MARINE PROTECTED AREA (MPA) LESSON PLANS

GRADES 6-8

SAN DIEGO MPA COLLABORATIVE

WILDCOAST COSTASALVAJE

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Intertidal Transects

Rocky Intertidal - Grades 6-8

Learning Objectives

A) Students will use vertical transect surveys to collect population data for key intertidal organisms at sites inside and outside of the South La Jolla State Marine Reserve (Part 1).

B) Students will use descriptive statistics to analyze the abundance of species found inside and outside of the MPA
(Part 2).

C) Students will compare abundance inside and outside of the MPA to draw conclusions about MPA impact on abundance
(Part 3).

NGSS: DCI (Disciplinary Core Ideas):
LS2.A
LS4.D

Time: Four to nine 50-minute class periods plus one and a half to two hour field trip

Materials for the Teacher
- -Living on the Edge: Field Guide to the Intertidal Teacher Edition
- -Quadrat photos if not doing field trip

Materials for the Students
- -Living on the Edge: Field Guide to the Intertidal Student Edition
- -Clipboard
- -Vertical Transect Datasheet (from appendix) and pencil
- -0.5m x 0.5m quadrat
- -Transect tape or string

Part 1: Data Collection

Background information:

(recommended one to six 50-minute class periods)

See *Living on the Edge: Field Guide to the Intertidal Zone* for more background information and classroom activities that may accompany this lesson. It is recommended you take one 50-minute class period to cover each of the six topics covered in the field guide: The Intertidal Zone, Adaptations, Tidepools, Tides, Marine Protected Areas, and Taxonomy/ID.

Marine Protected Areas (MPAs)

We can think of marine protected areas, or MPAs, as underwater parks. Just like we have national, state, and regional parks on land, there are many different types of MPAs. Different parks allow different activities - same with MPAs! In some of them you can fish, while in others you can't. Some MPAs allow all kinds of activities (fishing, swimming, boating, etc.) while others are much stricter. By restricting what people can do and take in these underwater parks, we can protect California's natural resources.

California has 124 MPAs all along the coast. These MPAs protect many different habitats where many different animals live. MPAs give marine species a safe place to breed and grow. Animals inside of MPAs may be larger than those found outside of MPAs, allowing them to have more offspring than smaller animals. Offspring born within MPAs may also have access to more food, space, and other resources, allowing offspring to be healthier.

MPAs also provide opportunities for people to see beautiful, protected ocean spaces through snorkeling, scuba diving, swimming, kayaking etc. Sometimes, people don't know that they are in an MPA and accidentally do something they aren't supposed to do. That's why it is important to understand what MPAs are, why we have them, and where they are - so you know if you are in one!

Also, have students start to think about the following now. We will discuss it more in-depth at the end off the lesson: Evidence suggests that MPAs may increase biodiversity and abundance by giving species a safe place to live, grow, and reproduce; however, this success is threatened by other activities such as marine debris/pollution. What are some complementary solutions that may be enacted to help reduce or eliminate the threat of marine debris to MPAs?

Intertidal Zone

MPAs protect a wide range of ecosystems in Southern California, including kelp forests, rocky reefs, sandy shores, and the intertidal zone. This lesson will focus on the unique and fun intertidal zone.

The **intertidal zone**, the area between the high and low tide lines, is a harsh and unforgiving habitat. The highly adapted species that live there are subject to the rigors of both the land and the sea, going from completely submerged to only occasionally wet within just a few feet of space. Organisms that inhabit the intertidal zone must endure extreme fluctuations in moisture level, temperature, salinity, and sunlight. Those that are able to do so make up a robust assortment of biologically diverse organisms with specialized adaptations. Visiting these creatures in the space between land and sea is truly an adventure!

MPAs limit or prohibit which intertidal organisms humans may take. This reduces stress on intertidal organisms and safeguards marine resources within this dynamic environment.

Vocabulary

-*Marine Protected Area (MPA)*: MPAs are areas in or near the ocean made to protect or conserve marine life and habitat, safeguard cultural sites, and provide enhanced recreational opportunities.

-*Take*: To hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill any natural resources.

-*Natural Resource*: Materials or substances such as minerals, forests, water, or animals that are found in nature and are valuable to humans.

-*Intertidal Zone*: The area of land in between the high and low tidelines.

-*Abundance*: A measure of the number of individuals of a particular species in a sample.

-*Random sample*: Data collected from a random subset of a population, meant to represent the entire population.

Measuring Abundance

Abundance is a measure of the number of individuals of a particular species in a given area. In its most basic form, abundance equates to population size. For example, if you found 500 limpets at Site A and only 57 limpets at Site B in the same amount of space, then Site A would be said to have a greater abundance of limpets. However, as is often the case in science, things are not always so straightforward and measuring abundance usually involves quite a bit of math!

There are many ways to calculate abundance, including frequency, density, or simple presence/absence. In this lesson we will use descriptive statistics to compare the abundance of target species at two sites using frequency (the percentage of subsamples, in this case quadrats, that contained our target species), density (in this case calculated by average number of individuals found per square meter), and range.

