Lesson Plan: Life in an Ocean World

GRADE LEVEL
9-12; can be adapted to different age levels

FOCUS QUESTION
What is it like to be a blue king crab around the Pribilof Islands? What challenges do BKCs face in an ocean world?

LEARNING OBJECTIVES
Students will learn about the habitat around the Pribilof Islands and will begin to connect the information learned in the life history lesson to understand why the blue king crabs have such an insular distribution. They will apply the information they learn about life in the Bering Sea in a case study of blue king crabs.

Students will learn about the basics of life in the oceans, and they will have an understanding of the importance of ocean habitat and conditions on blue king crabs.

MATERIALS
- Activity playing cards – print and cut up
- "Habitat" PowerPoint – if needed

TEACHING TIME
One hour – adaptable

KEYWORDS/VOCABULARY
Physical oceanography
Eastern Bering Sea
Benthic community
Predator/prey interactions

BACKGROUND INFORMATION
In further studying blue king crabs, it is essential to examine the habitat in which they live to understand the variety of factors influencing crab survival. In the "Life History" lesson plan, we learned about blue king crab distribution. This leads to some questions: Why are blue king crabs distributed around the Pribilof Islands and St. Matthew Island in insular pockets? How does this differ from red king crabs? Why? What challenges do blue king crabs face in the Bering Sea as an ocean ecosystem?

The goal of this lesson plan is to give an overview of the factors that may influence blue king crab survival – from ocean characteristics to benthic habitat. We will continue to use the Pribilof Island blue king crabs as a case study. To examine the ocean habitat around the Pribilof Islands, one must also study the characteristics of the greater Bering Sea. This lesson plan provides a general overview of some important aspects of blue king crabs, and offers one suggestion for a lesson activity. Note that the potential activities to teach this material are vast, and there are many different resources available. Also provided under "For More Information" are other lessons and resources that could be beneficial in teaching about ocean functions.

Habitat
Juvenile blue king crabs are limited to near shore areas around the Pribilof Islands because they are dependent on the intact shell that is found on the bottom (Armstrong et al, 1985). This varied bottom material consisting of shell, gravel, and rocks provides habitat rarely found elsewhere in the Bering Sea (Palacious, 1985). Juvenile king crabs likely inhabit the shell, rocky, cobble substrate because it offers protection. After age 2, red king crabs have differing juvenile body morphology with long spines and exhibit a podding behavior, both of which may provide protection (Armstrong et al, 1985). In addition to the habitat, it is important to consider the coloration of each of these species: red king crab juveniles are red, and thus at depth might not be visible due to the depth red light penetrates (Widder, 2004), while blue king crab juveniles are mottled and patchy, with large variation in their color pattern, potentially hiding them well amongst the shell and cobble bottom.

The extent of shell habitat characteristic of the Pribilof Islands is rare in the Bering Sea, and is an essential component in understanding how to manage the blue king crab species because the juvenile blue king crabs will not survive without the shell habitat (Armstrong et al, 1985). It is also important to think about the variety in color morphology that juvenile blue king crabs display – with colors ranging from grey to blue to white to mottled tan to orange. How does the shell color and substrate composition relate to predation?

Bering Sea characteristics

The Pribilof Islands are situated in the Bering Sea on the edge of the continental shelf. The physical oceanography of the Bering Sea is dynamic and complex. The continental shelf is located in the eastern portion of the Bering Sea, and is characterized by varying water column structures between the coastal edge of Alaska and the continental shelf edge (Armstrong et al, 1987). Deep, cool nutrient-rich water from below the continental shelf seeps up onto the shelf, forming a deep layer of cold water. Above this deep, cold layer are at times two layers: a middle cool layer, and a top mixed layer. This upper layer varies in nutrient availability, and is typically productive because nutrient-rich deep water is mixed by winds and tides, and is brought up from below the continental shelf (Stabeno, 2008). The mixed layer varies in depth based on the wind speed, less mixing often causes formation of different layers of water. In winter, the winds typically blow strongly from the north, while in summer the winds are weaker from the south (Armstrong et al, 1987; Stabeno, 2008).

