Biological Field Techniques for Lithodid Crabs

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Contents

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Preface

This field guide primarily concerns four commercially fished species of king crabs in the North Pacific Ocean and Bering Sea, namely *Paralithodes camtshaticus*, *P. platypus*, *Lithodes aequispinus,* and *L. couesi*. The information also may be applicable to other related species. This publication is complementary to *Biological Field Techniques for Chionoecetes Crabs* (Jadamec et al. 1999) and is designed to mirror that publication where appropriate.

State, federal, and university scientists have used different criteria when collecting data on king crabs. This leads to problems in data compatibility and interpretation. The intent here is to allow for standardization of data collection by fisheries observers, shoreside samplers, shellfish scientists, and fishermen. Such standardization would improve data accuracy, and thus promote better management of these commercially important crabs. When data are collected citing this publication, there should be little or no ambiguity as to measurements taken and definitions used. This guide is not all inclusive, but is intended to identify structures and organs, measurements and descriptions, and techniques that are commonly used in lab and field studies on king crabs.

About Nomenclature

The family Lithodidae (stone or king crabs) has 16 genera and 95 known species. King crabs are among the largest arthropods. The term *Lithodes* is derived from the Greek lithos, meaning stone, and eidos, meaning form. Therefore, the genus name *Lithodes* can be taken to mean "resembling a stone" or to "have a stony nature or structure."

Several common names have been used interchangeably with this group of crabs. Most confusion has been with the common name of *L. aequispinus*. The accepted common name is "golden king crab" (Williams et al. 1989); however, the term "brown king crab" is commonly and incorrectly used in Alaska (see State of Alaska 2003). "Brown king crab" correctly refers to *Paralithodes brevipes* (Dawson 1989). There also remains confusion concerning the correct spelling of the specific names for red and golden king crabs. These issues have been clarified for *P. camtschaticus* (Shirley 1990) and for *L. aequispinus* (Shirley 2002).

King crabs belong to the infraorder Anomura. The term anomura refers to those crabs or stalk-eyed crustaceans with "unsymmetrical tails." This is somewhat of a misnomer as there are many anomurans that have perfectly symmetrical tails. The meaning of anomura may have been in the Greek sense of "anomalos," uneven, irregular, inconsistent, abnormal, unusual, and deviating from the regular rule. This meaning would have been applied to differentiate these crabs from the "true" crabs or Brachyura to which *Chionoecetes* crabs belong (Rafael Lemaitre, National Museum of Natural History, Washington D.C., Oct. 2003, pers. comm.). For reviews of nomenclature, see Dawson 1989 and Zaklan 2002.

1. Taxonomy

The king crabs were originally described by Tilesius (1815) as a member of the genus *Maja*, family Majidae. Latreille (1829) recognized that king crabs were not brachyurans but rather anomurans, and consequently transferred king crabs to the genus *Lithodes*. Bouvier (1896) split the genus *Lithodes* primarily on the basis of the different pattern of calcification of the plates of the second abdominal segment of the abdomen, and erected the genus *Paralithodes* for those forms with five distinct plates separated by well defined sutures (Bright 1967).

Classification of the genera Lithodes Latreille 1806 and Paralithodes Brandt 1850

Phylum:	Arthropoda
Subphylum:	Crustacea
Class:	Malacostraca
Subclass:	Eumalacostraca
Superorder:	Eucarida
Order:	Decapoda
Suborder:	Pleocyemata
Infraorder:	Anomura
Superfamily:	Paguroidea
Family:	Lithodidae
Genus:	*Lithodes, Paralithodes*

Species:

P. camtschaticus (Tilesius 1815), red king crab
P. platypus Brandt 1850, blue king crab
L. aequispinus Benedict 1895, golden king crab
L. couesi Benedict 1895, scarlet king crab

A taxonomic key to the four species of king crabs commercially fished in Alaska waters is presented on pages 2–5.

Photos and life history information for other species of related lithodid crabs that occur in the North Pacific Ocean and Bering Sea are presented in Appendix 1.

Key to Species of King Crabs (*Paralithodes* and *Lithodes*)

1a. Rostrum spine 1 ends in a single sharp-tipped projection. Second abdominal segment is covered by five distinct plates (Fig. 1) .....**2a** *Paralithodes* spp.

