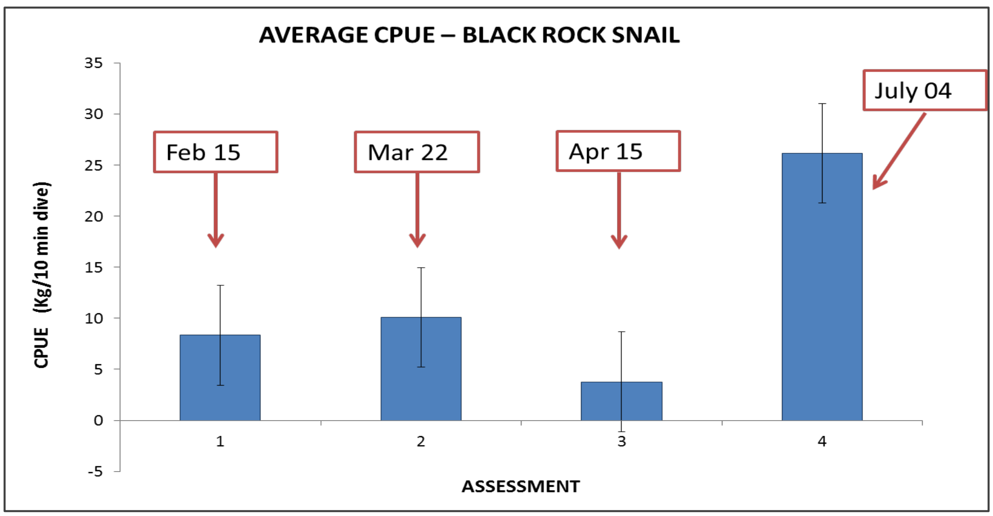
Area B Assessment:



Area C Assessment:

19. The fishers you are working with decided to close off The Isleta, a small island with a perimeter of 1.4 km near Ancón. So far they have closed it to fishing for 5 months. During this time, you've worked with the divers to collect scientific data on the CPUE for Black Rock Snail. Here the CPUE is measured in kilograms of snails collected during a 10 minute dive. Based on the graph below, describe the effect of the closure on CPUE.

The Isleta near Ancón, Peru where a snail fishing area has been closed
Image credit: TNC



CPUE of Black Rock Snail at the Isleta after 5 months of closure. Note that monitoring was not performed in May and June due to poor weather conditions.

20. Now that you have these data, what more do you need to know? Will you continue the closure? For how long? Do you feel that 5 months of investigation is long enough to understand all of the factors involved in the population dynamics of the snail? What further investigations might you propose in order to develop a management strategy for the Black Rock Snail in this area?