Winds play an important role in ocean currents, sea surface temperature, and sea ice cover (Armstrong et al, 1987). Winds and density of sea water are the primary drivers of ocean currents (NOAA OSE, 2007). Ocean currents have an effect on where larval crabs settle into the juvenile stage, because larval blue king crabs are not able to control movement, other than small vertical motions (Armstrong et al, 1987). Figures 1 and 2 display the general circulation patterns for the Bering Sea, and Figure 3 displays a close up of circulation patterns around the Pribilof Islands. The clockwise currents around the Pribilof Islands may be the result of daily tidal flow around the islands (Kowalik, 1999; Stabeno, 2008). This circulation pattern is important because it helps retain the larvae near the Pribilof Islands, rather than being swept away and failing to find suitable habitat.

Sea ice is an important element in the Bering Sea (McNutt). Sea ice is intricately connected to atmospheric and ocean conditions. Timing of sea ice melt is an essential factor in larval crab success. The timing of sea ice melt – in addition to nutrient availability and sunlight – determines what species of phytoplankton are dominant and when the spring phytoplankton bloom occurs, in turn affecting the survival of crab larvae and supporting the entire Bering Sea ecosystem (Zheng and Kruse, 2000; McNutt). As we learned in the Life History lesson plan, phytoplankton are the base of the entire marine food web. Phytoplankton convert sunlight and nutrients to organic matter, and nutrients are a limiting factor for their growth; increased mixing by winds is strongly correlated to more growth of phytoplankton because nutrient rich deep water is mixed with surface water (Mantua & Hare, 2002).

Sea surface temperature and bottom temperature have an effect on egg development in adult crabs, time of hatching of embryos, and the survival and growth rate of larvae (Armstrong et al, 1987). Blue king crabs are an excellent example of a species that is almost perfectly adapted for the unique habitat in which it lives, and survival is dependent on many variable conditions, including sea ice cover, temperature, weather. In thinking about the life cycle of the blue king crab, the external environmental conditions are merely one of the challenges facing the survival of the blue king crab; they are also faced at all life stages with competition by other species for resources, predation, and the ever-increasing human effect (fishing, climate change, ocean acidification, and habitat destruction).

LEARNING PROCEDURE

1) Before beginning the activity, review the background material and explore anything that is unclear. If you would like to focus the lesson more on oceanic processes, there are many alternative lesson plans included in the "For More Information" Section. Also, maybe think about having your students read this short article about Bering Sea and ice: http://www.beringclimate.noaa.gov/essays_mcnutt.html
2) Included in this packet is a PowerPoint with some images and graphs that could be useful to illustrate the substrate around the Pribilof Islands, as well as some distribution graphs from the research cruises during the 1980s.
3) If you did not use the "Life History" lesson plan, it may be helpful to briefly introduce the blue king crab to your students using the included PowerPoint, "Introduction to Blue king crabs." If you did use the "Life History" lesson plan, then briefly review the material with your students (5 min.)

4) Introduce the Bering Sea as a dynamic and harsh environment, and discuss what challenges a crab might face living in an ocean world. Maybe think about showing the students this graph, it clearly shows the different habitats of the Bering Sea: http://www.pmel.noaa.gov/np/pages/seas/bphysdom.html
5) Explain the game as follows:
    a. Each student will be randomly assigned a "character card," of either a Predator or a Prey. Each Prey will also get a Habitat card. The students with Prey cards should keep their information secret, as the goal of the game is to stay "hidden" in your habitat and not get eaten by the Predator.
    b. The students will mingle about and the Predators will approach the Prey and ask them a series of "yes/no" questions (along the same lines as 20 Questions), with the goal that the Predator will correctly guess the Prey color and habitat location, resulting in the "death" of the Prey (the prey then surrenders the character card to the Predator as "food." Questions could be as follows:
        i. Are you a crab? Are you a blue or red king crab? Is your shell white? Is your habitat rocky? Is it sandy?
    c. The Predator has 3 questions at first, and if 2 or more are answered as "No", then the Predator must move on, and the Prey is safe in the meantime (it might be in the best interest of the Predator to have a good memory for the "Yes" answers!). If the Prey answers "Yes" to all three questions, they "are eaten." If they only answer "yes" to two of the three questions, the Predator gets one more question. If three "yes", then the Prey "dies", if "no" then the Predator must move on and the prey is momentarily safe.
    d. The game continues until the Predators have "eaten" all of the Prey.
    e. Also, the teacher represents the wild and unpredictable Bering Sea! At any point during the game, the teacher has the power to introduce a change into the system (could be winter storms, etc.). The teacher can change the number of questions that the Predators has to ask in order to "eat" the Prey, and can restore life to the Prey randomly and at any time.
6) Follow up the activity with a discussion about what the students learned? What did they learn during the game that they did not know previously? What types of habitat were beneficial to crab survival?