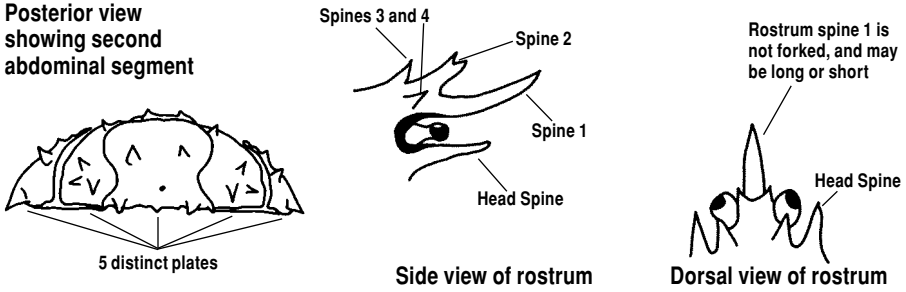


Figure 1. Posterior view of the second abdominal segment, and side and dorsal views of the rostrum showing the key characteristics of Paralithodes crabs. (S. Byersdorfer)

1b. Rostrum spine 1 is divided into a paired tip and rostrum has a large, down-curved spine in side profile. Second abdominal segment plates are completely or partly fused; there are fewer than five in number (Fig. 2) .....**3a** *Lithodes* spp.

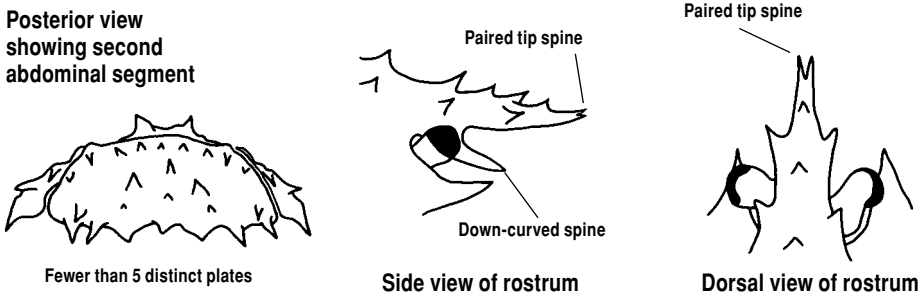


Figure 2. Posterior view of the second abdominal segment, and side and dorsal views of the rostrum showing the key characteristics of Lithodes crabs. (S. Byersdorfer)

2a. Mid-dorsal plate of carapace usually has three pairs of prominent spines. Antennal scaphocerite in form of a sharp spine. Carapace surface more spinous in young specimens than in adults. Live specimens are red to reddish-purple dorsally (Fig. 3a).

Red King Crab, *Paralithodes camtschaticus*

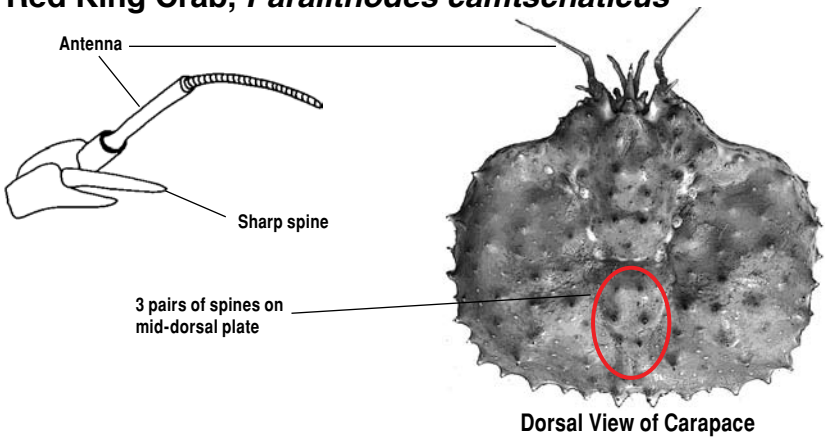


Figure 3a. Dorsal carapace view of mature male red king crab showing mid-dorsal plate spination and antennal scaphocerite. (S. Byersdorfer)

2b. Mid-dorsal plate of carapace bearing two pairs of large spines. Antennal scaphocerite in form of a long biramous spine. Live specimens are dark blue or yellow/blue dorsally (Fig. 3b).

