Fun with Fishes: Making Fish Diversity More Accessible to the Public Using the SIO Marine Vertebrate Collection

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Bridget Altman
Capstone Report

Master of Advanced Studies in Marine Biodiversity and Conservation

Scripps Institution of Oceanography
Center for Marine Biodiversity and Conservation
June 2016

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Research Question and Project Objectives

How can we more effectively use the Marine Vertebrate Collection at Scripps Institution of Oceanography to help the public understand and appreciate the diversity of fishes?

Objectives:

1. Create a lesson plan for Ocean Discovery Institute's 4th grade "Ecosystem Scientist" curriculum that incorporates common estuarine fishes of the San Diego area using specimens from the MVC
2. Create multi-purpose educational fact sheets for common estuarine fishes of San Diego containing lesson plans that can be tailored to grades 3-6
3. Highlight features of the collections through use of poster and video in an up-to-date "exhibit corner" in the collection in Vaughan Hall 225 in order to enhance visitor experience during collection tours.

Background and Purpose:

The importance of fish collections dates back to the early age of exploration. Scientists on expeditions would collect whatever they could and preserve it in whatever they could find, be it rum or wine, for examination and prestige. These early collectors had foresight unbeknownst to even them. They created collections as a way to preserve their wonderment with creatures, and advance the science of their times but they also contributed to future scientists. "Natural history museums are so focused on the future that they have for centuries routinely preserved such specimens to answer questions they didn't yet know how to ask, requiring methodologies that had not yet been invented, to make discoveries that would have been, for the original collectors, inconceivable" (Conniff, 2016).

However, funding curation and protection of these historical treasures is often difficult. The National Science Foundation (NSF) estimates that less than 10% of the 611 polled biological collections receive enough funding from government to remain open without alternate sources of funding (NSF, 2009). Thus it is more critical now than ever to increase awareness about the importance of maintaining these specimens and to inspire the public to continue to support the collections, through government funds as well as private donations.

The Marine Vertebrate Collection (MVC), one of five oceanographic collections at SIO (https://scripps.ucsd.edu/collections), is home to nearly 2 million specimens, representing more

than 6,000 species of fishes. The MVC features special collections of otoliths, skeletal materials and tissue samples for researchers to further advance their science. The mission of the MVC is "To enhance fundamental knowledge and understanding of the fishes of the world", of which outreach is a large component. The MVC regularly lends specimens for use in classroom and other various public presentations. Tours are also given of the collections to private groups upon request (for groups ages 12 and older) as well as a public open house once a year (Scripps Day). In order to maintain the space and care for these specimens, funding is critical. Funding for the collections comes from a suite of institutional funds, donors, foundations and the government. As Scripps Institution of Oceanography (SIO) enjoys an unparalleled worldwide reputation for the quality and importance of its science, it is imperative for the MVC to tangibly document and display its importance to SIO and the worldwide scientific community.

Specimens from oceanographic collections can be used as indicators for the health of our oceans. By examining fish preserved from the past, we can learn about how our planet has changed and is continuing to change. Fish specimens specifically from the SIO MVC have been cited in over 1,200 scientific papers. One example is from the CalCOFI Report in 2000. Dr. Robert Lea and Dr. Richard Rosenblatt compared specimens from the SIO MVC from previous El Niño events (1957-59 and 1982-84) to the 1997-98 event. Due to the presence and absence of certain species, they concluded that the El Niño event of 1997-98 was "perhaps the most dramatic of the twentieth century" (Lea and Rosenblatt, 2000).

Phil Hastings of Scripps Institution of Oceanography (SIO) recently obtained a grant from the National Science Foundation (Division of Biological Infrastructure) to incorporate specimens from the former UCLA fish collection into the Marine Vertebrate Collection (MVC). As a part of the "broader impacts" component of the grant, a portion of these specimens will be used to "significantly expand our outreach activities by developing and implementing curricula on the diversity and ecology of fishes as components within Ocean Discovery Institute's (ODI) educational initiatives (Hastings, 2014)".

Ocean Discovery Institute (ODI) is a San Diego-based non-profit organization that strives to connect the community of City Heights with the ocean environment. Within the confines of the NSF grant "broader impacts" requirement and the needs of Ocean Discovery Institute, I have

incorporated MVC specimens into an effective and impactful addition to the fourth grade curriculum for underserved schools working with ODI.

Fourth grade learning goals for students in San Diego County include understanding why ecosystems are important, and the connections between living-to-living things and connections between living-to-non-living things. To help address this goal, ODI runs a program called "Ecosystem Scientists" for fourth grade students in underserved community schools. In this program, fourth grade classes working with ODI use coastal wetland/estuarine habitats as a model for learning about these ecosystem connections. After discussions with ODI and the MVC staff, I have chosen eight common estuarine and bay species of fishes from San Diego County to help portray various aspects of estuarine ecology. I created a curriculum that incorporates these eight species to reinforce the topics covered in the program. The primary objective of the lesson will be: *To get students to understand the connection between estuarine species and their estuarine habitat.* More specifically, the students should be able to understand (1) how the estuary is crucial to the survival of these species, (2) how the estuary depends on these species, and (3) why the estuary is vital to overall ecosystem health.

The estuarine species from the MVC used in the curriculum are:

1. Leopard Shark (*Triakis semifasciata*)
2. Round Stingray (*Urobatis halleri*)
3. Bay Pipefish (*Syngnathus leptorhyncus*)
4. California Killifish (*Fundulus parvipinnis*)
5. Longjawed Mudsucker (*Gillichthys mirabilis*)
6. California Halibut (*Paralichthys californicus*)
7. Barred Surfperch (*Amphistichus argenteus*)
8. Striped Mullet (*Mugil cephalus*)

I have also created fact sheets for the species of each specimen utilized in the curriculum so the instructors will better understand the species in hopes of answering any student questions that may arise. In conjunction with the specimen fact sheets, I developed an adaptable additional activity revolving around the life history of the respective species or a relevant overarching environmental topic.

In addition to incorporating estuarine fish specimens into a fourth grade program for Ocean

Discovery Institute, I worked to improve in-house outreach efforts by creating promotional materials and engaging displays for the MVC. Public outreach is the thread that ties this project together. These objectives help promote a greater overall understanding of the diversity of fishes and their importance in our world.

Methods

Ocean Discovery Institute*:* In collaboration with Ocean Discovery Institute, I created a lesson plan and "outreach kit" containing preserved specimens in jars from the MVC. The lesson is called "Wetland Ecology Explorers" (Appendix A). The "outreach kits" include instructions for the teachers and worksheets for the students (Appendix B). The kits also have an absorbent yellow mat and instructions on what do should a spill occur.

I created a series of fact sheets for the instructors, using a combination of Adobe Illustrator and Microsoft Publisher, with life history information regarding each species used for the activity. These fact sheets also contain additional activities for teachers to use in their class or afterschool program regarding topics other than wetland ecology (Appendix C). The difficulty of each additional lesson can be tailored to fit the Next Generation Science Standards of grades 3-6 (NGSS, 2015).