EVALUATIONS

- Can observe how students participate as one option. Also can have them write up their responses to the game on a piece of paper, turn in at the end of class.

EXTENSIONS

- This lesson would be an excellent opportunity to have the students conduct independent research, and present their findings to the class (potentially in groups). Each group could be assigned or could choose a different characteristic of the Bering Sea (such as sea ice, currents, wind, storms, etc.). The students could work in teams to build their own comprehensive presentation or poster to teach their peers what they researched.
- An alternative lesson could include the "Habitat" PowerPoint, and you guide the students through the slides, maybe ask the students questions or have them comment about the different factors and things they notice in the images. The students should comment on important aspects relating to blue king crab survival, including habitat, competition, predation, or differences between red and blue king crabs.
    - Points to reinforce:
        - The cryptic coloration and smooth carapace of the blue king crabs compared to the red color and spiky carapace of the red king crabs
        - The red king crab podding behavior – why might it be beneficial for the red king crabs? Possibly a mechanism to prevent predation?
        - The maps of the Pribilof Islands could be a good illustration of the restricted habitat availability for the blue king crabs – this is demonstrated in the map of distributions of several stages of blue king crabs around the islands (larval distribution, juvenile distribution, and adult distribution). Also note that the maps show male and female abundance by the two colored bars, and that the distribution of blue king crabs declines swiftly with increasing distance from the islands.

FOR MORE INFORMATION

- This is a great lesson plan that teaches about ocean currents and waves. It could be used as a supplement or for more information about general ocean currents.
  http://oceanservice.noaa.gov/education/lessons/ocean_motion.html

- This is an amazing virtual lesson that focuses on ocean acidification. It highlights important information about the process of ocean acidification and the effect it will have on ecosystem diversity. I highly recommend using this as a resource if you have the technology available! http://virtualurchin.stanford.edu/AcidOcean/AcidOcean.htm
- This is a great animation for illustrating surface currents and wind direction, and it is from this website (http://cleanet.org/resources/39059.html) ➔http://www.classzone.com/books/earth_science/terc/content/visualizations/es2401/es2401page01.cfm?chapter_no=visualization
- Here is an incredible lesson plan for teaching students to graph sea ice extent! It is AMAZING. http://www.windows2universe.org/teacher_resources/graphs/teach_sea_ice_extent.html
- Here is a hand's on activity that demonstrates ocean currents and deep ocean currents. http://www.bigelow.org/shipmates/deep_currents_standards.html
- Here is yet another lesson plan for demonstrating ocean currents, including the Coriolis effect http://www.marine.usf.edu/pjocean/packets/sp98/om_2.pdf
- This is an amazing article about the importance of sea ice in the Bering Sea http://www.beringclimate.noaa.gov/essays_mcnutt.html
- This is a really interesting (possibly too complex) video that discusses scientific examination of Bering Sea Benthos sampling https://www.youtube.com/watch?v=6R9fP2jl_ME
- This is an excellent resource for more information about the Bering Sea from PMEL and NOAA http://www.beringclimate.noaa.gov/links-info.html
- NOAA has several lesson plans available about light penetration in the ocean, which might be a great supplement if the point is confusing to your students. Here is the link to the overview page: http://oceanexplorer.noaa.gov/facts/red-color.html
    - Grades 9-12: http://oceanexplorer.noaa.gov/explorations/02sab/background/edu/media/sab_blinded.pdf
    - Grades 5-6: http://oceanexplorer.noaa.gov/explorations/02hudson/background/edu/media/hc_bright_red.pdf

NATIONAL SCIENCE EDUCATION STANDARDS

- Content Standard C: interdependence of organisms, and behavior of organisms
- Content Standard F: natural resources, and environmental quality

