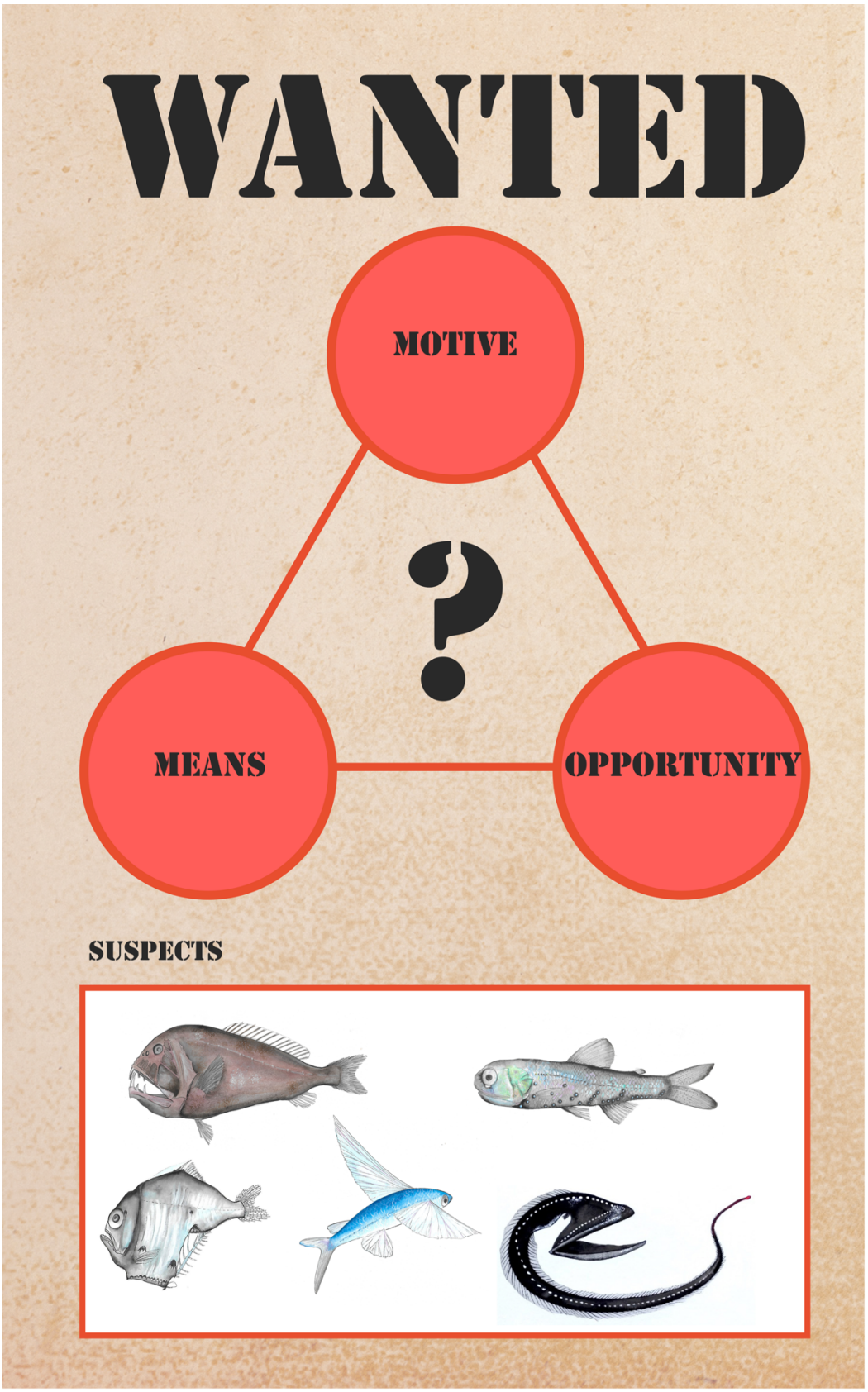


Figure 1: In this lesson plan, students will use ecological information about marine animals to solve a murder mystery, identifying motive, means, and opportunity for each animal suspect.