So why do all of this math when we are studying conservation? One of the primary goals of MPAs is to protect, or even increase, species abundance. By limiting or restricting take, we will hopefully increase the number of breeding females as well as allow those females to have more offspring, thereby increasing population size at a rate higher than non-protected areas. See the Big Old Fertile Female Fish (BOFFF) activity for a great representation of this concept. Quantifying the increase in species abundance inside of MPAs helps to guide informed MPA management.

It is important to note that it is nearly impossible to count every single individual of a species at any given site. As is typical in science, instead of observing an impossibly large scale, we will look at a representative subset and build our hypothesis based on inference. We will do this using a method called random sampling. In random sampling, we collect data for a randomly chosen subset of the population. It is crucial that the subset be chosen randomly so as to not introduce human bias (i.e. sampling the individuals that are biggest, easiest to find, or prettiest, as would be tempting to do!).

One of the methods of random sampling that we often use in the intertidal zone is something called a vertical transect. A vertical transect is a line, often marked off by meter tape, that runs perpendicular to the water along which we collect samples. We place squares, called quadrats, at regular intervals along the transect and count only what is within the quadrat. By repeating this several times, we are able to get a subset of data, which is (usually) representative of the entire population. We can then run statistics on this data to draw conclusions about the whole population.

-*Vertical Transect:* A fixed path (with a start and end point) along which one counts and records scientific data. In this case, one that runs perpendicular to the water.
-*Quadrat*: A frame, traditionally square, used in ecology and geography to isolate a standard unit of area for study
-*Experimental site*: The site receiving the experimental treatment (in our case the protection afforded by MPAs)
-*Control site*: The site not receiving experimental treatment.
-*Holdfast*: a root-like structure that anchors aquatic organisms to the substrate. Holdfasts vary in shape and form depending on the species and the type of substrate.Substrate: The surface or material on or from which an organism lives.
-*Frequency*: The number of times something occurs, often represented as a percentage.

Suggested procedure:

Teacher Prep

1) Divide your class into research groups of about four students each.
2) Create a field kit for each group consisting of:
   - -One clipboard
   - -One datasheet and pencil (see Appendix)
   - -One quadrat (see Appendix; students may assemble)
   - -One meter tape (or string with meters marked on it)

Student Prep

1) In class, study MPAs, the intertidal zone, abundance estimates, and vertical transect surveys. Use the information and activities in Living on the Edge: Field Guide to the Intertidal Zone (recommended activity: Tidepool in a Pan).
2) Have students form a hypothesis for the following research question: Is there a difference in species abundance inside an MPA compared to outside an MPA?
3) Let students explore field kits. First, assemble the quadrats by attaching each of the 0.5m pieces of PVC pipe together using the 90-degree elbows to form a square. Go over the rest of the kit in class with students.
4) Take quadrats and meter tape outside to the schoolyard or a local park. Practice proper placement of meter tape and quadrats until students are comfortable with methodology and instruments (see Conducting Vertical Transects in the Field Trip section below).

Field Trip *(recommended 1.5-2 hours in the field)*

Getting Started

1) Check the tide ahead of time to determine which day and time will have an acceptable low tide for this project. Negative, outgoing tides are recommended. The best tides are in the spring. Tides for La Jolla may be found here: https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9410230

2) **Meet at the following location:**
Windandsea Beach in La Jolla
Parking lot at the corner of Nautilus Street and Neptune Place
Street parking is also available for free.
Note, this location does not have public restrooms.

3) Make sure to cover good tidepooling practices with the students:
-Watch where you step, that might not be a rock!
-Leave things how you found them. If you turn over a rock, put it back exactly how you found it.
-Take only pictures. Leave all rocks, plants, animals, and other tidepool creatures exactly how you found them.
-Leave animals be. Tidepool organisms have a hard enough life as it is without being touched by a bunch of sticky fingers.
-Be careful where you put your fingers. Many animals like sea urchins and crabs have defenses against predators.
-Never turn your back on the ocean.... it needs you too much! But seriously, watch out for waves and the incoming tide.
4) Designate a meeting location and end time for the activity. Depending on the group, tides, and weather conditions, often about 45 minutes to an hour is appropriate for data collection.
5) Split the class into two groups, making sure the student research groups of 2-4 students are kept together. One group will descend the stairs below the parking lot and collect data on the rocks just to the north. This group is the Windandsea Beach control group.
6) The other group will head about 10 minutes south and take the stairs down to the beach by Palomar Ave. This group will be the South La Jolla State Marine Reserve experimental group.
7) Make sure to assign at least one chaperone with each group to ensure best practices are met.

Conducting Vertical Transects
*These data collection methods are adapted from NOAA's LiMPETS Monitoring Program.
1) Help students set up one transect per group parallel to each other and perpendicular to the water by laying meter tape or a string with meters marked on it from the highest accessible point in the tidepools to as close to the water as is safe. Please be mindful of the tide. This activity is best done on a negative, outgoing tide.
2) Center a quadrat directly over the meter tape at even intervals (i.e. every three meters) depending on the length of the transect.
3) Record species abundance within the quadrat by counting how many individuals of each species on the datasheet are present.
4) Count only live invertebrates and algae that are attached to the substrate as well as those attached to sessile organisms within the quadrat (e.g., algae

-*Descriptive statistics*: Mathematical means of describing a particular set of data.
-*Central Tendency*: Estimate of the "center" of a distribution of data. This includes mean, median, and mode.
-*Dispersion: Spread of data around the central tendency.*

California Department of Fish and Wildlife Key Messages:
-MPAs protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.
-MPAs help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.
-MPAs improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and manage

growing on mussels). For algae, only count it if the holdfast is contained inside the quadrat.
5) When the count for one quadrat is completed, proceed to the next location along the transect. Continue until the entire length of the transect has been counted .
6) Students will typically be excited about what they saw and will want time to share with others. Once the class regroups, give them time to
share their observations as well as any surprises they experienced, challenges they faced, or favorite things they saw.

these uses in a manner consistent with protecting biodiversity.
-MPAs protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic values.