Blue King Crab, *Paralithodes platypus*

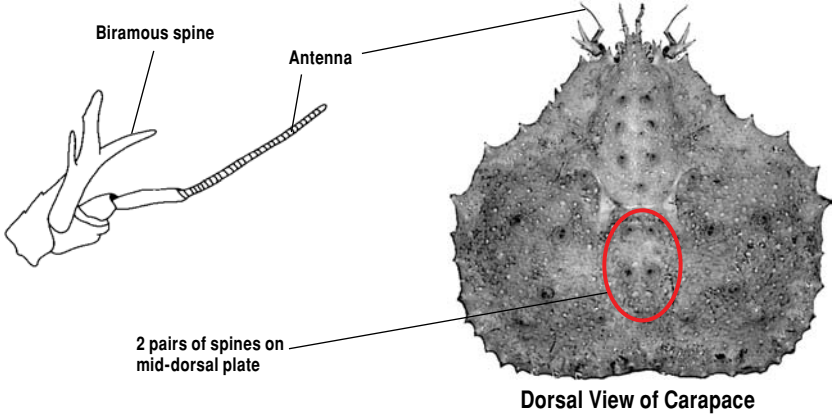


Figure 3b. Dorsal carapace view of mature male blue king crab showing mid-dorsal plate spination and antennal scaphocerite. (S. Byersdorfer)

3a. Carapace covered in spines approximately equal in length. Spines of the lateral margins are equal in length or slightly larger than those on dorsal surface. Rostrum has fairly broad base and is armed with 9 to 10 spines. Mid-dorsal plate of carapace has 5 to 9 spines. Live specimens are golden (Fig. 4a).

Golden King Crab, *Lithodes aequispinus*

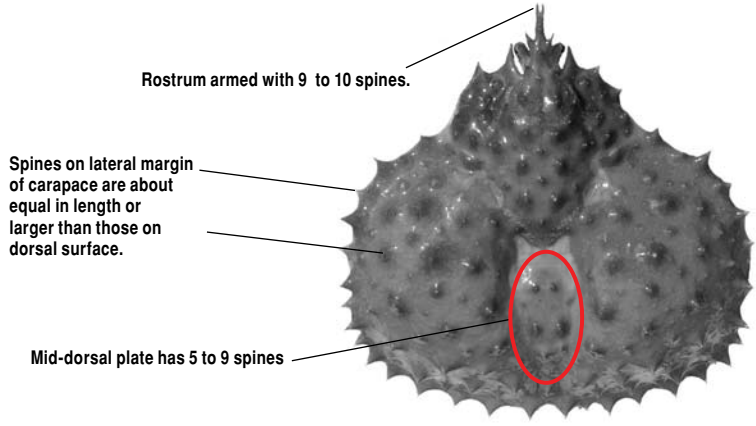


Figure 4a. Dorsal carapace view of mature male golden king crab showing mid-dorsal plate spination, lateral spines, and rostrum length/width. (S. Byersdorfer)

3b. Carapace covered in spines of different lengths; at least 2 of the spines on the lateral margins are distinctly longer than the spines of the dorsal surface of the carapace. Rostrum is long and slender, and armed with 7 spines. Mid-dorsal plate is narrow relative to *L. aequispinus* and has 4 to 6 spines. Live specimens are brick red to pinkish (Fig. 4b).

Scarlet King Crab, *Lithodes couesi*

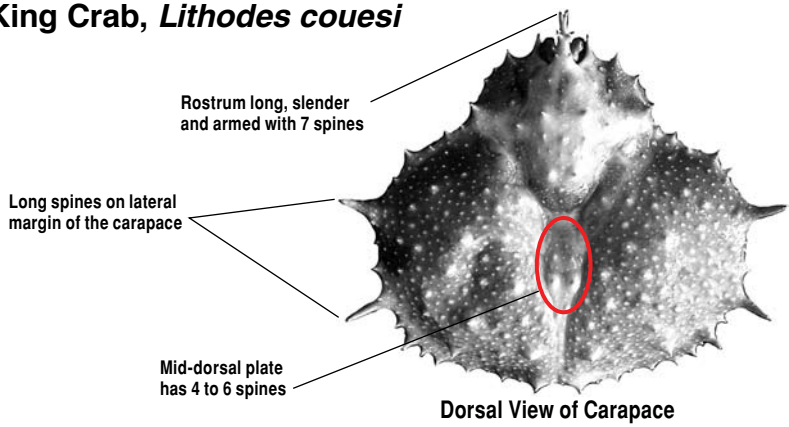


Figure 4b. Dorsal carapace views of mature male scarlet king crab showing mid-dorsal plate spination, lateral spines, and rostrum length/width. (S. Byersdorfer)

Paralithodes camtschaticus,
red king crab, has 6 prominent spines on mid-dorsal plate.

Paralithodes platypus,
blue king crab, has 4 prominent spines on mid-dorsal plate.

Lithodes aequispinus,
golden king crab, has 5–9 spines on mid-dorsal plate.

Lithodes couesi,
scarlet king crab, has 4–6 prominent spines on mid-dorsal plate.