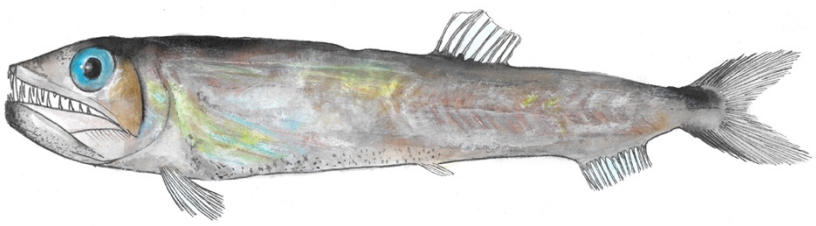
A murder occurred under cover of darkness in the ocean - your help is needed to reveal which marine creature is the culprit!

Name(s):
Date:

Activity A ("Cold, Dark, and under Pressure")
Directions:
Plot the following temperature data on the depth profile graph on the right. The axes, depth zones, and other environmental variables are already provided on the graph. After you have plotted the data, draw a line to connect your data points and complete the following discussion questions:



Zone	Depth (m)	Temp. (°C)
Sunlight	0	20
	200	16
Twilight	400	10
	800	6.5
	1000	5
Midnight	2000	4.5
	4000	4



Activity A Discussion Questions:

1. What is your independent variable? What are your dependent variables?

2. Photosynthetic plants, known as phytoplankton, are the base of the food web in the open ocean. Phytoplankton live near the surface because they need sunlight to photosynthesize. If photosynthesis can only occur in the Sunlight Zone, how do you think food webs are different in deeper depth zones (without light)? Hint: if you are struggling with this question, check out this article: https://www.nytimes.com/2017/12/19/science/deep-sea-food-web.html?unlocked_article_code=1.jU8.KEKA.CHP8VQYfT44z&smid=url-share

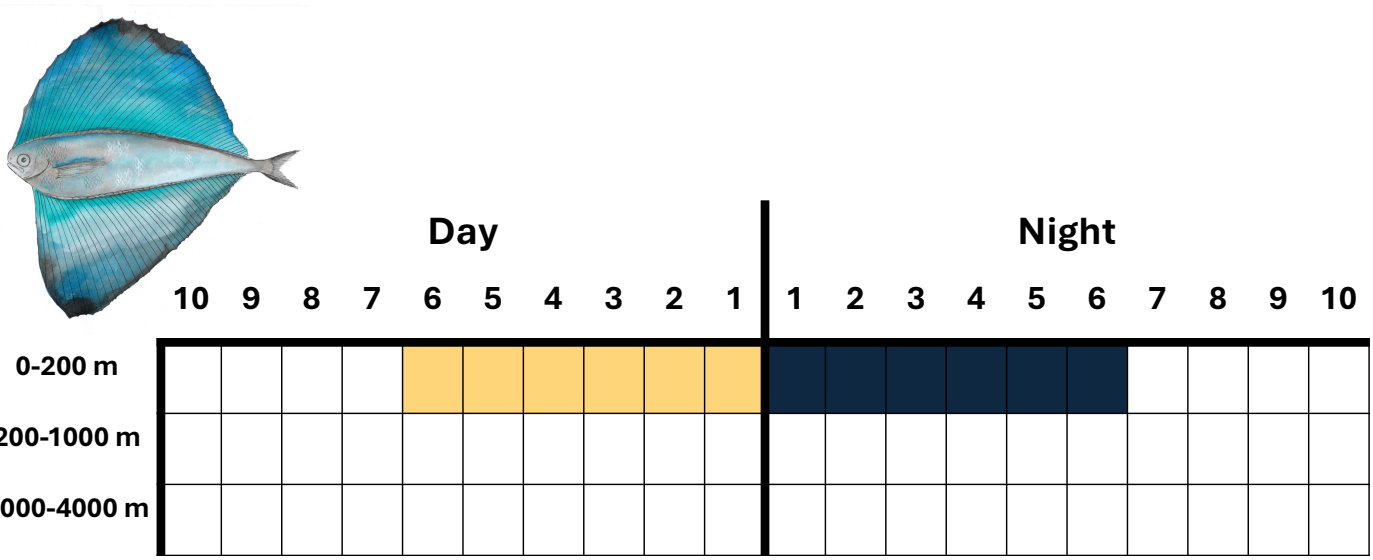
3. Describe how each variable (temperature, pressure, and light) changes as depth increases. What environmental conditions do organisms living in the Twilight and Midnight Zones experience?