Each represented species features a characteristic that relates to the main theme of Ocean Discovery Institute's Fourth Grade Ecosystem Scientist Program: connections of living to living things and connections of living to non-living things. The characteristics showcased by species based on the lesson are:

1. Utilizing the wetland as a shelter (nursery) for young
    a. Leopard shark (*Triakis semifasciata*)
    b. Barred Surfperch (*Amphistichus argenteus*)
2. Crypsis in the environment for protection from predators
    a. Bay Pipefish (*Syngnathus leptorhyncus*)
    b. California Halibut (*Paralichthys californicus*)
    c. Round Stingray (*Urobatis halleri*)
3. Burrowing in the substrate for protection from predators
    a. Longjawed Mud-sucker (*Gillichthys mirabilis*)
4. Using large fins to help swim faster (and discuss acting as a decomposer by eating dead organic matter)
    a. Striped Mullet (*Mugil cephalus)*
5. Providing a food source for other species (seabirds)

a. California Killifish (*Fundulus parvipinnis*)

***Marine Vertebrate Collection**:*
In efforts to make the inside of the MVC more engaging, I created a budget plan for additions to the collections. The budget request was submitted to the head curator as follows:

Item	Use	Link	Cost
Smart TV w/USB Port. 32 inch or 42 inch recommended.	• Replaces construction paper fish posters. • Allows easy streaming of PowerPoints and videos during tours.	http://www.bestbuy.com/site/searchpage.jsp?id=pcat17071&st=42+inch+flat+screen+tv	$250-$350 for 42 inch
Poster displaying highlights of collection (inside collection room to replace fading/torn poster)	• Showcases some cool facts about the collections. • Incorporates the map and records held by the MVC in a colorful/concise way.	N/A	Just the cost of printing. Approx. $20.
Total Estimated Cost			$270- $370

A Samsung 45 inch TV was purchased and mounted on the wall in the collections. The poster (Appendix D) will be printed and hung on an adjacent wall.

Public outreach materials for the MVC were created using a combination of Adobe Photoshop, Adobe Illustrator, Microsoft PowerPoint, iMovie and Venngage (infographic design program). Videos were recorded of the curators of the MVC and the physical space of the collection itself using a high quality video camera on loan from the Center for Marine Biodiversity and Conservation (CMBC). The posters will be displayed in the foyer leading to the MVC and in the "Exhibit corner" of the collection. The videos will be played on the television monitor mounted in the "Exhibit corner" and available online via YouTube for general public viewing.

In addition to the video featuring of highlights of the MVC, I created a PowerPoint presentation to be played during tours on the television inside the collections. The video features slides of colorful images and/or GIFs of live fish that are frequently discussed during the tours. Fish shown in the presentation include: Leafy Seadragon (*Phycodurus eques*), Whale Shark (*Rhincodon typus*), Garibaldi (*Hypsypops rubicundus*), Flying Fish (Exocetidae), Blobfish (*Psychrolutes* sp.), Goblin Shark (*Mitsukurina owstoni*), Blackbelly Lanternshark (*Etmopterus lucifer*), Myctophidae and *Cylothone* spp., Anglerfish (Lophiiformes), Torpedo Ray (*Diplobatis*

ommata), California Halibut (*Paralichthys californicus*), Hatchetfish (Sternoptychidae), Fangtooth (*Anoplogaster cornuta*), Remora (Echeneidae), Dragonfish (*Stomiiformes* spp.), Barreleye (*Macropinna microrostoma*), Sarcastic Fringehead (*Neoclinus blanchardi*), Blue Tang (*Paracanthurus hepatus*), Cookie Cutter Shark (*Isistius brasiliensis*), Scythe Butterflyfish (*Chaetodon falcifer*), Stonefish (*Synaceja verrucosa*), Umbrella Mouth Gulper Eel (*Eurypharynx pelicanoides*). All images used were taken from WikiMedia Commons (commons.wikimedia.org), Arkive (arkive.org), Giphy (giphy.com), or with the permission from the owner. In the future, it is easy to add new fishes to the presentation since the template is purposefully simple to replicate. Fish species can be added to or removed from the presentation as the tour guide sees fit.

Discussion

On May 25th, 2016 I took specimens of these eight species to a 4th grade classroom at Joyner Elementary School. The class had 36 students, all of whom had already participated in the 4th grade "Ecosystem Scientist" curriculum, assuring they had the prior knowledge necessary for the "Wetland Ecology Explorer" lesson. These students had already visited Emery Cove Wetland in San Diego. The "Wetland Ecology Explorer" lesson builds upon their understanding of the connections between living and non-living factors of a wetland ecosystem as well as the importance of wetlands.

The students answered the questions on the worksheet with the correct answer (Appendix B). They were engaged, as measured by observing them actively participating and answering oral questions. They were able to answer the final assessment question correctly, thus proving the lesson successful. As a result of the success of the "Wetland Ecology Explorer" lesson, this lesson plan will be incorporated into ODI's "Ecosystem Scientist" curriculum for 2017.

I piloted the "We're Gonna Need A Bigger Boat" lesson from the Leopard Shark fact sheet (p. 26) at a conference at the Ocean Institute in Dana Point for Middle School girls interested in ocean science on February 20, 2016. The point of this lesson is to broaden the student's idea of what a shark is and expose them to different adaptations sharks have for their environment. The students created their own shark with a unique set of adaptations and placed it in an environment where it would have the highest chance of survival. They labeled the features on the shark and explain why it lives in the habitat they choose. The girls came up with the most creative

adaptations for sharks to survive in various habitats. One example of a shark invented by the students was a “deep-sea shark” called the “glowing grip shark”. She explained that in the deep sea, light was limited and so is food so her shark has special adaptations to glow in the dark and find food. It was fun and educational; the ideal kind of lesson!

The video created to promote the highlights of the MVC is being played on loop on the television mounted in Vaughn Hall 225 in order to provide context for visitors walking through the collection. The PowerPoint presentation will be used for public tours, such as Scripps Day, in order to display colored images and videos of respective fish specimens discussed in the tour.

Limitations

Time is a major limitation. With more time, I could have created additional species fact sheets, as well as more promotional materials. Working within the confines of ODI’s fourth grade curriculum (as per the NSF grant) was also limiting in the content I was able to successfully implement at this time. I would have liked to create lesson plans around more than just wetland habitats, however, I am grateful for the opportunity to work with the amazing ODI organization!

Technology was another limitation. I had to teach myself Adobe PhotoShop, Adobe Illustrator and how to become savvier with iMovie software. My graphic design skills have drastically improved as a result of trial error over the course of this project. I would have also liked to have created a promotional supplementary website for the MVC if I had the HTML coding skills necessary.

Potential Expansions

If there were more time to complete this capstone project, I would have loved to create a virtual tour of the diversity of fishes housed within the MVC. I had hoped to create a visually appealing graphic of a tree that one can click through to see all of the included groups in phylogenetic sequence. The plan was to start with representative orders and families within the Chondricthyes (cartilaginous fishes) that includes 14 orders and over 1,200 species of chimaeras, sharks and rays. A script needs to be created for each of the orders and representative families. These clips could then be streamed together to create the informational part of the virtual tour that a user can click on to learn about the various groups of cartilaginous fishes. This evolutionary tree approach will paint a clear picture of how various important traits have evolved within these fishes over

millions of years. Additionally, this also provides a nice setup for the completion of the remaining lineages of fishes housed within the MVC at SIO after the time for my project has ended and would serve as a model for expansion to other groups of fishes as time allows.