ACKNOWLEDGMENTS

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RESOURCES

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FIGURES

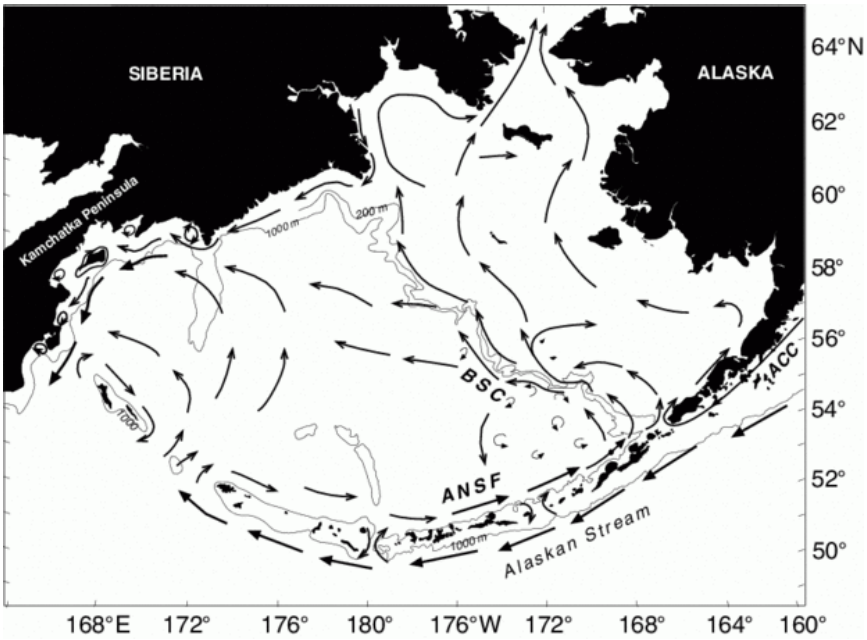

Figure 1. This map shows the generalized currents in the Bering Sea. (Source: http://www.eoearth.org/view/article/150494/)

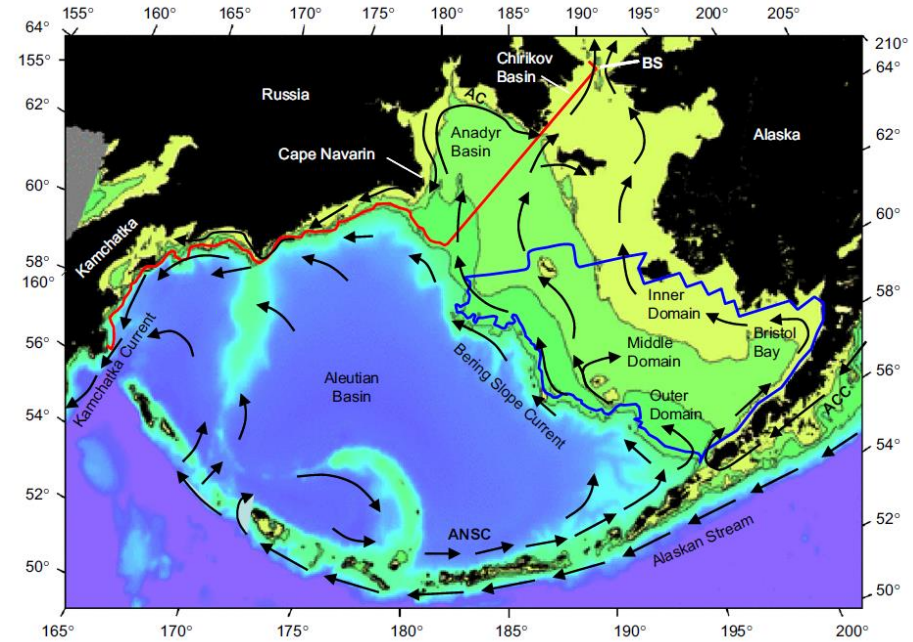

Figure 2. The Bering Sea, with boundaries of the southeast Bering Sea shelf (EBS, blue line), and the western Bering Sea shelf (WBS, red line). Isobaths shown are 50m (between inner and middle domains), 100m (between middle and outer domains) and 200m (between outer domain and slope/basin). Schematic of major currents based on Stabeno et al. (1999). AC: Anadyr Current, ACC: Alaska Coastal Current, ANSC: Aleutian North Slope Current, BS: Bering Strait. (Source: Dave Armstrong)