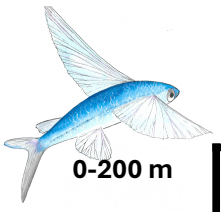
4. Can you think of any adaptations that populations of deep-sea animals may have evolved to be better suited to living in these harsh environments? Hint: if you are struggling with this question, check out this interactive article: https://nyti.ms/3PpBx7a

Activity B ("Deep-Sea Sampling") Directions: Open your "nets" (plastic bags containing beads, candies, or printed illustrations) and begin sorting and counting the "captured animals" (beads, candies, or illustrations). Record your results in the following table. Be sure to keep the contents of each "net" separate (you will compare the contents of each net). You should have six different nets (representing three depth zones and two time periods – day or night).

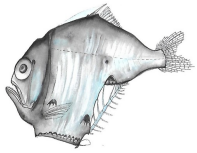
Depth Zone	Flying fish		Hatchetfish		Pelican eel		Lanternfish		Fangtooth	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Sunlight: 0-200 m										
Twilight: 200-1000 m										
Midnight: 1000-4000 m										

Graphing Instructions: Plot the abundance data for each animal on the following depth profiles as horizontal bar graphs. Use a yellow marker to shade the bars representing abundance data from the daytime tow and use a brown/black marker to shade the bars representing abundance data from the nighttime tow. An example is shown below for a Fanfish.





	Day										Night									
	10	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	10
0-200 m																				
200-1000 m																				
1000-4000 m																				



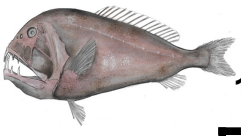
	Day										Night									
	10	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	10
0-200 m																				
200-1000 m																				
1000-4000 m																				



	Day										Night									
	10	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	10
0-200 m																				
200-1000 m																				
1000-4000 m																				



	Day										Night									
	10	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	10
0-200 m																				
200-1000 m																				
1000-4000 m																				



	Day										Night									
	10	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9	10
0-200 m																				
200-1000 m																				
1000-4000 m																				

Activity B Discussion Questions

1. Complete the chart below:

Animal	Where are they during the day?	… during the night?	Diel vertical migrator?
Flying fish	Sunlight/Twilight/Midnight	Sunlight/Twilight/Midnight	Yes/No
Hatchetfish	Sunlight/Twilight/Midnight	Sunlight/Twilight/Midnight	Yes/No
Pelican eel	Sunlight/Twilight/Midnight	Sunlight/Twilight/Midnight	Yes/No
Lanternfish	Sunlight/Twilight/Midnight	Sunlight/Twilight/Midnight	Yes/No
Fangtooth	Sunlight/Twilight/Midnight	Sunlight/Twilight/Midnight	Yes/No

2. In this activity, depth zones were defined for you. If we didn't know the depth of the net, which variable from Activity A has a predictable relationship with increasing depth, and could be used as a *proxy (substitute) for depth*?

3. Scientists have discussed several theories on the most important variable that organisms undergoing diel vertical migration track to know *when* to migrate. While many scientists agree that light is a primary cue for organisms, many scientists also think daily, internal circadian rhythms (part of an organism's "biological clock") may also help animals know when to migrate. How could you test the importance of light vs. biological clocks as migration cues?