Acknowledgements:
Thanks to my chair Phil Hastings for the opportunity to work on this project and for all of the hours spent helping me develop this into all it could be. Thanks to H.J. Walker, Ben Frable and the entire Marine Vertebrate Collection staff for the continuous help every step of the way, and for always letting me geek out about your sharks. Special thanks for Rochelle Mothokakobo for her constant support and advice regarding the curriculum creation. Thanks to Ocean Discovery Institute for the opportunity to create a lesson plan that can be put to use to help enhance the understanding of marine science in San Diego youths. Thanks to Oriana Poindexter, Dan Conley, Garfield Kwan, and Noah Ben-Aderet. Thanks to Phaedra Doukakis, Jane Weinzierl, Penny Dockry, Dick Norris, Greg Rouse, and the CMBC community. Finally, thanks to the entire MAS-MBC class of 2016 for all of the love and friendship, without which I would not have completed this project.

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Website Resources:

Arkive www.arkive.org

Giphy www.giphy.com

Ocean Discovery Institute. www.oceandiscoveryinstitute.org

Ocean Literacy Network. http://oceanliteracy.wp2.coexploration.org

SIO Marine Vertebrates Collection**.** https://scripps.ucsd.edu/collections/mv

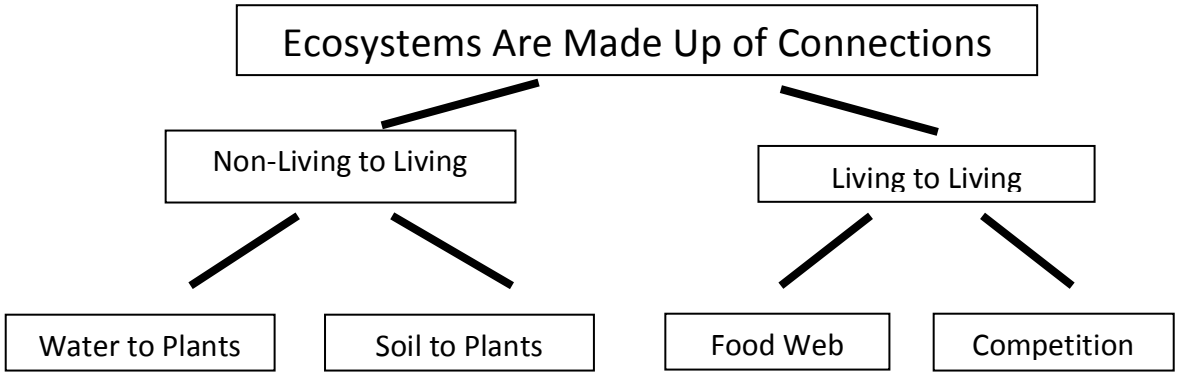
Sharks 4 Kids. http://sharks4kids.com

WikiMedia Commons. www.commons.wikimedia.org

Appendix A. Lesson Plan for Ocean Discovery Institute's 4th Grade Ecosystem Scientist Curriculum. Wetland Ecosystem Explorers

Lesson 3: Wetland Ecology Explorers

Concept Map:



Goal: Students will understand the connection between estuarine species and their estuarine habitat.

Objectives:

- Students can list three parts of a wetland
- Students can name three species in San Diego that rely on wetlands
- Students can list three examples of why wetlands are crucial to the survival of these species.

CA State Standards:

2. B. Students know producers and consumers (herbivore, carnivores, omnivores, and decomposers) are related in food chains and food webs and may compete with each other for resources in an ecosystem.

CA NGSS:

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

LS1.A: Structure and Function

Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction. Each structure has specific functions within its associated system. [Assessment Boundary: Assessment is limited to macroscopic structures within plant and animal systems.]

LS1-2. Systems and System Models

A system can be described in terms of its components and their interactions.

National Standards:

Science as Inquiry, Content Standard A: Understanding about scientific inquiry.
Life Science, Content Standard C: The characteristics of organisms.
Life Science, Content Standard C: Organisms and environments.

Supplies:
Materials:

- Science Notebook worksheets (1 per student)
- Clipboards (1 per student)
- Specimen jars (8 species, 1 jar per species)
- Spill kit with instructions (3 per classroom) (train staff on using kits)
- Pencils (1 per student)
- Instructor notes/fact sheets for each species
- Green ribbon placed in a clear container (quart size) with water to simulate eelgrass in a wetland

Visuals:

- Concept map w/ Velcro tabs
- Mudflat poster
- Tidal Channel poster
- Eelgrass Bed poster
- 3 parts of the wetland poster

Set-up:

- Hang tidal channel, mudflat, and eelgrass bed poster in three different corners of the room
- Place the specimen jars on desks or tables near the associated posters (see instructor notes for help)
- Science Notebook pages: pass out and explain science notebook pages.

Introduction (10 minutes):

- Good morning, Scientists! We are going to talk about three areas of the wetland you will be exploring today. Then you will go and take a look at some actual fish specimens in each of these parts of the wetland. So follow along carefully!
- Today, we will become a certain type of ecosystem scientist called wetland ecologists. Who knows what ecologists study? Ecologists study ECOSYSTEMS!
- Raise your hand if you remember what an ecosystem is. Good. An ecosystem is the connections between living and non-living things in a specific area. (Place "living to living" and "living to non-living" on concept map).
- And wetland ecologists study wetland ecosystems! (Write on board "Wetland Ecologist= studies wetland ecosystems").
- Who has been to a wetland? Great! So what is a Wetland? Does anyone remember? *A wetland is an area where water and land meet*. Exactly! A wetland is an area where land and water meet, an example is when an ocean meets a river or stream on land.

- Do you think all of these connections we just talked about are in a wetland? *YES*
- Remember our list of non-living things in an ecosystem from last week. These are important for figuring out where different species can live. Ecologists can look at the non-living things in an ecosystem to help determine what species live in that ecosystem. Today that is what we are going to do! Now we are going to take a look at three different areas of the wetland that we didn't get to see at Emery Cove because they are under water!
- We are going to explore these three parts of a wetland (Instructor hangs up 3 Parts of a Wetland Poster): Mudflats, Tidal Channels and Eelgrass beds. By the end of the lesson, you guys are going to be able to tell me what lives in each of these habitats and why!
- Eelgrass is a type of plant that grows in really big areas and becomes home to lots of wildlife (hold up ribbon to simulate eelgrass). An eelgrass bed is like a grassy meadow on land but it is in the wetland. I'm going to place this jar of "eelgrass" next to the specimens in the eelgrass corner. Have a look at it up close, it's not real eelgrass but it is a great example of what it looks like in the wetlands!
- Mudflats are areas in the wetland where waves and tides have created a thick blanket of mud on the floor of the wetland, making a cozy home for many species. Just like when we snuggle up under our blankets at night, some fish hide under the mud for protection. Or use their camouflage to blend in!
- Tidal channels are areas in the wetland that change water depth based on the tides. At high tide, the tidal channel is deeper, and at low tide, the channel is shallower.
- In just a minute, we are going to start our scientific explorations and send you to your first part of the wetland. You will have the chance to visit all three parts of the wetland.
- In the field, scientists make lots of observations that help them make hypotheses. What is a hypothesis? A hypothesis is an educated guess based on scientific information you already have. We are going to take a look at specimens and make our own observations and hypotheses about why these species live in the wetland. At each station, you are going to pick one of the specimens and describe it. You should draw it with as much detail as you can! The more detailed your drawing is, the more it will help you make your hypotheses later on. Be sure to fill out all of the questions in your Science Notebook Worksheet for each part of the wetland you visit.
- As wetland ecologists, we will be thinking about what makes a wetland so important to many types of fish that live in San Diego. As we work, we will be making hypotheses about what makes these fish so perfectly adapted to live in these habitats. After we have made all of our hypotheses, we will all come back to this circle and talk about our hypotheses to see if they are correct.
- (Instructor sends the students to each of the three areas, asks them to PLEASE not touch anything until they receive further instructions) There are fragile specimens in special jars at each station so please don't touch them until we tell you how to handle the jars.
- At your station you should see two or three jars, each containing a different species of fish that calls this wetland habitat home. These animals are preserved in jars so

