Lesson Plan: Life Cycle of Blue King Crabs

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

FOCUS QUESTION
What challenges do blue king crabs face throughout their life cycle? How does the blue king crab life cycle help determine its distribution?

LEARNING OBJECTIVES
Students will be able to identify life stages of blue king crabs. Students will learn about the life history of blue king crabs compared to red king crabs, and will be able to infer distribution based on life history traits.

Students will be able to relate temperature and the effect it has on development.

MATERIALS
- Copies of the *Blue King Crab: Chutes and Ladders* – enough for one per group of 3 – 4 students.
  - Also need one dice per group
- Copies of the *Blue King Crab Activity Worksheet* – enough for each student
- PowerPoint for introduction

TEACHING TIME
One or two hour class period(s) – adaptable

KEYWORDS
King crab fishery
Eastern Bering Sea
Crustacean life cycle

BACKGROUND INFORMATION
In the early 1980s, the commercial fishery stocks of red king crab (*Paralithodes camtschaticus*) crashed, so the comparable blue king crab (*Paralithodes platypus*) became more popular (AFCS). Not long after the increase in blue king crab catches, however, the blue king crab populations also experienced a huge decline in abundance. In the 1990s, the fishery was closed due to low abundances (ADFGa, 2014).

Although red king crabs and blue king crabs appear very similar as adults, the two species have key differences in life history traits and distributions. Blue king crabs are fascinating because the populations exhibit a very insular distribution, with the major "pockets" residing around the Pribilof Islands and St. Mathew Island in the Bering Sea, and with smaller pockets scattered in fjords along the coast of Alaska and Russia (ADFGa, 2014). This contrasts greatly with the red king crab, populations of which are more continuously distributed throughout the Eastern Bering Sea and the Gulf of Alaska (Donaldson & Byersdorfer, 2005). (See MAP resources at the end of the document.)

It is important to compare red king crab and blue king crab life history traits because they have very similar ranges and yet they often don't inhabit regions together. This is potentially a result of increases in water temperature following the most recent period of glaciation (Somerton, 1985). The insular distribution of blue king crabs may be a direct result of temperature stress on the crabs, and an indirect result of the changing temperatures that expanded the range of warm water competitors and predators. Blue king crabs are likely adapted for colder waters. Hypotheses accounting for the difference in distribution between red and blue king crabs include differences in optimum temperature for reproduction, competition with the red king crab for resources, exclusion by predators, and habitat requirements of juveniles (Somerton, 1985; ADFGa, 2014). Of these hypotheses, the juvenile dependence on shell hash habitat is likely the most important, because shell hash is uncommon in the eastern Bering Sea (Armstrong et al, 1985).

King crabs are a complex group of decapod (ten legged) crustaceans within the family Lithodidae. King crabs are characterized by the asymmetrical abdomen and five pairs of legs: the first pair are claws, the middle three pairs are walking legs, and the fifth pair is hidden inside the rear of the carapace – the shell that makes up the back. The fifth pair of

legs have specialized uses for males and females; they are used by males to transfer and spread sperm packets to the female during mating, females use the fifth walking leg to clean embryos (Donaldson, 2005).

When female king crabs are ready to reproduce, they shed their old shell and form a new one in a process called molting. Molting is an essential part of growth that occurs during many stages of the crab life cycle. Because crabs have a ridged shell, in order to grow crabs must first shed the old shell (molt) and then swell to a larger size and harden a new shell. Mating occurs after molting, during which a sexually mature male crab grasps the female and uses his fifth pair of legs to transfer the sperm to the eggs (Donaldson, 2005). After fertilization of 50,000 to 200,000 eggs, the eggs are held in the abdomen of the female blue king crab for a little over a year (12-14 months) before hatching. Female blue king crabs have a biennial reproductive cycle, meaning they reproduce every two years. This biennial cycle may be due to the inability of the female blue king crab to produce fully developed ovaries in one year, like the red king crab, possibly as a result of the energy requirements for annual ovary development or other factors (ADFGa, 2014; Jensen and Armstrong, 1989; Jensen et al, 1985). In contrast, red king crabs reproduce annually – on a 12 month cycle – and several days after eggs of one cycle hatch, the female red king crab molts, mates and extrudes another clutch of eggs (Donaldson, 2005). See figure 3 for diagram of life cycle.