4. The *depth that light reaches* in the water column changes across different parts of the world because of Earth's tilt on its axis. For example, near the Equator, light reaches deeper in the water column than near Antarctica. Animals undergoing diel vertical migration live in the Twilight Zone during the day to avoid visual predators that need light to see. Assuming animals have the same amount of time to complete their migration, how would you expect migration *distance* (difference between starting depth and ocean's surface) and the *speed* to change between animals living near the Equator versus Antarctica?

5. Due to climate change, the oceans are projected to become warmer and more stratified (less mixing/exchange between depth zones). Across large parts of the ocean, fewer phytoplankton (aquatic plants) are expected to bloom in the Sunlight Zone because the nutrients they need to grow will become "trapped" in deeper depth zones, inaccessible to these surface-living photosynthetic plants. If there are fewer phytoplankton, the base of the ocean food web, how do you predict that the number of *animals undergoing diel vertical migration* to the Sunlight Zone will change?

Activity C ("Solving the Murder")

Cyclops the copepod was killed (and eaten!) while in the surface Sunlight Zone at night. Luckily, there was a witness, and the authorities have provided you with a list of suspects. Use the clues from the witness's statement to authorities and the accompanying flashcards to fill in the provided table of suspects and solve the crime.

To identify the murderer, consider the following for each suspect and complete the table:
Motive: Does the suspect have a motive? Consider the suspect's diet, which could motivate them to kill and eat the victim.
Means: What are the suspect's unique characteristics (e.g., adaptations) that could allow them to subdue the victim?
Opportunity: Were the suspect and victim in the same place at the same time?

Detective Notes

- Crime occurred at night in the Sunlight Zone
- Witness reports "flash of light" emanating from murderer
- Witness reports murderer had long, slender body