scientists can study them over time. They were collected by our friends at Scripps Institution of Oceanography and are now kept in the museum there. They have loaned us these specimens, trusting that we will treat them with respect. These animals are preserved in a solution of alcohol and water that helps keep their physical features in tact so we can observe them. The solution is harmful to drink and touch, so we are going to leave these jars closed with the lids taped on. We are going to treat these specimens with the most care possible, hold them with TWO hands and observe the jars while they are placed on the desk. Even though they are dead, we are going to treat them with care since they are used for science! Take turns looking at each specimen at your station. I want to make sure that each of you gets to see each and every specimen so you can make the most accurate hypotheses possible.

- (Hand out clipboards with the Science Notebook)
- If you all can look at the top of your Science Notebook Worksheet, you will see today's learning goal. Raise your hand if you'd like to read the learning goal for me! *Learning goal: To understand the connection between wetland species and wetlands.*
- Awesome! Now, who would like to read me the focus question below the learning goal? *What are thee parts of the wetland, and why do different species of fish live in each of these parts?*
- Now you are going to get to pick one of the specimens at each station and work in groups of three and four to make your scientific observations! In your Scientific Notebook Worksheet, turn to the page where you see the questions for the station where you are now. Take 10 minutes to make your observations and answer these questions. Write down the answers in as much detail as you can to help you with your hypotheses! Now these tables are going to go start at the mudflat station, these tables are going to start at the eelgrass station, and these tables are going to start at the tidal channel station. Remember you will get to see all three stations, so don't rush through the activity, really think about the species you see in this first part of the wetland!

<u>Activity</u>:

First Station (10 minutes)

Guided questions for Mudflat-

- [Wait ten minutes. During this time, walk around and help students. Make sure they are paying attention to the activity.]
- This fish is called a mudsucker! They use their big mouths to scoop up mud. Why do you think the mudsucker scoops up mud?
- This is a halibut. Halibuts are really flat and have this speckled brown pattern. Why do you think this fish is flat and speckled?
- Now based on what you see from the specimens and what you know about the area, make your hypotheses about why the specimens at your station live in the habitat of your station! Think about the physical features of your habitats and what makes the species at your station unique. Pay attention and make sure you mark your hypotheses in the correct habitat. We'll go over these hypotheses at the end of the class.
- Now we are going to rotate to the next station. Everybody, move to the next station!

Second Station (10 minutes)
Guided questions for Eelgrass Beds-

- [Do the same thing again]
- This fish is called a pipefish. It's like a seahorse but with a straight tail instead of a curled tail. Think about what the eelgrass looks like (point to jar with eelgrass) when thinking about why the pipefish lives here.
- This is a leopard shark. Do you think little leopard sharks or big leopard sharks live here? Think back to Emery cove and the uses of the wetland "Rock-a-bye Fishie…"
- Now lets rotate to our last station!

Third Station (10 minutes)
Guided questions for Tidal Channels-

- This is the hardest station. And it's a really tough environment for animals to live.
- mullet is a tough one to figure out. Look at where the fins are. The fins on the underside are really small so it can move around the shallow water really easily! So body shape can really tell you a lot about where an animal can live!
- Something you might not be able to see but you should know is that the mullet is a really important species because of its diet. Instead of eating smaller fish or eelgrass, the mullet's favorite food is dead organic material. Does anyone remember what an animal that eats dead organic material is is called? *Decomposers!*
- Barred Surfperch is a fish that actually gives birth to live young! Why do you think the tidal channel is a good place for these fish to give birth? *Because some big fish would have a hard time surviving in such shallow water!*
- California Killifish are really small. What might some challenges be of being small? Do you think they are at the top or bottom of the food chain?

Wrap-Up (10 minutes)

- To wrap up, I need all of you scientists together in the center of the room.
- Did everyone get to make hypotheses at all three stations? Great!
- Let's start in the Mudflats. What species did you see in the mudflats? *I saw a Halibut and a Mudsucker*. Great! What do you think makes these species adapted for the mudflats? What hypotheses did you come up with for the mudflat species? *Camouflage and burrowing!* Good job! How many of you also mentioned Camouflage? *Students raise hands.* Why did you choose camouflage? *Because the flat body and the pattern of the Halibut makes it easy to blend in with the muddy bottom in the mudflats!*
- What are some other hypotheses? Did anyone mention burrowing? Why are these burrowing fish perfect for living in the mudflats? *Because it has a big head that can stick up from the sand. Its fins are like hands keeping its head propped up from the mud.* Awesome.
- Now lets move to the Tidal Channels. Why do you think the Mullet is in the Tidal Channels? (This is a tough one, so ask this prompting question…)Who can remind me what a decomposer is? Decomposers eat the dead organic material in the environment and turn it into raw materials. What was an example of a decomposer

we saw from a few weeks ago in class? *The earthworm!* Right! And why are decomposers important? Because without those decomposers there might not be an ecosystem because the decomposer recycles all the raw materials that an ecosystem needs to thrive. Mullets are the decomposers of the wetland, so they are very important fish to the wetland. Just like the earthworms are important on land!

- What about the Surfperch? Remember from our trip to the wetland that estuaries can be "Fish Nurseries?" Well the Surfperch is so small that it uses the Tidal Channels as a safe haven to raise their young since larger marine predators have a hard time accessing the Tidal Channels.
- Like the Surfperch, what else did you see in the Tidal Channels that are small? *Killifish!* That's right, the Killifish. The importance of the killifish actually has something to do with other species that feed on them. Lets think about food webs again. What do you think eats fish in a wetland? *Birds!* That's right, the wetland is like a "Bird Motel and Restaurant!" And the killifish is the birds' most favorite food.
- Now lets talk about the Eelgrass Beds. Why do you think a fish that is long and skinny like the Pipefish would live in the Eelgrass Beds? *Camouflage!* Exactly! Its unique body shape makes it perfect for hiding in all of the eelgrass.
- What about a Leopard Shark? What hypotheses did you come up with for why leopard sharks are in Eelgrass Beds? *Because it is the perfect place for baby leopard sharks to grow up without bigger things trying to eat it.* That's right! All of the eelgrass makes perfect hiding spots for baby leopard sharks.