Connections:
Art, science, engineering

Ocean Literacy Connection:
-The ocean supports a great diversity of life and ecosystems.
-The ocean and humans are inextricably interconnected.

Suggested extensions:
-For advanced classes, conduct additional data analysis looking at the difference in abundance among the different zones within the intertidal.
-Omit the field trip portion and substitute with quadrat photos in the classroom. Create a table with your findings and complete Parts 2 and 3 of this lesson plan.

PART 2: Data Analysis

(recommended one 50-minute class period)

Background information:

We will be using descriptive statistics to determine whether our data support our hypothesis. **Descriptive statistics** are mathematical means of describing a particular set of data (such as we just collected), as opposed to inferential statistics, which are used to reach conclusions that extend beyond the immediate data set.

There are three major characteristics that descriptive statistics aim to describe:

-Distribution, or frequency of individual values, often represented as a percentage
-Central tendency, or estimate of the “center” of a distribution of data (mean, median, and mode are all measures of central tendency)
-Dispersion, or spread of data around the central tendency, often represented as the range or standard deviation

For this lesson, we will be measuring the distribution of a certain species within our transects using a percentage, central tendency using mean (which will then be used to calculate density), and the dispersion using the range to compare our control and experimental sites. Additionally, we will use the mean to determine the density of a certain species within the sample.

Suggested procedure:

Compile data from all of the transects done at each site on the board. For example, if you did four transects at Windandsea Beach, the students will combine the data from all four of those transects when they do their analysis. Each transect is a replicate, or close copy, of the other transects.

Control (Windandsea Beach)	Green sea anemone	Purple sea urchin	Chiton	Shore crab	California mussel
Transect 1 Quadrat 1 (T1Q1)	# individuals found				
T1Q2					
T1Q3					
T1Q4					
T2Q1					
T2Q2					
T2Q3					
T2Q4					
T3Q1					
T3Q2					
T3Q3					
T3Q4					
T4Q1					
T4Q2					
T4Q3					
T4Q4					

-Instead of calculating abundance by hand, have students complete calculations in Excel.
-Mix and match the six lessons and various activities in Living on the Edge: Field Guide to the Intertidal to meet classroom needs.
-Allow students to conduct a separate inquiry project using the datasets they produce.

Assign each group one species (or more, depending on your time!) on which to conduct their analysis. Make sure that whatever species you choose is represented and analyzed for both the experimental site (South La Jolla SMR) and the control site (Windandsea Beach). For example, if you choose to have students from South La Jolla SMR run the calculations for green sea anemones, make sure one of the groups from Windandsea Beach also runs calculations for green sea anemones so we may compare findings in Part 3.

Have each group conduct the following analysis using data on only one species from one site (experimental OR control) at a time. So, when we are talking about combining quadrats, we mean we are combining quadrats from either the experimental site or the control site, not both.

Calculating Frequency

When calculating frequency, we want to know how often a certain species was found along our transects. This is fairly easy and involves the use of presence/absence data and some simple math.

1) Divide the number of quadrats at one site in which your species was present by the total number of quadrats. For example, if green sea anemones were found in 12 of the 16 quadrats you sampled at Windandsea Beach the frequency would be 12/16 = 0.75 = 75%. So the frequency of green sea anemones at Windandsea Beach would be 75%!

$$\textbf{Frequency (\%)} = \frac{\textbf{\# quadrats in which your species was present}}{\textbf{Total number of quadrats}} \times 100$$

Calculating Central Tendency

There are three ways to calculate central tendency: mean, median, and mode. For this activity, we will be using the mean to calculate the density. You may choose to have students calculate median and mode as well, then hold a discussion about which is most appropriate for this study.

To calculate the mean, we will use the total number of individuals found in each quadrat at a particular site and divide by the total number of quadrats. For the purposes of this study, we may combine the data from all quadrats sampled at one site regardless of which zone in the intertidal they came from, since we are looking at abundance for the entire sampled area. It is important to explain to the students that sometimes vertical transects are used to compare data between the zones within the intertidal (i.e. the abundance of green sea anemones in the spray zone versus the high tide zone) - in that case we would only combine quadrats from the same zones. Since we are not distinguishing between zones in this study, we do not need to worry about this.

1) To calculate the mean, make a list of how many individuals of a certain species were found in each quadrat.