Figure 5. Comparison of color and mid-dorsal spine patterns for four species of king crabs. (S. Byersdorfer)

2. Life History

King crabs are anomuran decapods belonging to the family Lithodidae. Red king crabs and blue king crabs are considered shallow water species while golden and scarlet king crabs are deepwater species.

King crabs are not considered "true" crabs, as are the brachyurans. Distinguishing king crab characteristics include asymmetrical abdomen, asymmetrical 1st pair of walking legs, and modified 5th pair of walking legs, which are hidden inside the branchial chambers.

The available information on these four species of king crabs is incomplete. Red king crab life history is best understood. Much of what is known about the life history of these four species has been summarized in Appendices 2–4. The appendix tables are from NPFMC (1998) and Zaklan (2002), and have been modified and reproduced here.

The following text presents a brief and general life history based on available literature. Where not specific, the text is based on literature for red king crabs. For more specific information by species, refer to the appendix tables.

Prior to mating, female king crabs must shed their old shells and produce a new one in a process called molting. Immature females with ripe ovaries that are ready to mate for the first time are referred to as pubescent or adolescent. As they prepare to undergo the molting process, it is thought that they release pheromones into the water that are detectable by male crabs for up to several weeks before the molt.

When a male locates a female, he grasps her first anterior pair of legs in his claws called chelae and holds her facing himself for up to several days. This behavior is called "hand-holding or grasping." Soon the female begins to molt, her old shell separates, and within a 15 minute period she wriggles out of her old shell and is covered in a new, softer shell. At the same time she absorbs water and swells up, thus growing in size. After the female has molted, the male releases the old shell and delicately regrasps the softshell female. The male then places her upside-down and beneath him, and inserts his ventral surface between her abdominal flap and body. Males extrude strings of sperm packets (spermatophores), from the opening at the base of their 5th pair of legs. Using the brushy tip of these legs, he spreads the spermatophores onto the carapace area around the gonopores of the female. This process may require several attempts over a period of hours. After copulation, the male releases the female and shows no further interest.

Females extrude their ova from paired openings (gonopores) on the underside of the second walking legs. Upon exposure to seawater, a sac forms around each ovum, which attaches itself to the small hairs of the pleopods. During this process sperm from the spermatophores fertilize the ova. Female king crabs cannot store sperm.

Therefore, they must mate when ready to extrude ova. If a male does not fertilize a female with ripe ovaries, she may resorb ova inside of her body and not extrude them (Paul and Paul 1997). Alternately, she may extrude the unfertilized eggs, which will later be lost. The success rate of fertilization depends on male size and mating history. The proportion of eggs fertilized by small red king crab males less than 90 mm carapace length (CL) declines from 68% on their first mating to 12% on their third, whereas males > 135 mm CL can fertilize up to four females with 100% success (Paul and Paul 1990, Paul and Paul 1997).

Females producing their first clutch of eggs immediately after reaching sexual maturity are called primiparous. Those producing their second and additional clutches are called multiparous. The number of eggs produced by each female (fecundity), increases linearly with female body size in weight.

Embryos are incubated on the abdomen of females for 11–12 months. After hatching, larvae pass through four zoeal and one glaucothoe stage (Fig. 6). Hatching (eclosion) of red king crabs usually occurs concurrent with the spring phytoplankton bloom; early stage zoeae are primarily herbivorous, but later zoeal stages become increasingly zooplanktivorous (Shirley and Shirley 1989). Primiparous females hatch their eggs earlier than multiparous females, having been able to mate, extrude eggs, and begin brooding earlier the prior year (Shirley et al. 1990).

Each zoeal instar lasts approximately two weeks, but this varies with water temperature. Settlement of glaucothoe usually occurs in early July, but this varies with hatching date and water temperature (Shirley and Shirley 1989). The glaucothoe metamorphoses into the first instar, which takes up a benthic existence. Soon after settlement and metamorphosis to the first crab stage, juvenile red king crabs are considered to be in their "early benthic phase" (Loher 2001). Crabs in this stage are highly susceptible to predation. This period of their benthic life is probably the most dangerous, and has the highest mortality because they are too small to escape large predators. In the Bering Sea, major predators of small crab include Pacific cod *Gadus macrocephalus*, Pacific halibut *Hippoglossus stenolepis*, Alaska plaice *Pleuronectes quadrituberculatus*, yellowfin sole *Limanda aspera*, flathead sole *Hippoglossoides elassodon*, arrowtooth flounder *Atheresthes stomias*, walleye pollock *Theragra chalcogramma*, Pacific herring *Clupea pallasi,* and sockeye salmon *Oncorhynchus nerka* (Livingston and Ward 1993, Loher 2001). Predation by these commercially important fish is well documented; however, major predation also occurs by noncommercial species though it is less well documented. Those species include sculpins *Myoxocephalus* spp., Irish lords *Hemilepidotus* spp., snailfish *Liparis* spp., and skates *Raja* spp.