Conclusion (10 minutes)

- Okay so lets take a look at one last species together (Assistant helps pass around last jar, the Stingray).
- As (Assistant Instructor) is passing around the stingray, look at the flat shape of its round body. Think about what else we saw that was flat and why that was helpful. The stingray also has a cool adaptation to defend itself against predators. Does anyone know what it is? *It's stinging tail!* Yes! Take a look at its tail. There is a venomous barb on its tail that it uses to defend itself from things trying to eat it. The stingray hides in sand or mud and sticks up its tail as defense. Awesome!!
- Has everyone gotten a chance to see the stingray? *Yes.*
- Thinking about its shape and the characteristics we talked about and you just saw, what part of the wetland do you think the stingray lives in? *Mudflats!* Wow! Correct, the stingray lives in the mudflats!! You guys are such amazing adaptation detectives! So what are some other reasons why it is important to keep the estuaries clean and protect these habitats? *Because lots of fish call them home, because other organisms rely on these species for food, because it helps stop erosion "dirt, don't enter!"*
- You've become experts on thinking about how a fish's habitat is made perfect for that fish. We'll see you next week to continue learning about ecosystems!

Summary:

The "Wetland Ecologist Explorers" activity gets students to understand the link between physical features of fish and their habitat. Students will "explore" three different parts of a wetland: **Tidal Channels, Mudflat, and Eelgrass Beds**. Using **specimens** from the Scripps

Institution of Oceanography's Marine Vertebrate Collections, students will examine the specimens and make **hypotheses** about why they think each specimen lives in its representative habitat based on its physical features. Students will get to examine the specimens in jars placed near a poster of the representative wetland area. Each poster will display a color image of a living fish matching up with the species represented by the specimens. Students will draw observations and write down inferences about these species. The instructor will lead a concluding discussion about how each of these species rely on the wetland for survival and ask students to recall the overall importance of **wetland conservation**. By the end of the lesson, the students should be able to explain that physical features of species can be **adaptations** to their environment and give clues to what types of environment that species should call home

Key Words: Tidal Channels, Mudflats, Eelgrass Beds, Adaptations, Wetland Conservation, Specimens, Hypothesis

Appendix B. Student Worksheet for Ocean Discovery Institute's 4th Grade Ecosystem Scientist Curriculum.

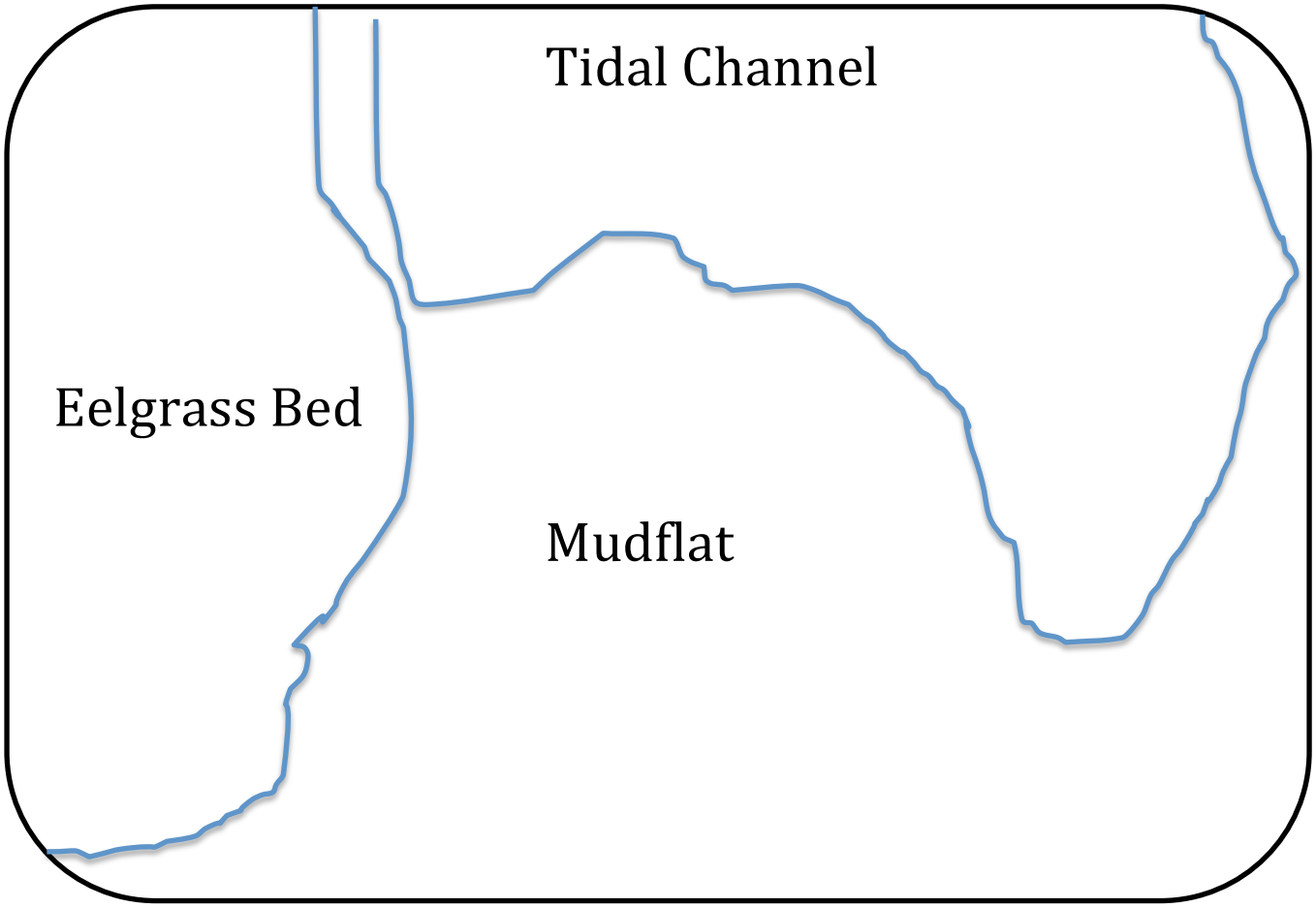
Become a Wetland Ecologist!

Learning Goal: To understand the connection between wetland species and wetlands

Focus Questions: What are three parts of the wetland, and why do different species of fish live in each of these parts?

Draw a wetland, complete the map!

Here, you are going to complete the drawing of the three parts of the wetland. Be sure to draw and label the non-living and living factors that belong in each section of the wetland! Use the features from the word bank we created together on the SmartBoard.



Let's make scientific observations about these three parts of the wetland:

Eelgrass Bed

Draw a picture of one of the species that lives in the Eelgrass Beds

Write down observations about this species. Describe it using 2 full sentences.

1._____
_____
_____

2._____
_____
_____

Write down 2 *hypotheses* about why the species at this station live in this habitat.

1._____
_____
_____

2._____
_____
_____

Mudflats

Draw a picture of one of the species that lives in the Mudflats

Write down observations about this species. Describe it using 2 full sentences.