Control (Windandsea Beach)	Green sea anemone
Transect 1 Quadrat 1 (T1Q1)	# individuals found
T1Q2	
T1Q3	
T1Q4	
T2Q1	
T2Q2	
T2Q3	
T2Q4	
T3Q1	
T3Q2	
T3Q3	
T3Q4	
T4Q1	
T4Q2	
T4Q3	
T4Q4	

Control (Windandsea Beach)	Green sea anemone
Transect 1 Quadrat 1 (T1Q1)	4
T1Q2	6
T1Q3	4
T1Q4	7
T2Q1	9
T2Q2	2
T2Q3	1
T2Q4	2
T3Q1	5
T3Q2	6
T3Q3	7
T3Q4	3
T4Q1	1
T4Q2	8
T4Q3	4
T4Q4	2

2) Add up the numbers: Example

4 + 6 + 4 + 7 + 9 + 2 + 1 + 2 + 5 + 6 + 7 + 3 + 1 + 8 + 4 + 2 = 71

3) Divide by the number of quadrats:

71/16 = 4.4

4) So, in this example, we found an average of 4.4 green sea anemones per quadrat!

$$\textbf{Mean} = \frac{\textbf{Total number of individuals of a species found in all quadrats}}{\textbf{Total number of quadrats}}$$

Calculating Density

Now that we have found the mean of our data, it is very easy to calculate the density. In fact, you pretty much already have! Density is a measure of the average number of individuals of a species per a certain unit area. Our quadrats measured 0.5m x 0.5m, or a quarter square meter, which is already a unit of area. However, it is simpler and more common to communicate our data in terms of square meters. So, let's do that calculation.

1) From our calculations above, we concluded that there was an average of 4.4 green sea anemones per quadrat. Since our quadrats represented 0.25m2, how do we calculate how many green sea anemones we found per square meter? Multiple our answer by 4!

4.4 x 4 = 17.6 green sea anemones per square meter!

Density (per m2) = Mean x 4

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Calculating Dispersion

To calculate the dispersion of a species, we will use the range. The range is the difference between the highest and the lowest value in a dataset. So, for our data, it is the highest number of individuals of a species found within one quadrat minus the lowest number of individuals of a species.

For our example of green sea anemones, the highest amount of green sea anemones found in any one quadrat was 9. The lowest found in any one quadrat was 1. So our range is 9 – 1 = 8.

Range = Highest number of individuals found in one quadrat – lowest number of individuals found in one quadrat

PART 3: Drawing Conclusions

(recommended one 50 minute class period)

Class Discussion

1) Discuss what the frequency, mean, density, and range each tell us for each site. All of these are technically measures of abundance. What are the pros and cons of using each one for this particular example?
2) Most likely, if we were presenting this data to others, we would draw conclusions based on the density. It is the easiest to compare and probably the easiest for the public to understand. Compare the density for each species between the experimental and control sites. Did any species have a higher abundance inside the MPA? Did any have a lower abundance inside the MPA? [MR1] Did your data support or refute your hypothesis? What conclusions can you draw from this data?
3) Do you think your results are accurate? What are some sources of error? What would you do differently if you did this project again? What would you suggest for future studies?
4) What natural resources did you observe that may be important to humans? How might MPAs protect them? What would happen to the ecosystem if that resource no longer existed? What would happen to humans if that resource no longer existed?

Activity

Have each student write a short op-ed article reflecting what he or she did and learned in the lesson. Articles should be written for a general audience, i.e. the public, who likely does not know much about the intertidal zone, MPAs, or data collection.

A good article about writing tips for aspiring op-ed writers may be found here: https://www.nytimes.com/2017/08/25/opinion/tips-for-aspiring-op-ed-writers.html

Articles should include the following in 3-5 paragraphs:

1) At least one picture or drawing related to the activity
2) A catchy title
3) A hook or first sentence that draws the reader in
4) What is an MPA?
5) What is the intertidal zone?
6) What did you study?
7) How did you study it?
8) What were your results?

9) What were your conclusions?
10) Why is your data important? Why should your readers care?
11) What can your readers do to help save the coast and ocean?

Consider publishing any great articles in the school newspaper, on the school's social media, even in a local newspaper or magazine!

Engage: Play one of the games or complete one of the activities from Living on the Edge: Field Guide to the Intertidal. After reviewing background information, have students practice collecting data with the transects in the schoolyard or park.
Explore: Conduct vertical transect surveys at local tidepools.
Explain: Explain abundance and how we measure it.
Elaborate: Have students calculate abundance using frequency, mean, density, and range.
Evaluate: Ask the students questions relating to what they have learned (more questions may be found in Part 3 of this lesson plan).
Q1: What are the differences between the different measures of abundance?
Q2: Which site had higher abundance? Inside the MPA or out?
Q3: What natural resources are present in the intertidal zone?
Q4: How do MPAs protect those natural resources?

NGSS Alignment

LS2.A Ecosystems have carrying capacities resulting from biotic and abiotic factors. The fundamental tension between resource availability and organism populations affects the abundance of species in any given ecosystem.

LS4.D Biodiversity is increased by formation of new species and reduced by extinction. Humans depend on biodiversity but also have adverse impacts on it. Sustaining biodiversity is essential to supporting life on Earth.

Science and Engineering Practices

Asking Questions: Ask questions that arise from examining models or a theory to clarify and/or seek additional information to determine relationships, including quantitative relationships between independent and dependent variables, and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the sustainability of a design.

Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution, apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data, and evaluate the impact of new data on a working explanation and/or model.

Using Mathematics and Computational Thinking: Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Constructing Explanations and Designing Solutions: Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.

Engaging in Argument from Evidence: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence and make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge.

Crosscutting Concepts

Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Online Resources

La Jolla Tide Charts: https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9410230

NOAA LiMPETS Program: http://limpets.org/rocky-intertidal-monitoring/ri-methods/vertical-transect/

New York Times “Tips for Aspiring Op-Ed Writers”: https://www.nytimes.com/2017/08/25/opinion/tips-for-aspiring-op-ed-writers.html

South Coast Baseline Program Final Report: Rocky Intertidal Ecosystems: https://caseagrant.ucsd.edu/sites/default/files/SCMPA-22-Final-Report_wAppendices.pdf

Appendices

Datasheet on next page

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Intertidal Transects Data Sheet

Site: Control or Experimental

Date:

Site Name:

Time:

Group Members:

Transect (T) Quadrat (Q)	Species:	Species:	Species:	Species:	Species:
T1Q1					

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All Waterways Lead to the Ocean

Sandy Shore - Grades 6-8

Learning Objectives

A) Students will explore their place in the watershed and model how activities upstream affect sandy shores downstream. Students will participate in a beach cleanup and record community science data for the Ocean Conservancy (Part 1).
B) Students will use basic statistics to categorize and analyze how much marine debris they find and possible sources of the debris (Part 2).
C) Students will use insight and data from parts 1 and 2 to develop possible complementary solutions to protect marine protected areas from marine debris (Part 3).

NGSS: DCI (Disciplinary Core Ideas):
MS-ESS2-2.
MS-ESS2-4.
MS-ESS3-3.
MS-ESS3-4.
MS-ETS1-1.

Time: Four to nine 50-minute class periods plus one and a half to two hour field trip

Materials for the Teacher
- -Life in the Sand: Field Guide to Sandy Shores
- -Plastic, paper, and other tiny scraps
- -Vegetable oil
- -Food coloring

Part 1: Data Collection

Background information:
(recommended one to six 50-minute class periods)
Sandy shores are dynamic habitats, constantly changing due to impacts from the ocean, wind, tides and people. One of the most challenging aspects of sandy shore conservation is connecting people who live far from the beach with this important habitat. In this lesson students will learn about watersheds and how all waterways lead to the ocean. Students will participate in a community science program collecting data about the impacts of activities upstream, including marine debris, to draw conclusions about how they can take steps to protect beaches.

Marine Protected Areas (MPAs)

We can think of marine protected areas, or MPAs, as underwater parks. Just like we have national, state, and regional parks on land, there are many different types of MPAs. Different parks allow different activities - same with MPAs! In some of them you can fish, while in others you can't. Some MPAs allow all kinds of activities (fishing, swimming, boating, etc.) while others are much stricter. By restricting what people can do and take in these underwater parks, we can protect California's natural resources.

California has 124 MPAs all along the coast. These MPAs protect many different habitats where many different animals live. MPAs give marine species a safe place to breed and grow. Animals inside of MPAs may be larger than those found outside of MPAs, allowing them to have more offspring than smaller animals. Offspring born within MPAs may also have access to more food, space, and other resources, allowing offspring to be healthier.

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MPAs also provide opportunities for people to see beautiful, protected ocean spaces through snorkeling, scuba diving, swimming, kayaking etc. Sometimes, people don't know that they are in an MPA and accidentally do something they aren't supposed to do. That's why it is important to understand what MPAs are, why we have them, and where they are - so you know if you are in one!

Also, have students start to think about the following now. We will discuss it more in-depth at the end off the lesson: Evidence suggests that MPAs may increase biodiversity and abundance by giving species a safe place to live, grow, and reproduce; however, this success is threatened by other activities such as marine debris/pollution. What are some complementary solutions that may be enacted to help reduce or eliminate the threat of marine debris to MPAs?

Materials for the Students

- -Life in the Sand: Field Guide to Sandy Shores Student Edition
- -Map of local watersheds
- -One paint tray (preferably metal and reusable)
- -Enough sponges or scraps of towel to fill width of paint tray
- -Monopoly houses (3-10 per group usually works well)
- -Water
- -Natural materials such as dirt, rocks, sticks, leaves
- -Trash bag or bucket (one per group)
- -Gloves (two per person)
- -Trash pickers (if available)
- -Clipboard (one per group)
- -Talking Trash data sheet (one per group; see appendix)
- -Pen or pencil
- -Poster board or butcher paper
- -Markers
- -Marine Debris Possible Solutions activity sheet (see appendix)

Sandy Shore

Sandy shores are areas where deposits of sand or other sediments cover the shoreline. To beachgoers, sandy shores often appear to be devoid of life, made up only of sand, shells, and the occasional piece of driftwood. But in reality, this dynamic habitat is home to a diversity of species, each specially adapted for life above or below the sand. These organisms must contend with pounding waves, changing tides, and constantly shifting sand particles - not to mention people who love to visit and develop beaches!