Suspect 1
Flying fish

Motive:_____
Means:_____
Opportunity:_____



Suspect 2
Hatchetfish

Motive:_____
Means:_____
Opportunity:_____



Suspect 3
Pelican eel

Motive:_____
Means:_____
Opportunity:_____



Suspect 4
Lanternfish

Motive:_____
Means:_____
Opportunity:_____



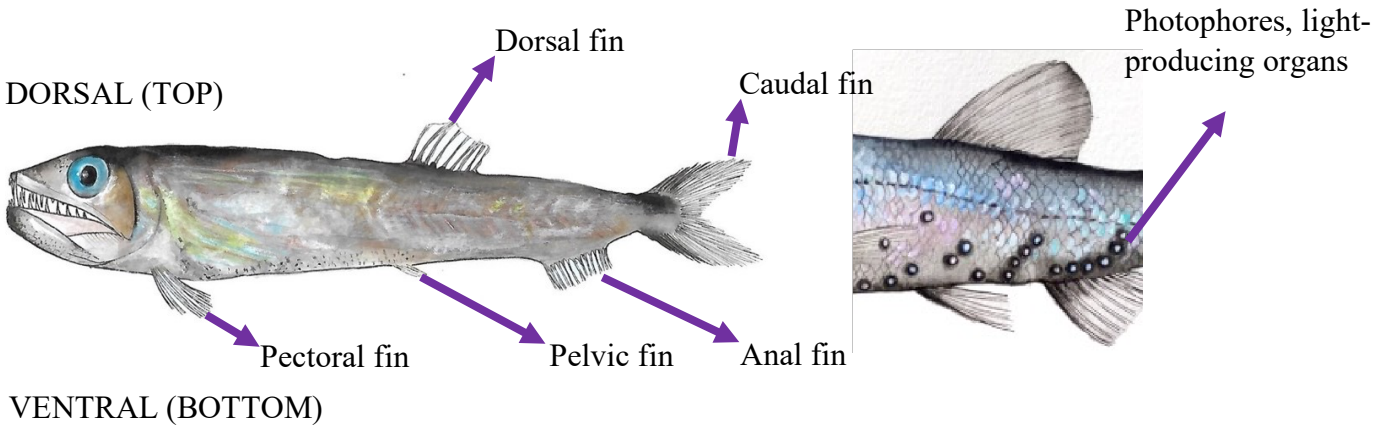
Suspect 5
Fangtooth

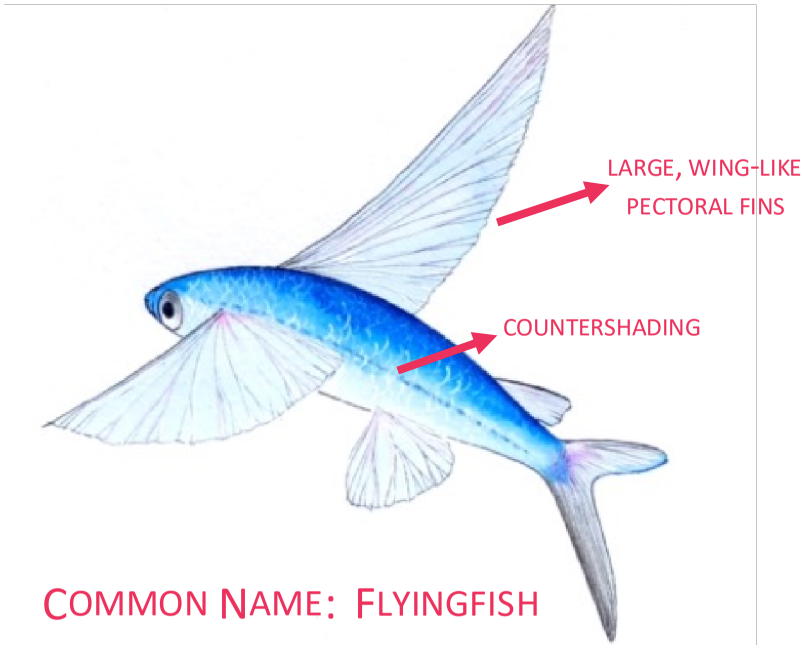
Motive:_____
Means:_____
Opportunity:_____

Which suspect is the murder? _____

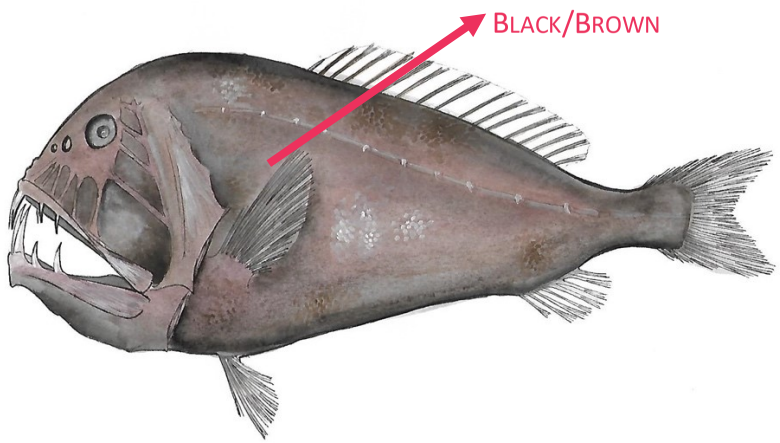
Glossary:

Bioluminescence: the biochemical production of light from organisms
Counterillumination: active camouflage and the production of light to match background light in intensity and wavelength
Countershading: camouflage strategy where the top (dorsal) surface of the organism is darker to match surrounding water (when viewed from above) while the bottom (ventral) surface of the organism is lighter to match downwelling light (when viewed from below).
Crypsis: ability to avoid being detected by other animals, including for the purposes of predator evasion or to capture prey
Diel vertical migration: the daily vertical migration of animals from the deep sea to the surface waters at dusk and return to deep waters at dawn to avoid visually cued predators in the surface layer. This key behavioral adaptation enhances foraging opportunities and minimizes predation risk: migrators avoid being consumed by visual predators in the Sunlight Zone during the daytime, while grazing on surface plankton during the nighttime.
Food web: a system of related food chains
Isolume: a line of constant light intensity
Marine snow: organic material originating from upper layers that showers the deeper layers of the water column, typically comprised of fecal pellets, carcasses, dead cells, and animals
Mirror concealment: camouflage strategy to reflect light to match background light and reduce the angles at which detection can occur
Mixed Layer: a depth interval near the surface that is thermally homogenous due to wind-driven mixing
Morphological: relating to an organism's form or structure
Nekton: free swimming and able to move independently of currents
Photophores: light-producing organs that are found as luminous spots on animals
Photosynthesis: the conversion of light energy to chemical energy through the reaction of light and carbon dioxide into energy-rich organic molecules (glucose) and oxygen
Phytoplankton: aquatic plants that cannot actively swim against currents and photosynthesize; phytoplankton are autotrophic or "self-feeding"
Physiological: relating to biochemical reactions and bodily functions of living organisms
Thermocline: a layer of water where the temperature changes significantly from the layers above and below it. In the pelagic ocean, the thermocline separates the homogenous and warm surface mixed layer and the thermally stable, cold, deep ocean.
Zooplankton: animals that drift or wander in the ocean; they consume other zooplankton or phytoplankton; zooplankton are heterotrophic or "other-feeding"

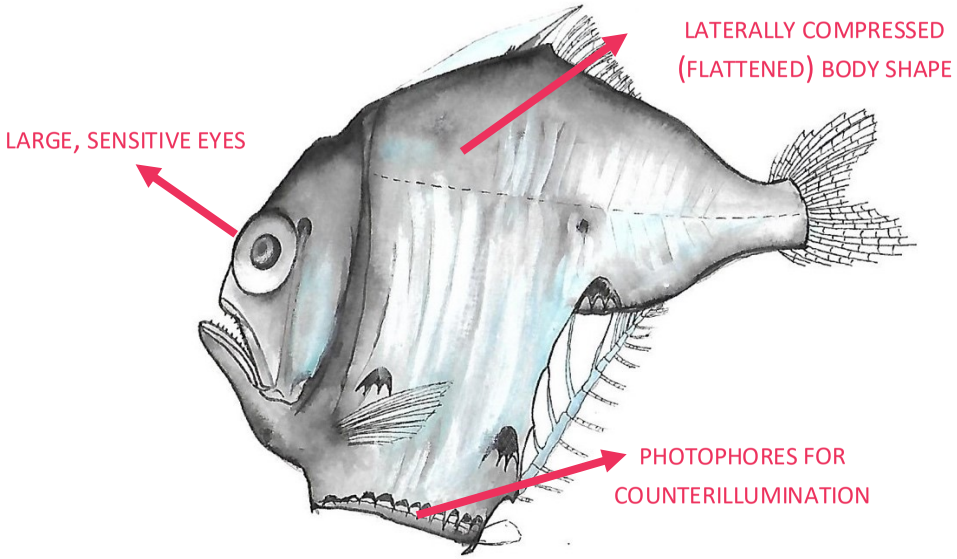




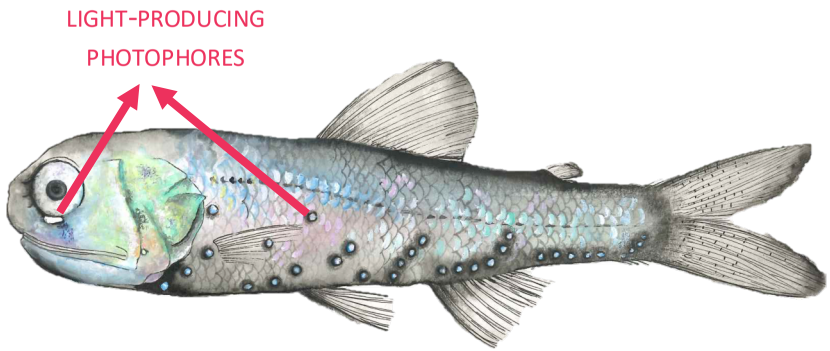
COMMON NAME: FLYINGFISH



COMMON NAME: FANGTOOTH



COMMON NAME: HATCHETFISH



COMMON NAME: LANTERNFISH

Diet: Generalist (consumes zooplankton, including copepods)
Color in the Ocean: In the open ocean, light is differentially absorbed, meaning that wavelengths of light (corresponding to certain colors) are no longer visible at depth in the water. Many deep-dwelling animals are red or black because of this phenomenon (red and black cannot be discerned at depth, making them virtually invisible), while surface communities of animals are often transparent or blue.