1._____
_____
_____

2._____
_____
_____

Write down 2 *hypotheses* about why the species at this station live in this habitat.

1._____
_____
_____

2._____
_____
_____

Tidal Channels

Draw a picture of one of the species that lives in the Tidal Channels

Write down observations about this species. Describe it using 2 full sentences.

1._____
_____
_____

2._____
_____
_____

Write down 2 *hypotheses* about why the species at this station live in this habitat.

1._____
_____
_____

2._____
_____
_____

Make your hypothesis about the Round Stingray!

Conclusion Question:
If the Round Stingray camouflages in the environment for protection from predators, and has a round, flat and mud-like coloration, then the Round Stingray must live in the _____.

Bay Pipefish (*Syngnathus leptorhynchus*)

Habitat: Bay Pipefish live in eelgrass beds in bays and estuaries for their entire lives.

Feeding and Diet:
They create a vacuum inside their mouth through which their prey is automatically sucked inside. They feed on small crustaceans like copepods, amphipods and shrimp.

Miscellaneous: Females transfer embryos to the males to carry the babies in brood pouches. Females are larger than males. They have a short life span, usually not lasting more than two years. They are able to withstand a range of freshwater and marine conditions.

(Love, 2011)

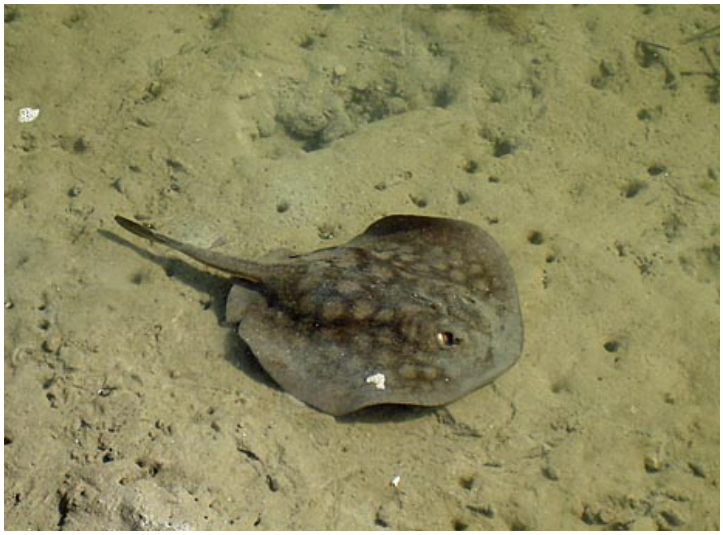
Activity: *I Spy, Estuary Edition*

Have buckets with a lot of eelgrass (green ribbon) and hide toothpicks (representing pipefish) in the eelgrass. Have another bucket with less eelgrass and some plastic pollution (straws) and some toothpicks. Have a third bucket with no eelgrass and only toothpicks and straws. Break class into three teams. Time teams for how fast they pick out the toothpicks representing the pipefish in each bucket. Have each team pretend to be a predator of the pipefish: a Smoothhound Shark, a Spotted Sand Bass, or an Elegant Tern. Colored toothpicks can add another degree of challenge to this activity.

Take away message:

The eelgrass provides a perfect habitat for the pipefish to camouflage and hide. Polluting the eelgrass beds removes opportunities for the pipefish to protect itself from predators. It is important for the survival of pipefish that the bays and estuaries remain clean. The more eelgrass, the happier the pipefish! If different colored toothpicks are used in this activity, it can be a great opportunity to discuss camouflage (crypsis).

Round Stingray (*Urobatis halleri)*



Habitat: Round Stingrays are bottom-dwellers. They are found on soft-bottomed substrate like mudflats or sandy bottoms.

Feeding and Diet:
They find their food by flapping their wing-like pectoral fins, clearing sediment underneath the ray and exposing their prey. They feed primarily on crustaceans, small fish, clams and sea cucumbers.

Life History: They are born on sandy bottoms in shallow, quiet water. They can live up to 14 years. Round stingrays give birth to live young but rely on a yolk sack rather than a placenta, like some sharks. Before they are born, the embryos turn their tails so their stinging spines do not harm the mother. A population numbering 280,000 of these round rays lives year round in San Diego Bay (Allen, 2002).

(Love, 2011)

Activity: *Stingray Shuffle*
Have students stand up and shuffle their feet across the room, pretending to kick up mud and sand to let the stingray know a human has entered its home. Play a fun dance song of teacher's choice while students are shuffling along.

Take away message:
Stingrays have a venomous barb near the end of their tails to defend against a predator. To avoid stepping on a stingray and getting stung, which is very painful, you can shuffle your feet when you are in shallow, coastal, murky waters. By shuffling your feet, the stingray will swim away from you and nobody will be hurt (you or the animal!)

Leopard Shark (*Triakis semifasciata)*

Habitat: Leopard sharks are nearshore (coastal) shark born in calm, shallow bays: mudflats or eelgrass beds. The adults are found over sand, mud, mixed rocky

Feeding and Diet:
Leopard sharks are small mouthed bottom dwellers that feed on crabs, fish, fish eggs, squid and octopuses. They have reportedly been eaten by Broadnose Sevengill Sharks, and even California Sea Lions. (Love, 2011)

Miscellaneous: Every year predominantly pregnant females gather en masse on La Jolla Shores in the summer to rest and take advantage of the warm water (Nosal, 2014). They are thought to live up to 26 years. Nobody has ever been killed by a Leopard Shark!

Activity: You're Gonna Need a Bigger Boat

Have students create their own shark in a different habitat. Talk about sharks that live in the deep sea and some adaptations these sharks may have, like light organs. Talk about how sharks that live in the open ocean need to be more streamlined to swim faster. Discuss how some sharks live close to shore and feed on the sandy bottoms (like Leopard Sharks and Nurse Sharks). Discuss how some sharks don't even eat fish, but rather eat plankton (Whale Sharks, Basking Sharks and Megamouth Sharks). Have the students work in pairs to draw their own shark based on the habitat where their shark will live. Have them label 3 features on their sharks that act as adaptations to their shark's environment. Be sure to have them write down the diet of their shark.

Take away message:

Sharks are NOT man-eating monsters. Sharks come in all shapes and sizes. Each shark is uniquely adapted to its own environment. See Sharks4Kids.com for additional resources and information regarding the diversity of sharks.

Longjaw Mudsucker (*Gillichthys mirabilis*)

Habitat: They live in burrows that they may excavate with their large mouths. They are found in mudflats of salt marshes, estuaries and mangroves.

Feeding and Diet:
They are generalists that feed on small invertebrates like amphipods and polychaetes as well as crustaceans, tiny fish and even algae.

Miscellaneous: Males flare out their big mouths to defend their territory and win over mates. The males go mouth to mouth, blocking their vision during these fights. The stronger male wins. They only live about two years, and are sexually mature at six months.

(Love, 2011)

Activity: *Scoop, baby, Scoop*
Have three tupperwear containers. Fill each with one of the following: mud, sand, water. Place a plastic spoon by each container. Ask students to take one scoop from each of the containers. The spoon represents the Mudsucker's mouth. Compare what happened in each of the different mediums/substrates. Ask which habitat they think is most suitable for the Mudsucker's permanent home. Emphasize that they are looking to find a PERMANENT burrow.