Community Science

Community science (also known as citizen science) involves members of the general public (that's you and me!) collecting data that can then be used in scientific research. Anyone can participate in community science. It's a great way for people to help out professional scientists!

There are many different types of community science. Some involve using an app on your phone to take pictures or measurements that are then sent to professional scientists. Today, we are going to do a type of community science that involves taking notes about what you see.

Ocean Conservancy Fighting for Trash Free Seas

From the Ocean Conservancy:

"Ocean trash affects the health of wildlife, people and local economies. Trash in the water and on the shore can be mistaken as food by wildlife, or entangle animals with lethal consequences. Plastic also attracts and concentrates other pollutants from surrounding seawater, posing a contamination risk to those species that then eat it. Scientists are studying the impacts of that contamination on fish and shellfish as well as the possible impact it may have on human health as well.

From plankton to whales, animals across ocean ecosystems have been contaminated by plastic. Plastic has been found in 59% of sea birds like albatross and pelicans, in 100% of sea turtle species, and more than 25% of fish sampled from seafood markets around the world.

Marine debris isn't an ocean problem—it's a people problem. That means people are the solution. Ocean Conservancy is committed to keeping our beaches and ocean trash free. For more than 30 years we have organized the International Coastal Cleanup, where nearly 12 million volunteers from 153 countries have worked together to collect more than 220 million pounds of trash. And we're not the only ones who care about ocean trash: Every day, all over the world, concerned people take the problem into their own hands by cleaning up their local waterways.

Tackling the problem of plastic in the ocean begins on land. Reduction in plastics use, especially of single-use disposable products, and the collection and recycling of plastics in developing countries can help to reduce the amount of plastic waste that enters the ocean."For this activity students will be participating in the Ocean Conservancy's Trash Frees Seas community science program to collect marine debris from a local beach, analyze what they find, and explore the impact on local ecosystems and wildlife.

Vocabulary

-*Marine Protected Area (MPA)*: MPAs are areas in or near the ocean made to protect or conserve marine life and habitat, safeguard cultural sites, and provide enhanced recreational opportunities.

-*Take*: To hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill any natural resources.

-*Community (or citizen) Science*: The collection and/or analysis of scientific data by everyday people.

-*Marine Debris*: Human-created waste that has deliberately or accidentally been released in a lake, sea, ocean, or waterway.

-*Watershed*: An area of land that channels rainfall and snowmelt to creeks, streams, and rivers, and eventually to outflow points such as reservoirs, bays, and the ocean.

-*Main stem (watershed)*: the major river all the water drains into.

Our Place in the Watershed

Most people, including most or all of your students depending on your school, live far upstream from a sandy shore. Far too often there is a disconnect between what one does upstream and the impact it has in the ocean. This lesson will explore the idea that all watersheds lead to the ocean and create a connection between students, wherever they may be in the watershed, and the beach.

Watersheds in San Diego

San Diego County is home to eleven westward draining watersheds (see map in appendix for full list). Most of these empty to the ocean adjacent to a sandy shore. Three San Diego County watersheds end in an MPA:

-Carlsbad Watershed: Swami's State Marine Conservation Area (Cardiff State Beach)

-Peñasquitos: Matlahuayl State Marine Reserve (La Jolla Shores)

-Tijuana Watershed: Tijuana River Mouth State Marine Conservation Area

Activity: Map Your Watershed

1) Pull up a map of your local watershed.

2) Have students identify where their school is located within the watershed.

3) Have students identify the parts of their watershed: the main stem, tributaries, headwaters, and mouth (make sure to point out any sandy shores located around the mouth).

   a. **Main stem**: the major river all the water drains into
   b. **Tributaries**: smaller rivers that flow into a larger river
   c. **Headwaters**: the beginning of the river
   d. **Mouth**: where it empties into the ocean, often surrounded by sandy shores (beaches)

4) Ask students: Is our school located in the headwaters, along the main stem, along a tributary, at the mouth?

5) Have students identify the main human communities (i.e. cities) in the watershed.

6) Have students identify any MPAs within your watershed or into which

your watershed empties.

7) If your school is not located in the same watershed where you will be holding your cleanup, also have students map that watershed and make sure to identify the beach where you will be.

8) Ask students to think about the following questions: How might people affect the ecosystems and wildlife within the watershed? Sandy shores tend to accumulate trash more so than some other parts of the watershed – why might this be?

Activity: Watershed in a Pan

In this activity students will use science and engineering to design and construct a watershed model that effectively protects human communities while reducing pollution of the watershed and marine protected areas downstream. It is recommended that this activity take place outside where students may dig in the dirt. The Carlsbad Watershed will be used in the example below.

9) Divide students into research teams of approximately four people. They will stay in these teams for the remainder of the lesson.