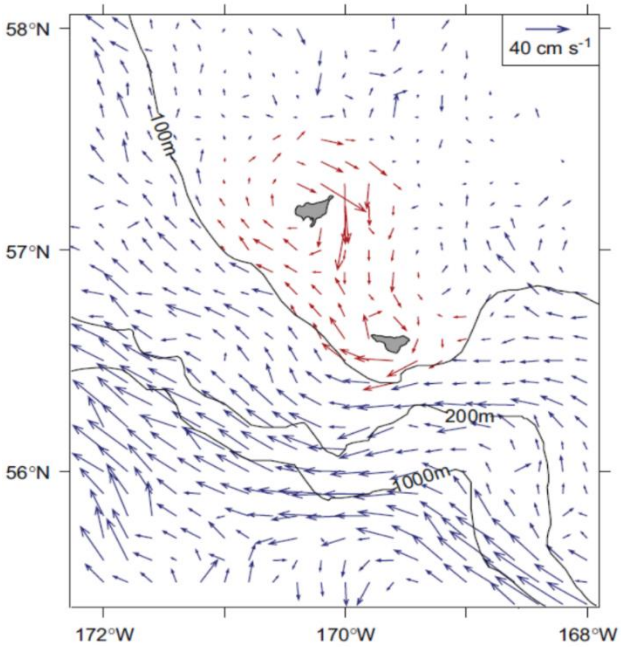

Figure 3. Red arrows are Pribilof domain circulation, (Stabeno et al, 2008)

PREY: Blue king crab juvenile -Color: grey-blue -Size: small, still edible to most predators -Alone, hiding during the day and active at night	PREY: Blue king crab juvenile -Color: mottled tan -Size: several molts into juvenile stage, still small, but shell is stronger than before—can only be eaten if on exposed sediment -Alone, nocturnally active	PREY: Blue king crab juvenile -Color: white-tan -Size: small, easy to hide in appropriate substrate but easy to be eaten if seen -Alone, nocturnally active	PREY: Blue king crab juvenile -Color: orange -Size: small, easy to hide but be careful of your bright coloration! -Alone, nocturnally active
PREY: 2 yr old red king crab juvenile -Color: red -Size: small, spines for protection -Location: in the center of the pod protected from predation	PREY: 2 yr old red king crab juvenile -Color: red/orange -Size: small, spines for protection -Location: a the edge of the pod, exposed to predators	PREY: Blue king crab juvenile -Color: blue-white -Size: small, easy to be eaten -Alone, nocturnally active	PREY: Blue king crab juvenile -Color: white and orange -Size: small, make sure you stay hidden on shell hash! -Alone, nocturnally active

HABITAT: Pulverized shell hash habitat is not suitable protection, be cautious!!	HABITAT: Intact shell and cobble substrate is excellent for protection.	HABITAT: Intact shell and cobble substrate is excellent for protection.	HABITAT: Sandy gravel substrate at the edge of some shell hash. Better move quick!
HABITAT: Rocky sandy substrate, a little exposed for the crab's liking! Be wary.	HABITAT: Flat sandy expanse on the continental shelf east of the Pribilof Islands = danger!	HABITAT: Flat sandy expanse on the continental shelf east of the Pribilof Islands = danger!	HABITAT: Pulverized shell hash habitat is not suitable protection, be cautious!!

PREDATOR: Pacific cod -you are mobile and free swimming, so you are able to eat any prey you can see!	PREDATOR: Halibut -you also live on the bottom of the ocean, disguising yourself as the sandy bottom. But you have the flexibility and easy of swimming as an option and are able to swim. You hunt for prey and gobble it up.	PREDATOR: Larger king crab -you scavenge the ocean floor looking for anything and everything you can find, if you happen upon another RKC or a BKC you will not hesitate to eat it! However size is a limitation for you, you must be large enough to kill and eat your prey.	PREDATOR: Octopus -you are mobile and fluid in your movements along the bottom of the ocean. If you find prey, you pull it into your mouth with your long tentacles and eat it!
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