Take away message:
The mud scoops out to form more long-lasting burrows than the other mediums. Sand and water cave in around a hole whereas mud makes a perfect medium for a permanent burrow.

Barred Surfperch (*Amphistichus argenteus*)

Habitat: Barred Surfperch are schooling fish found within the surf zone out to depths of nearly 40 feet. The newborns are found in shallow waters over sand.

Feeding and Diet:
Their diet primarily consists of sand crabs. However they have been known to eat clam siphons, bits of sea urchins and gooseneck barnacles.

Miscellaneous: They give birth to LIVE YOUNG, between 4-113 at a time! They have internal fertilization where the male inseminates a female by using his swollen anal fins to help insert sperm that the female stores until the eggs are ready to be fertilized (usually in the winter). They live to be at least 9 years old. Females live longer and grow larger than males. (Love, 2011)

Activity: I Will Survive

Give half the class access to a bucket of ping-pong balls and half the class access to a bag of marbles. Give the marble students a spoon. Have students race across the room carrying their "young". The ping-pong ball students can use their hands but they can only carry one ball at a time. The marble students can carry as many marbles as they can fit on their spoon at a time, but they must only use their spoon to transport their marbles. Tally up how many large eggs (ping pong balls) made it versus small eggs (marbles).

Take away message:

There is a trade-off between survivorship in species that lay a lot of small eggs and those that lay fewer large eggs. The percent survivorship of the large eggs is greater than that of the smaller eggs, yet there are fewer large eggs. However, eggs are more plentiful in number.

California Killifish (*Fundulus parvipinnis*)

Habitat: California Killifish are schooling estuarine fish that often live among eelgrass, over mudflats and within shallow tidal

Feeding and Diet:
Feed on small arthropods such as crabs, amphipods, copepods, shrimp, spiders and insects. Lots of birds and other fish rely on killifish for their primary prey.

Miscellaneous: They are a short-lived species, averaging an 18 month lifespan. They lay eggs on the bottom substrate, attached with loosely sticky filaments.

(Love, 2011)

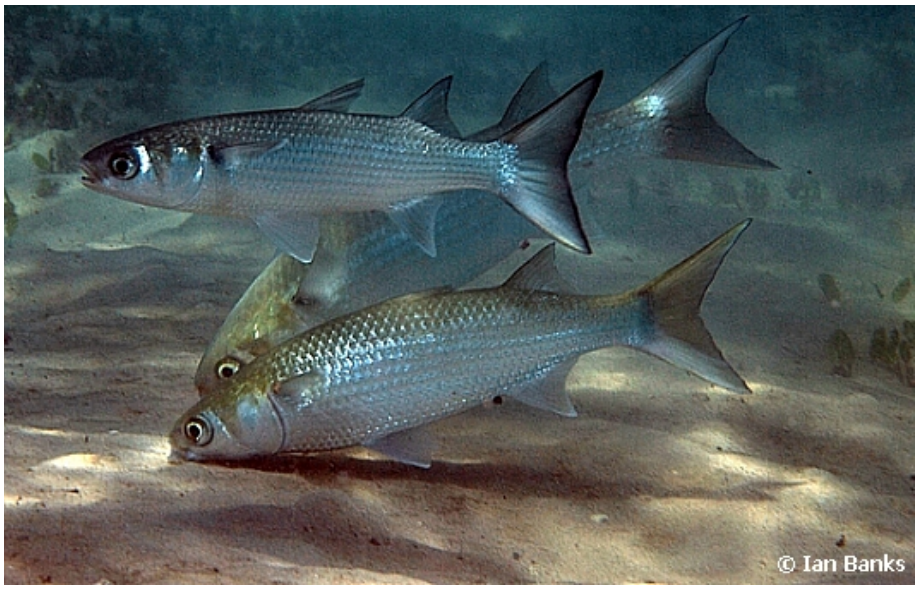
Activity: Survival of the Fishest

Lots of predators eat fish: larger fish, seals, bears, birds, etc. Many fish hide from predators under rocks, among cattails, mangroves or other places. One student will be designated a predator. The predator tries to catch the prey fish (the other students) by tagging them. The predator can choose what kind of animal to be. Fish are "safe" if they stand on or touch a safe spot, like a lily pad (hula hoop), cattail (safety cone), rock (cardboard box), or mangroves (carpet square). To keep things moving, fish can stay in the safe spot only as long as it takes them to count to five. After the predator catches 3 fish, play again with a new predator. Remove shelters as each round goes on to show habitat destruction effects on fish.

Take away message:

Fish rely on shelter from their environment to escape predation. Without these shelters, fish cannot sustain as they become too susceptible to predation.
(Adapted from Project WILD's "Fish Tag")

Mullet (*Mugil cephalus*)



Habitat: Shallow waters of lagoons, mangroves, tide pools and bays. Schools of adults are found over "soft seafloors in quiet coastal areas, estuaries and in freshwater."

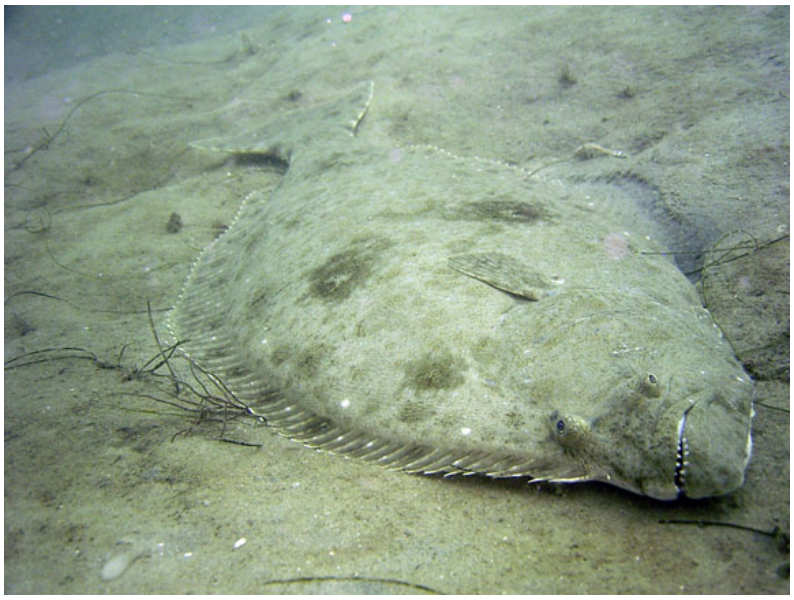
Feeding and Diet:
They feed on dead organic materials. They also reportedly feed on copepods, foraminifera, diatoms and invertebrate eggs.