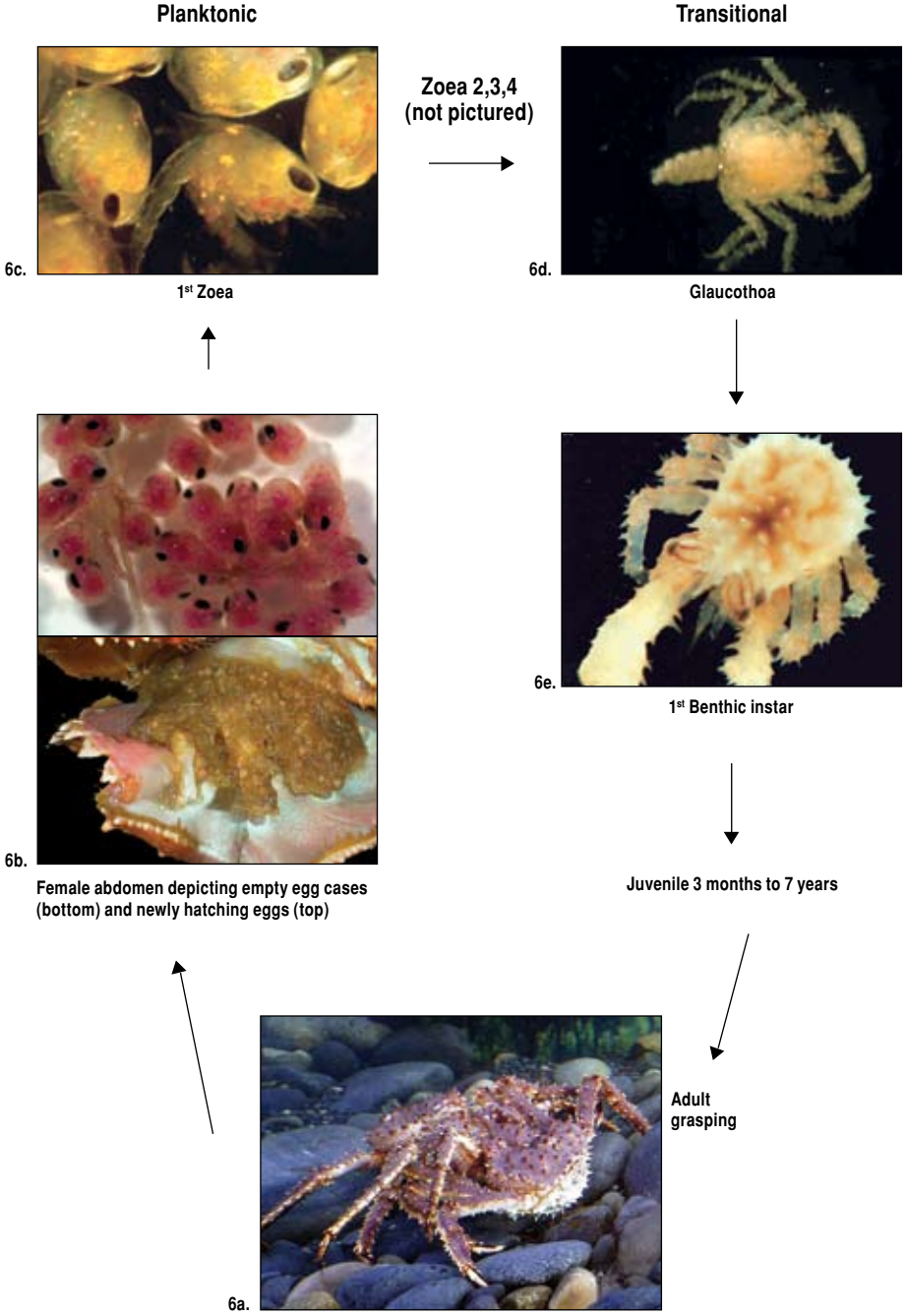


Figure 6. Generalized red king crab life cycle showing grasping adults through the first benthic instar. (a. J. Haaga. b-e. S. Byersdorfer)

Another major predator, and perhaps one of the most significant, is the larger king crab. Up to age 1, juvenile red king crabs are found on the same type of structurally complex habitat that is preferred by the settling stages. The presence of larger king crabs in such habitats could be a major limitation to successful recruitment (Loher 2001).