10) Each group will need:

a. One paint tray (preferably metal and reusable)
b. Enough sponges or scraps of towel to fill width of paint tray
c. Monopoly houses (3-10 per group usually works well)
d. Water
e. Natural materials such as dirt, rocks, sticks, leaves
f. Plastic, paper, and other tiny scraps to simulate litter
g. Vegetable oil to simulate motor oil
h. Food coloring to represent other pollution

11) In the classroom explain the following:

a. Each research group will be building a model of their watershed. The model should be of the watershed which includes the sandy beach where you will do your clean up.

b. The deep end of the paint tray, where the paint would normally go, represents the MPA. For the Carlsbad Watershed this would represent Swami's State Marine Reserve.

c. The sponges or scraps of towel will be used to separate the paint well (the MPA) from the rest of the tray. This represents the wetland separating the rest of the watershed from the ocean. In the Carlsbad Watershed this is the San Elijo Lagoon State Marine Conservation Area (also an MPA!).

d. Once outside students will use natural materials (i.e. dirt, rocks, sticks, leaves) to fill in the remaining part of their paint tray. Students must also place at least three houses in their watershed. They may place more if desired. Have each research team discuss a strategy and draw out a plan before leaving the classroom

12) Take students into the field. Give them boundaries and instructions on which plants not to pick and then tell them to begin building their watersheds. This typically takes about 20 minutes for the first round.

13) Once teams finish building their watershed models call them all

- *Tributaries (watershed)*: smaller rivers that flow into a larger river.
- *Headwaters (watershed)*: the beginning of the river.
- *Mouth (watershed)*: where it empties into the ocean, often surrounded by sandy shores (beaches).

California Department of Fish and Wildlife Key Messages:

-MPAs protect the natural diversity and abundance of marine life, and the structure, function, and integrity of marine ecosystems.
-MPAs help sustain, conserve, and protect marine life populations, including those of economic value, and rebuild those that are depleted.
-MPAs improve recreational, educational, and study opportunities provided by marine ecosystems that are subject to minimal human disturbance, and manage

together and complete the following:

a. Fill the paint well with enough water to get the sponges/towels just a little wet. Remind them that this represents the wetland and MPA.

b. Ask students if humans put anything in to the environment. If so, what? (Common answers, trash/litter, pollution, etc.)

c. Tell students you will be representing pollution using scraps of paper and plastic for litter, vegetable oil for motor oil, and food dye for other pollution. Have students sprinkle the paper and plastic scraps around the houses. Pour about one capful of vegetable oil around the houses. Place five drops of food dye in front of each house. Note: you can add more types of pollution if you wish. Examples include chocolate sprinkles for dog poop, coffee grounds for top soil, etc.

d. Make it rain! Using a watering can (or bottles of water) pour water along the topmost part

of the watershed model. Pour in just enough that the water saturates the soil and runs through the watershed, but not enough to completely submerge everything in the model.

e. Have students evaluate how their model did. Did all the houses survive? Did any of the pollution make it to the wetland? The ocean? Where did each type of pollution accumulate? Did what happened upstream impact the sandy shore? How so? Did what happened upstream impact the MPA(s)? How so?

Suggested procedure:

Teacher Prep

1) Read pages 26-29 of Ocean Conservancy and NOAA Marine Debris' Talking Trash and Taking Action Instructor's Guide.

2) Gather clean up materials

   a. Trash bag or bucket (one per group)
   b. Gloves (two per person)
   c. Trash pickers (if available)
   d. Clipboard (one per group)
   e. Talking Trash data sheet (one per group)
   f. Pen or pencil

3) It is recommended that you visit the site ahead of time to determine meeting locations, boundaries, and meet with lifeguards to discuss clean up plan if possible.

Student Prep

1) In class go over MPAs,….to be filled in from field guide once it's done

Field Trip *(recommended 1.5-2 hours in the field)*

1) This activity could take place at any beach open to the public. We recommend Cardiff State Beach within the Swami's State Marine Conservation Area.

2) For this activity students will be working in their small research teams from the previous activity.

these uses in a manner consistent with protecting biodiversity.
-MPAs protect marine natural heritage, including protection of representative and unique marine life habitats in California waters for their intrinsic values.

Connections:
Art, science, engineering

Ocean Literacy Connection:
-The ocean supports a great diversity of life and ecosystems.
-The ocean and humans are inextricably interconnected.

Suggested extensions:
-Omit the field trip portion and substitute a clean up of a more local waterway (i.e. riverbank, lake or reservoir) or even a cleanup in your own schoolyard. If doing a cleanup in the schoolyard note proximity to any drains

3) Go over safety items:

a. Boundaries

b. Meeting spot for emergencies (make sure to leave a chaperone at the meeting spot at all times) and at end of project

c. End time

d. Stay in groups

e. Wear gloves

f. Do not touch sharp or hazardous material; alert adult of dangerous item(s)

g. Always watch the tide

4) Give each team:

a. Trash bag or bucket (one per group)

b. Gloves (two per person)

c. Trash pickers (if available)

d. Clipboard (one per group)

e. Talking Trash data sheet (one per group)

f. Pen or pencil

5) Take a before photo of your group and the beach!

6) Give students instructions for clean up

a. Follow all safety instructions

b. Pick up any trash and debris, record it on the data sheet (instruct students to use tick marks, words like "lots" and "many" are not useful for analysis), and put it in the bag (make sure to wear gloves whenever handling trash!)

c. Take pictures of interesting finds!

d. Record any animals you see on the back of the datasheet. Note if they are interacting with the marine debris in any way.

e. Return full bags to the meeting spot.

f. At the designated stop time collect all bags and weigh them if possible. Fish scales work well for this, if you do not have a fish scale assume 15lb per standard trash bag.

g. Collect all data sheets. Make sure students record how many people worked on each sheet.

h. Take an after picture with students, all their trash, and the clean beach!

i. E-mail completed data sheets to cleanup@oceanconservancy.org

More instructions and tips may be found on pages 26-29 of Ocean Conservancy and NOAA Marine Debris' Talking Trash and Taking Action Instructor's Guide.