Common Name: Fangtooth

Diet: Zooplanktivorous (consumes zooplankton, including copepods)
Fin Morphology: Flying fishes have large fins for gliding above the surface of the water to escape predators in the sun-lit surface zone.
Countershading: In the open ocean, many animals living near the surface in the sun-lit zone are blue or transparent to match their backlighting and to avoid being eaten by predators. The dorsal (top) half of the animal is often a deeper hue of blue so, when viewed from above, the animal matches the blue abyss, while the ventral (bottom) half of the animal is often lighter-colored so that, when viewed from below, the animal matches the downwelling light from the surface.

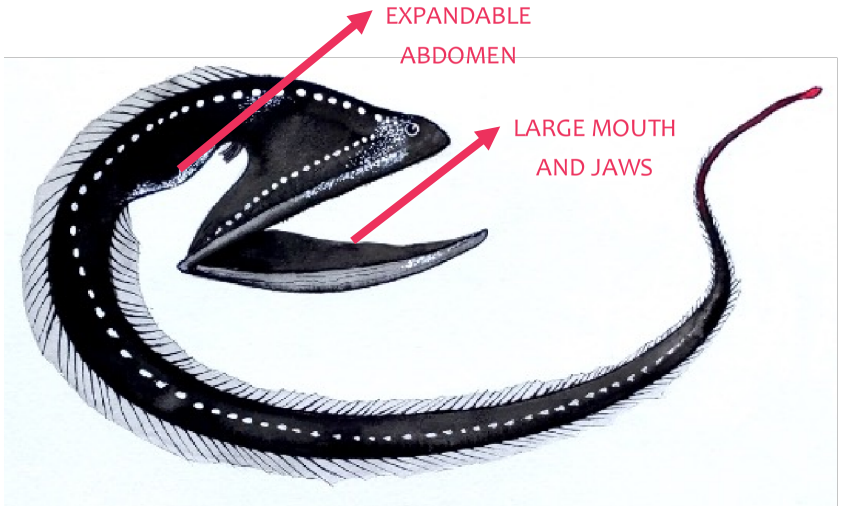
Common Name: Flyingfish

Diet: Zooplanktivorous (consumes zooplankton like copepods)
Counterillumination: Many deep-sea fishes, including lanternfishes and hatchetfishes, have a series of ventral photophores (light-producing organs along the bottom surface of their body) to match the downwelling light. These fishes use their own biologically generated light to match the intensity and color of the downwelling sunlight. This helps conceal their silhouette to predators who view them from below.

Common Name: Lanternfish

Diet: Zooplanktivorous (consumes zooplankton like copepods)
Mirror Concealment: Hatchetfishes (Family Sternopytchidae) and other flattened, silvery fishes have mirrored sides that reflect light to match their backlighting. The angles from which a hatchetfish can be detected by a predator are very small because of these mirrored sides and narrow profile.

Common Name: Hatchetfish



COMMON NAME: PELICAN EEL

DIET: GENERALIST (CONSUMES ZOOPLANKTON, INCLUDING COPEPODS)
LARGE MOUTHS: THE PELICAN EEL IS NAMED FOR ITS LARGE, EXPANDABLE MOUTH. IN THE MIDNIGHT ZONE, MANY ORGANISMS HAVE LARGE FEEDING APPARATUSES AND EXPANDABLE ABDOMENS SO THAT THEY CAN CONSUME A LARGE VARIETY OF DIFFERENT-SIZED FOOD IN A PATCHY HABITAT.

COMMON NAME: PELICAN EEL