At about 1–2 years of age, red king crabs begin to move to deeper water and gather into vertical piles. These piles are referred to as pods (Fig. 7a). Aggregations and pods have been defined for adult crab by Stone et al. (1993). They are referred to as pods if the majority of individuals are in physical contact with each other and stacked atop each other (Fig. 7b). Structurally dense and socially organized groups of adults are termed aggregations (Fig. 7c). Podding is thought to be an adaptation for predator defense (Powell and Nickerson 1965a, Dew 1990). Podding has not been observed in other lithodid species, but juvenile golden king and scarlet king crabs form dense aggregations (T. Shirley, University of Alaska Fairbanks, Juneau, unpublished observations).

Somerton (1981) noted five adaptations to a deepwater existence for scarlet king crabs: elongated legs, inflated branchial chambers, large exhalent openings, large scaphognathites, and bright red coloration. He noted that the bright red coloration is cryptic at depths inhabited by scarlet king crabs. Inflated branchial chambers, large exhalent openings, and large scaphognathites (appendages in the exhalent openings that pump water) are related to lower oxygen levels at increased sea depth. He stated that enlargement of these features, compared with related shallow-water lithodid crabs, implies that a relatively greater volume of water is pumped over the gills. The reduced musculature in elongated legs is most likely an energy conservation adaptation to great depth where food is scarce. Also, long slender legs may allow more rapid movement by taking fewer but larger steps over the seafloor.

King crabs are opportunistic feeders. In a study of red king crabs at Norton Sound, Alaska, the dominant crab prey items were unidentified fishes, sea urchins, hydroids, polychaete worms, bivalves, gastropod mollusks, crabs, sand dollars, brittle stars, and sea stars (Jewett et al. 1990).