Supplemental resources for Talking Trash and Taking Action may be found at: https://oceanconservancy.org/trash-free-seas/outreach-education/

and discuss where drains go. Data analysis may be done of the data students collect, just make sure to tie it in to the sandy shore by asking questions such as "If we had not picked this up, where might it have ended up?" "Is it possible that the items you found would have ü ended up at the beach?"

-Have students collect trash from two sites (i.e. near river mouth away from river mouth, high tide line vs water's edge, etc.) and compare quantity and origin of trash between sites.

-Create an Excel file with your findings and complete Parts 2 and 3 of this lesson plan on a computer.

-Mix and match the six lessons and various activities in Life in the Sand: Field Guide to Sandy Shores to meet classroom needs.

-Allow students to conduct a separate inquiry project using the datasets they produce.

PART 2: Data Analysis
(recommended two 50-minute class periods)

Categories of Trash

1) Compile data from all sheets to create a master list of debris found.
2) In small groups have students go over the data and look for ways to categorize where the trash likely came from. For example, beach/shoreline recreation, ocean/waterway activities, smoking-related activities, etc.
3) Come back together as a class and write the students' suggestions on the board. Look for commonalities and discuss to decide on a master list of categories. Any items that do not fit into a logical category may be placed in a category called "Other."
4) Next, have students calculate the percentage of trash that came from each of the categories upon which the group decided. Create a pie chart of this data.

Mean, Median, and Mode

1) Now that we know which proportion of trash is coming from where, it is helpful to know how much trash each category accounts for. We figure this out by calculating the mean, median, and mode for each of the categories.
2) Teacher's choice: Have students calculate the mean, median, and mode for how many pieces of trash were found for each category. You could have each research team do this for their own datasheet or have the class do it together off the master list of debris.
3) Ask students which is more important: the number of items found, the type of debris (i.e. plastic, paper, Styrofoam, etc), the weight?
4) As a fun addition, students may look up the approximate weight of each item to calculate how many pounds they found for each category.

PART 3: Drawing Conclusions
(recommended one to two 50-minute class periods; adapted from 5Gyres Institute Plastic Site Sampling Curriculum)

Class Discussion

Have each research group discuss the following:
1) What do your findings tell us?
a. How did these items get here?
b. Why were they made and what will happen to them?
c. What are potential sources for the items that you found?
d. Were the items found from packaging and do you think this packaging was necessary?
e. What other questions, thoughts, or ideas come up for you?
2) What story do your findings tell? Draw your story on butcher paper and share with the class.
3) What organisms did you observe during your clean up? What were their adaptations for living at a sandy shore?
4) Evidence suggests that MPAs may increase biodiversity and abundance by giving species a safe place to live, grow, and reproduce; however, this

success is threatened by other activities such as marine debris. What are some complementary solutions that may be enacted to help reduce or eliminate the threat of marine debris/pollution to MPAs?

Activity

Distribute a copy of the Protecting Sandy Shores Solutions Worksheet (see appendix) to each student. Have them evaluate how feasible and effective each of the solutions are for protecting sandy shores, especially those in marine protected areas, from pollution. Consider factors such as how well the solution helps prevent the problem, human behavior changes needed, and monetary costs. After evaluating the benefits and the challenges rank the following solutions from least to most effective (8 = least effective and 1 = most effective). You may add solutions if you wish. Be prepared to share your ranking with your class.

Engage: Map your watershed and build a model before heading out into the field.
Explore: Conduct a beach clean up at a local sandy shore.
Explain: Explain possible sources of trash and how we use math to categorize it.
Elaborate: Have students calculate the proportions and averages of where the trash came from.
Evaluate: Ask the students questions relating to what they have learned (more questions may be found in Part 3 of this lesson plan).
Q1: What do your finding tell us?
Q2: What story/stories do your findings tell?
Q3: What organisms did you find at the sandy shore? What were some of their adaptations for living there?
Q4: What are some complementary solutions that may be enacted to help protect MPAs from marine debris/trash?

NGSS Alignment

MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying times and spatial scales.
MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.
MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Science and Engineering Practices

Asking Questions: Ask questions that arise from examining models or a theory to clarify and/or seek additional information to determine relationships, including quantitative relationships between independent and dependent variables, and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the sustainability of a design.
Analyzing and Interpreting Data: Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution, apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data, and evaluate the impact of new data on a working explanation and/or model.
Using Mathematics and Computational Thinking: Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
Constructing Explanations and Designing Solutions: Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Engaging in Argument from Evidence: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence and make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge.

Crosscutting Concepts

Systems and system models: Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Online Resources

Watersheds of San Diego County:
https://www.sandiegocounty.gov/content/sdc/dpw/watersheds/Watersheds.html
Supplemental resources for Talking Trash and Taking Action may be found at:
https://oceanconservancy.org/trash-free-seas/outreach-education/

Appendices

See next page