Blue king crabs and red king crabs typically hatch in spring, corresponding with the spring bloom of phytoplankton (Donaldson, 2005). Upon hatching, the newly emerged king crabs enter the larval stage of their life as zoea. As larvae, the zoeal king crabs are planktonic, meaning they are free floating in the open water and have only limited vertical movement. The king crabs pass through four zoeal stages, initially feeding on phytoplankton, and then zooplankton as they grow larger. Phytoplankton are microscopic photosynthesizers that are the base of marine food webs (NOAA, 2014). Zooplankton are also tiny organisms that consume phytoplankton and are an important source of food for marine food webs (Hare).

Each larval stage lasts about 10-14 days, and the development time varies depending on water temperature (Donaldson, 2005). Colder water slows development, while warmer water increases the rate of development. At the end of the fourth zoeal stage, the king crabs enters the final larval stage of its life, called glaucothoe. During this stage, the larvae settles and metamorphoses into the first juvenile stage and becomes benthic – residing on the ocean floor – for the remainder of its life. Blue king crabs have the highest survival if they settle on shell and gravel substrate, the substance or material that makes up the ocean floor (Armstrong et al, 1987; Palacious et al, 1985). The total larval stage lasts for 2 to 3 months for red king crabs, and 3.5 to 4 months for blue king crabs (Armstrong et al, 1985; AFCS). It is important to consider the coloration of each of these species: red king crab juveniles are red, and thus in the ocean might not be visible due to the depth red light penetrates so they might be more cryptic (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.

During the juvenile stage of life, the king crabs molt frequently, growing several millimeters with each molt (Donaldson, 2005). As early juveniles, blue and red king crabs are small and rather defenseless, and this stage of life is characterized by the highest mortality because the crabs are too small to escape predation (Ibid). Complex habitat and cryptic coloration is essential for early juvenile king crabs. Red king crabs after 2 years of age often gather together and form pods – the crabs are physically touching and on top of one another forming a large ball – possibly for protection from predators (Ibid). This podding behavior has not been observed in blue king crabs. King crabs are frequently preyed upon by many species of fish in the Bering Sea, as well as by cannibalistic larger king crabs (Ibid; AFCS). Predators of king crabs include: Pacific cod, halibut, yellowfin sole, flathead sole, arrowtooth flounder, octopus, walleye Pollock, herring, Sockeye salmon, sculpins, Irish lords, skates, and snailfish (Donaldson, 2005).

King crabs themselves feed on a variety of organisms, depending on size and location. King crabs are omnivorous and are very opportunistic feeders, meaning will eat almost anything available on the ocean floor. This includes worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, crabs, other crustaceans, fish parts, sponges, and algae (Donaldson, 2005; AFCS).

Juveniles continue to grow and molt frequently until they reach maturity; for females this occurs no earlier than 5 years, for males this occurs around 6 years, maybe longer. Adult blue king crabs migrate annually from nearshore (shallow) to offshore (deeper). In winter blue king crabs migrate to shallow waters, and embryos hatch in spring. Because the crabs molt and lose the hard parts of their shells frequently, the average lifespan is unknown (ADFGa, 2014).

Key differences between blue and red king crabs (Somerton, 1985; ADFGa, 2014; ADFGb, 2014):

	Blue king crab	**Red king crab**
Distribution	Insular pockets – St. Matthew Is, Pribilof Islands, fjords along Alaskan coastline	Smooth dist. – East Bering Sea and Gulf of Alaska
Length of larval stage	3.5 – 4 months	2 – 3 months
Habitat preferences and juvenile behavior/color	-Specific to shell hash -Juveniles not known to form pods -Are solitary and nocturnal, do not have long spines -Grey/blue/white/mottled tan to orange	-Juveniles under 2 yrs hide in complex habitats, such as shell hash, cobble and structures -Juveniles at age 2-4 yrs form pods for protection from predation -Are active diurnally, have long spines -Bright orange/red coloring
Female reproductive cycle	Biennial -may require colder temperature	Annual -warmer temperature for reproduction

LEARNING PROCEDURE

1) In preparation for this lesson, review the background above and explore the Alaska Dept. of Fish and Game web page about blue king crabs. Determine what base knowledge about biology/ecology your class already knows, and what would be helpful to teach them. (http://www.adfg.alaska.gov/index.cfm?adfg=bluekingcrab.main).
2) Depending on your students' prior knowledge, maybe spend 10 minutes or so in class presenting the *Intro to Blue King Crabs* PowerPoint included in this lesson packet. See if any students have questions.
3) Play *Blue king crab: Chutes and Ladders!* Assign students into groups of 3 – 4 and give each group one game board and a dice. Have the students play the game for 45 minutes, as they play the game, be available for questions about the life cycle of blue king crabs.
4) At the end of the game, give each group (or each student) a worksheet to complete. This can be completed as a group, or it can be completed individually in or outside of class for homework.