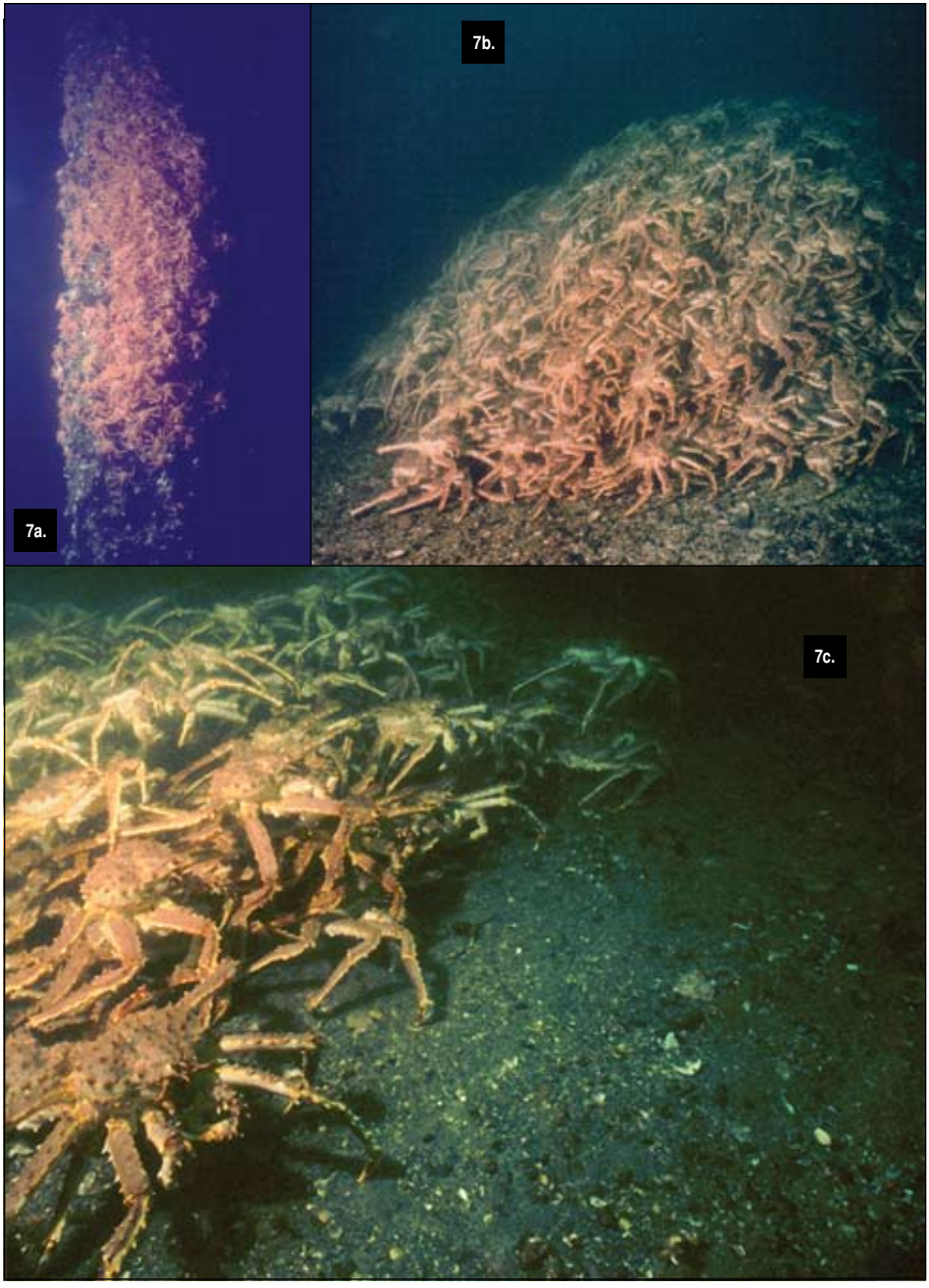


Figure 7. Red king crab pods. a. Pod of age-1 crab resting off-bottom. b. An 8 ft (2.7 m) high resting pod of 9,000 adult and sub-adult male and female red king crabs. c. The same pod as in (b), but now in its foraging mode. (B. Dew, 7c © Ecological Society of America)

3. Distribution

Red King Crabs

Red king crabs occur in the North Pacific: Bering Sea, Bristol Bay, Alaska, U.S.A. (Benedict 1895). Bering Sea to Sea of Japan (Marukawa 1930). Hokkaido, Japan; Cape Gamova, Sea of Okhotsk, eastern Kamchatka to Cape Olyutorsk, Russia; Aleutian Islands and Norton Sound, U.S.A. to Queen Charlotte Islands, B.C., Canada (Makarov 1962). Korea (Kim 1970). *P. camtschaticus* has been successfully introduced into the Barents Sea in the North Atlantic (Jørstad et al. 2002). Distribution in Gulf of Alaska, Bering Sea, and Aleutian Islands waters is depicted in Fig. 8.

Blue King Crabs

Blue king crabs occur in the North Pacific: Sea of Japan, south to Cape Gamova, Vladivostok; Sakhalin, Kurile Island, Kitami, Japan; Korea (Sakai 1976). Sea of Okhotsk, east Kamchatka, Russia; and Bering Strait (Makarov 1962). In Alaska, discrete populations exist around the Pribilof Islands, St. Matthew Island, and St. Lawrence Island. Smaller populations have been found at King Island, Nunivak Island, and Herendeen Bay. In the Gulf of Alaska populations exist at Olga Bay–Kodiak Island and at Port Wells–Prince William Sound, Russel Fiord, Glacier Bay, Lynn Canal, and Endicott Arm–Southeast Alaska (Somerton 1985). Somerton (1985) noted that both *P. camtshaticus* and *P. platypus* occupy the same latitudinal range in the North Pacific but that each species is absent or rare where the other exists. He speculated that the populations of blue king crabs that are present today might be relicts of a former, broader distribution. Somerton (1985) attributed the isolated distribution of *P. platypus* to three mechanisms either singly or in combination: reproductive interference, competitive displacement, and predatory exclusion. Distribution in Gulf of Alaska, Bering Sea, and Aleutian Islands waters is depicted in Fig. 9.