Miscellaneous: They come into the intertidal at high tide but they don't live in the tide pools. Their sturdy fins make them strong swimmers, allowing them to move between habitats and escape predators, like California Sea Lions and sailfish! They have also been seen exhibiting an unusual leaping behavior. (Love, 2011)

Activity: *Business in the front, party in the back*
Mullets are extremely hydrodynamic because of the placement and shape of their fins. Their caudal fin is especially large. Have students pair up. One student closes their eyes while the other grabs the "fans": a piece of cardboard and a piece of paper folded in half. The teacher will visually instruct the "fanners" to fan air towards their partner using the cardboard and then the paper. Place both fans down and ask everyone to open their eyes. Have the students answer which they felt blew air more strongly. Have the students answer which they thought was cardboard and which was paper. Ask them then to visualize fins, and talk about the benefits of having sturdy fins versus more flaccid fins. Discuss the obstacles of life in a tidal channel (constant waves, commotion, varying levels of water and high visibility to predators).

Take away message:
The students should come to agreement that the sturdy caudal fins make it easy for them to push through the water and escape predation easier!

California Halibut (*Paralichthys californicus*)



Habitat: California Halibut are born in shallow lagoons, estuaries, bays along the open coast. Adults are commonly found on sand and mud

Feeding and Diet:
California Halibut feed on crustaceans and small fish.

Miscellaneous: The California Halibut, like other flatfish, begins life as a "standard" fish larva, with one eye on each side of its head. But within 2 weeks of hatching, one eye starts migrating across the head to take its place directly next to the other eye. This species comes in both right and left-eyed versions.

(Love, 2011)

Activity: *Just for the Halibut*

Gather at least 250 brightly colored toothpicks. Make sure you have 50 of each of 5 different colors. Choose a grassy area outside. Mark at least 3 different areas off with string. Areas can be any shape you choose and should be 1 to 1.5 meters in diameter. Break the class into teams and assign an area to each team. Have them stand around their area. Give teams time to observe and record details about the ground cover of their assigned "ocean floor", i.e. is the grass tall or short; are there any bare areas in the field; are there any rocks in the field? While the teams are occupied writing their observations about the ground cover, scatter the supply of toothpicks at random throughout the individual hunting fields. Tell teams that they are responsible for hunting one area of the "ocean floor". When you give the signal, teams have 1 minute to find all the toothpicks they can in their area. At the end of the "feeding period" have teams count the toothpicks they found by color captured by each member of the team.

Take away message:

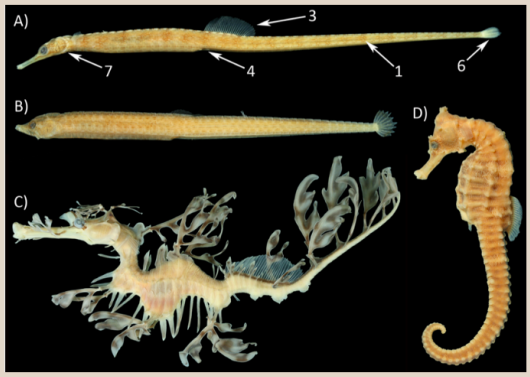
Camouflage helps halibut escape predation! Recommended debrief: *Did the different teams collect about the same number of toothpicks? Have students offer suggestions to explain. How did the totals of each color compare? Ask students to answer: Based on your findings, which toothpick was best "adapted" to its environment? Which was the least adapted? How did that influence the foraging? How would the hunt have changed if the toothpicks hid out in a bright red rug, a sandy beach or a concrete patio? Explain.*

(Adapted from the National Park Service Educational Resources)

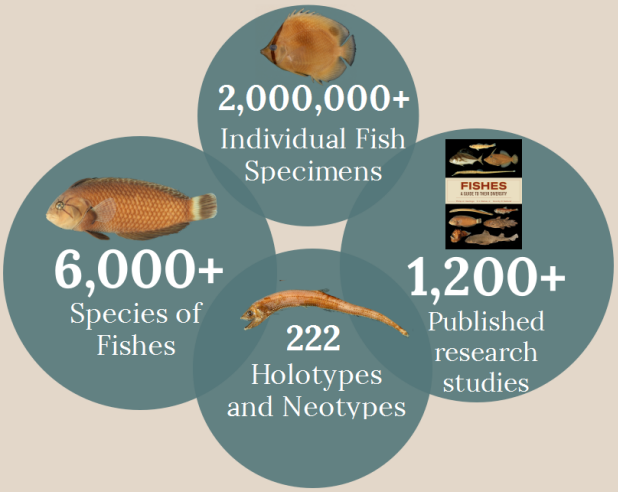
Appendix D. Poster for MVC

Marine Vertebrate Collection

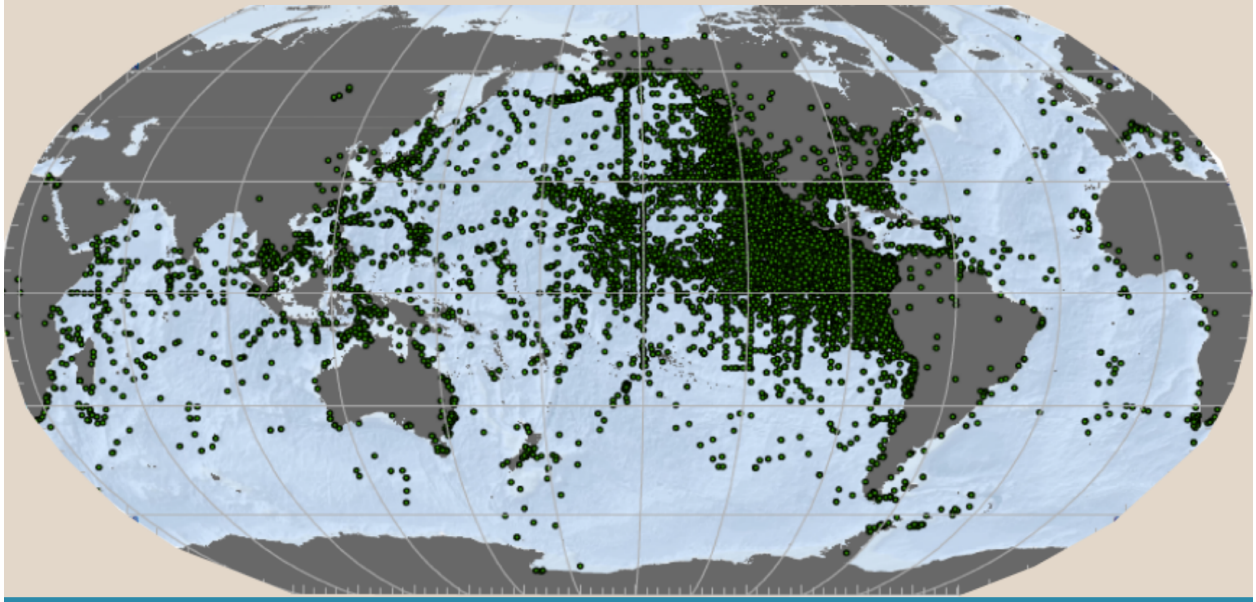
To Enhance Fundamental Knowledge and Understanding of the Fishes of the World



Syngnathidae – pipefishes & seahorses
Image from Fishes: A Guide to Their Diversity

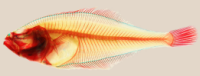


Over 20,000 Collections From Around the World



Featuring Special Collections in:

Otoliths



Skeletal Material

Tissue Samples

Scripps Institution of Oceanography, est. 1903