Answers to worksheet:

1. What are some factors that affect planktonic, larval blue king crabs? Explain. (Hint: think about the definition of pelagic)
   Answers might include: Availability of food (phytoplankton, zooplankton), when the spring bloom occurs (ice melt), predation, water temperature (affects rate of development), etc. Definition of pelagic: found in open water
2. What are some factors that affect benthic, juvenile blue king crabs? Explain.
   Answers might include: availability of food (on the ocean floor), settlement onto shell/gravel sediment, protection from predation, molting successfully (not getting preyed upon), etc. Definition of benthic: living on the ocean floor
3. What is the effect of temperature on growth of blue king crabs?
   Colder water decreases, while warmer water increases metabolic rate – affecting rate of development
4. Please describe the habitat requirements of the blue king crab throughout the life cycle. (Hint: think about the transition from larval stage to juvenile stage. What is an important factor for survival?)
   Larval stage requires water temperature to be just right, available food, and eventually requires shell hash for settling into juvenile stage. Juvenile stage requires the shell hash for protection. Adults can afford to be a bit more generalist with habitat, have more protection, still may be restricted by temperature.
5. What is molting? Why is it an essential part of the crab life cycle?
   Molting is the process shedding the old shell and growing a new one. It is essential so the crabs can grow larger!
6. Name three common predators of the blue king crab, and specify the life stages that are most vulnerable to predation. Why are these stages the most vulnerable?
   Mentioned in the game: Pacific cod, octopus, yellowfin sole. Most vulnerable to predation in larval stage and early juvenile stage, just after settling.
7. Please describe the reproductive cycle of the female blue king crab.

At about age 5yrs, the female is ready to reproduce, after finding a mate, she molts, mates, and begins carrying the eggs under her tail flap. (fertilized eggs are extruded outside the body and carried under the abdomen covered by the uropod, tail flap). She carries them for 12-14 months before they hatch into larval crabs. She then spends the next year developing her ovaries so she will be ready for the next time to mate.

8. Name two protective traits the red king crab has compared to the blue king crab. Explain why these two differences are beneficial.
   Red king crabs have long spines as juveniles and also exhibit podding behavior as protection from predators.
9. Using the resources available to you, complete the following table comparing and contrasting the life cycles of blue king crabs and red king crabs.
   Answers may include items listed in the table above, and others with resources cited.

EVALUATIONS

- Use the blue king crab activity worksheet as an evaluation of student progress.

EXTENSIONS

- This lesson plan could easily be adapted to be a longer project by assigning each student a topic/component to research. What are some of the major differences between blue and red king crabs life history traits? Maybe have students create a comparison table between the two species. Or in groups, research different aspect of the life history and teach to peers. This could be divided by life history stage, or by species.
- Maybe have students come prepared for class: ask them to research blue king crabs briefly, then write a reflection paper answering the following questions:
  - What is a blue king crab? Where do are they found? Did you know what a blue king crab was before your research?

FOR MORE INFORMATION

- The Alaska Dept. of Fish and Game website has a great overview of both blue and red king crabs. (Blue king crab: http://www.adfg.alaska.gov/index.cfm?adfg=bluekingcrab.main; Red king crab: http://www.adfg.alaska.gov/index.cfm?adfg=redkingcrab.main)
- Biological Field Techniques for Lithodid Crabs provides a lot of interesting (and more detailed) biological information about king crabs, and is available for free download from the Alaska Sea Grant bookstore (http://seagrant.uaf.edu/bookstore/pubs/AK-SG-05-03.html)
- This video shows a juvenile blue king crab on some shell habitat. https://www.youtube.com/watch?v=3OtlOTPQZgk

NATIONAL SCIENCE EDUCATION STANDARDS

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

ACKNOWLEDGMENTS

This lesson plan was created by Alexandra Doty for a project with the UW School of Aquatic and Fishery Sciences. Special thanks to the project team, David and Jan Armstrong, P. Sean McDonald, and Chris Long. Funds for these materials were provided through a subaward from the North Pacific Research Board. For questions or comments, please contact Alexandra Doty at dotya@uw.edu.

RESOURCES

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Blue King Crab Activity Worksheet

You just played *Blue king crab: Chutes and Ladders!* Using the knowledge you gained in this activity and your critical thinking skills, please answer the following questions to the best of your ability.

1) What are some factors that affect planktonic, larval blue king crabs? Explain. (Hint: think about the definition of planktonic)

2) What are some factors that affect benthic, juvenile blue king crabs? Explain.

3) What is the effect of temperature on growth of blue king crabs?

4) Please describe the habitat requirements of the blue king crab throughout the life cycle. (Hint: think about the transition from larval stage to juvenile stage. What is an important factor for survival?)

5) What is molting? Why is it an essential part of the crab life cycle?

6) Name three common predators of the blue king crab, and specify the life stages that are most vulnerable to predation. Why are these stages the most vulnerable?

7) Please describe the reproductive cycle of the female blue king crab.

8) Name two protective traits the red king crab has compared to the blue king crab. Explain why these two differences are beneficial.

9) Using the resources available to you, complete the following table comparing and contrasting the life cycles of blue king crabs and red king crabs.

	Blue king crab	**Red king crab**
Larval stage		
Juvenile stage (habitat preferences & color)		
Female reproductive cycle		
Distribution		

MAPS

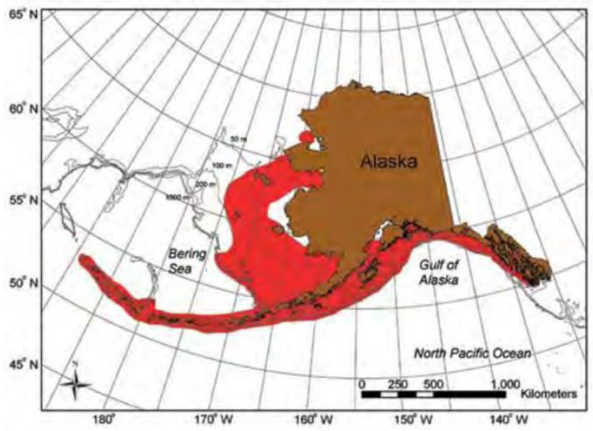


Figure 1. Map of red king crab distribution (Donaldson, 2005).

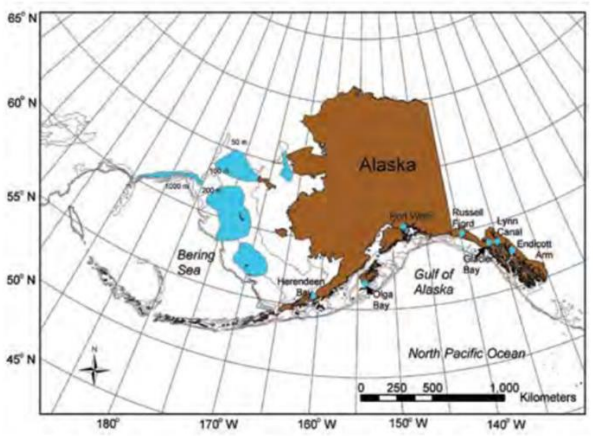


Figure 2. Map showing blue king crab distribution (Donaldson, 2005).

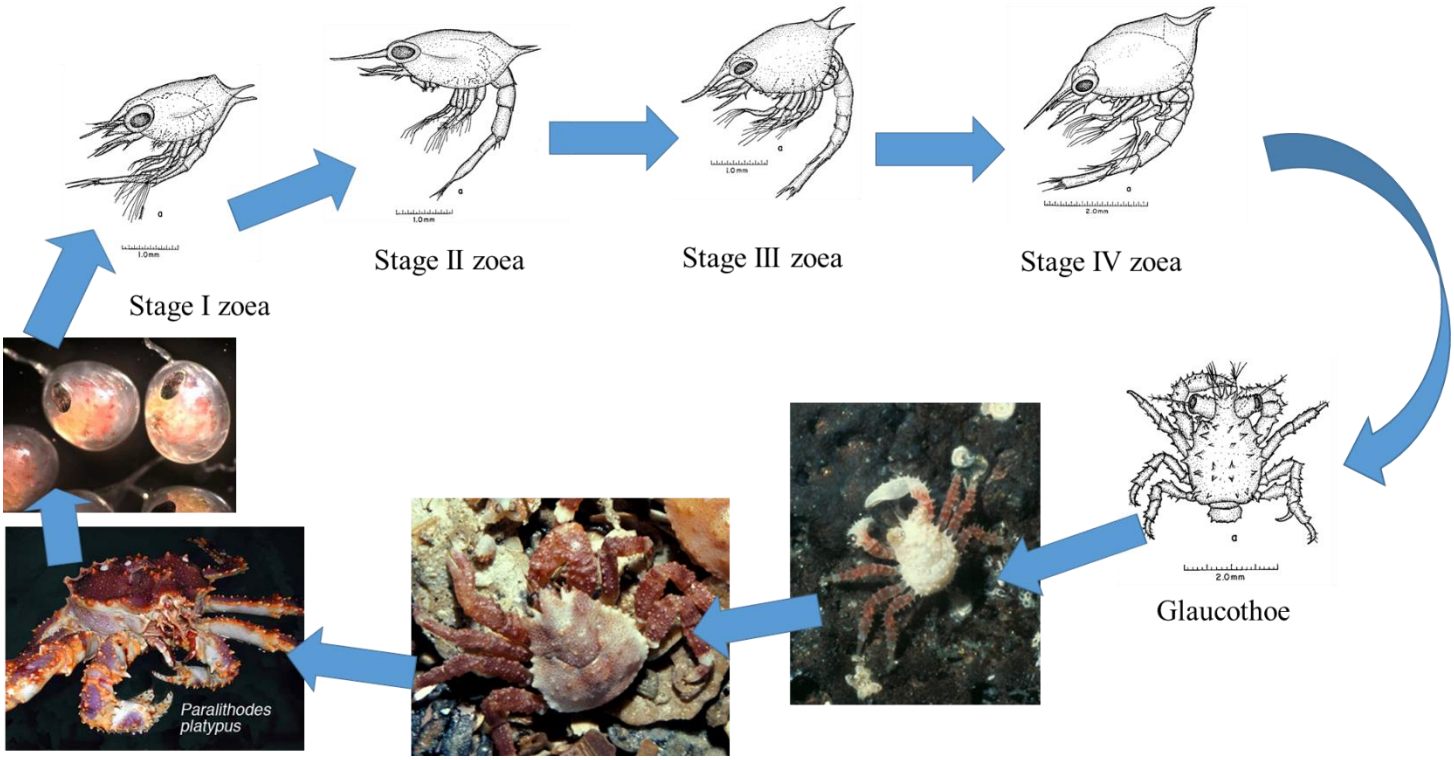


Figure 3. Life history diagram for blue king crabs.

START: Adult male and female blue king crabs mate and the female broods the embryos for 12-14 months

You hatch from the egg over the course of about 30 days and begin life as a planktonic, larval crab

Stage I zoea

Spring bloom of phytoplankton: using your limited vertical motion, you hunt for food. Move ahead 1 space.

Stage II zoea

You hide successfully during the day by staying deeper in the water column and avoid predation

You are nearing the end of your larval stage, and enter the final stage of your larval life as a glaucothoe

Stage IV zoea

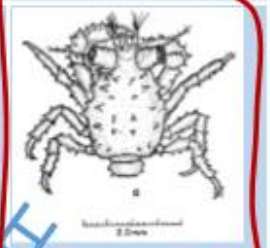
As you grow larger, you are able to eat zooplankton! Move ahead 2 spaces.

Stage III zoea

OH NO! You are eaten by a predator! Return to START and begin again.

Warm water increases your development! You can't eat enough food to support your rapid growth, so you perish. Try again!

You drifted in ocean currents away from your mother's home range at the Pribilof Islands to St. Matthew Island! But you're on shell hash, so safe! Move ahead 3 spaces.



Glaucothoe

You are ready to metamorphose into the juvenile stage. But you settled onto sand! Lacking protection, you are quickly eaten by a fish! Return to START.

You settle onto shell and gravel substrate and metamorphose into the juvenile stage (first instar). You are now benthic for the remainder of life!

You molt successfully several times and are able to stay hidden from predators!

The juvenile phase of crab life has the highest rate of mortality due to predation. You are eaten by a Pacific cod. Return to START and try again.

You survive 5-6 years of growth as a juvenile and finally mature into an adult crab, ready to reproduce.

As a juvenile blue king crab, you lack the protective spines relative the red king crab, and you are eaten by an octopus. Return to START and try again.

With each molt you grow a little bigger and are a bit more protected. Your shell disguises you perfectly on shell hash. Move ahead 3 spaces.

You are growing steadily, and need to molt again. After you emerge from your old shell, you are eaten by a yellowfin sole! Return to START and try again.

You are an opportunistic feeder, eating almost anything you can find on the ocean floor. You grow larger as you continue to molt and find food. Move ahead 1 space!

You are a mature adult crab and are ready to mate, but you cannot find another crab to mate with! Move back 1 space.

You are captured by fishermen! Are you a male or female crab? If you are a male, you are killed. Return to START and try again. If you are a female, you are thrown back. Move back 1 space.

If you are a female crab, you molt, mate, and begin carrying the next clutch of eggs. Move ahead 1 space.

Whether you are a male or female crab, both are susceptible to by-catch mortality! Move back 4 spaces.

HURRAY! You have completed the life cycle of a blue king crab

FINISH.