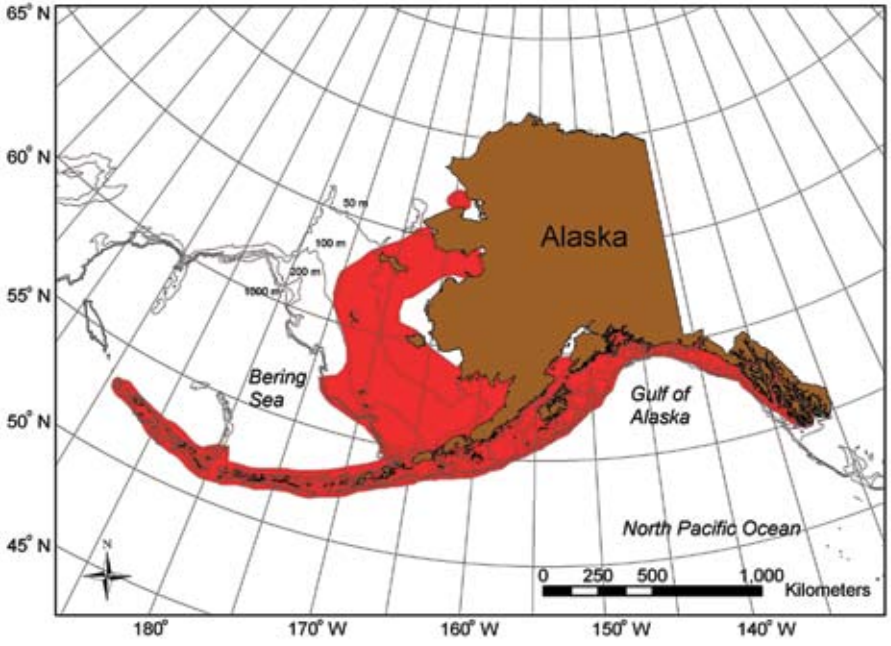


Figure 8. Distribution map of the red king crab Paralithodes camtschaticus in Gulf of Alaska, Bering Sea, and Aleutian Islands waters. (C. Armistead)

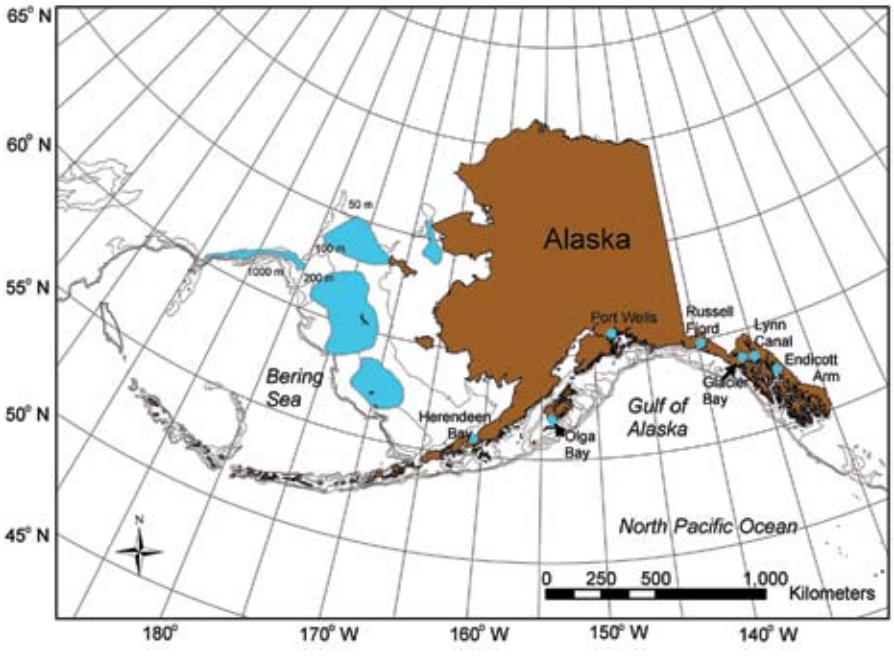


Figure 9. Distribution map of the blue king crab Paralithodes platypus in Gulf of Alaska, Bering Sea, and Aleutian Islands waters. (C. Armistead)

Golden King Crabs

Golden king crabs occur in the North Pacific: Bering Sea, Pribilof Islands; Sea of Okhotsk, Japan (Benedict 1895); east of Siwoya Cape (Makarov 1962) to south B.C., Canada, in the upper continental slope (Butler and Hart 1962); west Sagami Bay (Hiramoto and Sato 1970); Shioya-zaki, and Matsushima, Enoshima (Sakai 1976); and Suruga Bay, Japan (Suzuki and Sawada 1978). Golden king crabs also inhabit the Patton Seamount in the Gulf of Alaska (Hughes 1981). Distribution in Gulf of Alaska, Bering Sea, and Aleutian Islands waters is depicted in Fig. 10.

Scarlet King Crabs

Scarlet king crabs occur in the North Pacific: Bering Sea, north of Unalaska, near the Shumagin Islands, Alaska (Benedict 1895) to San Diego, California (Makarov 1962); N.W. far off Midway Island (32° 03.8′N 172°50.2′E); Kushiro, Shioya-zaki (Takeda 1974); Hokkaido and off Onahama, Japan (Sakai 1976). Scarlet king crabs are common on the seamounts in the Gulf of Alaska (Somerton 1981). Distribution in Gulf of Alaska, Bering Sea, and Aleutian Islands waters is depicted in Fig. 11.

Vertical distribution profiles for adult, juvenile, and reproductive components are depicted for red king crab in Fig. 12a and for blue and golden king crabs in Fig. 12b (NOAA 1990). See also Appendix 3, page 66, and Appendix 4, page 67. Sufficient data are not available to construct profiles for scarlet king crabs.

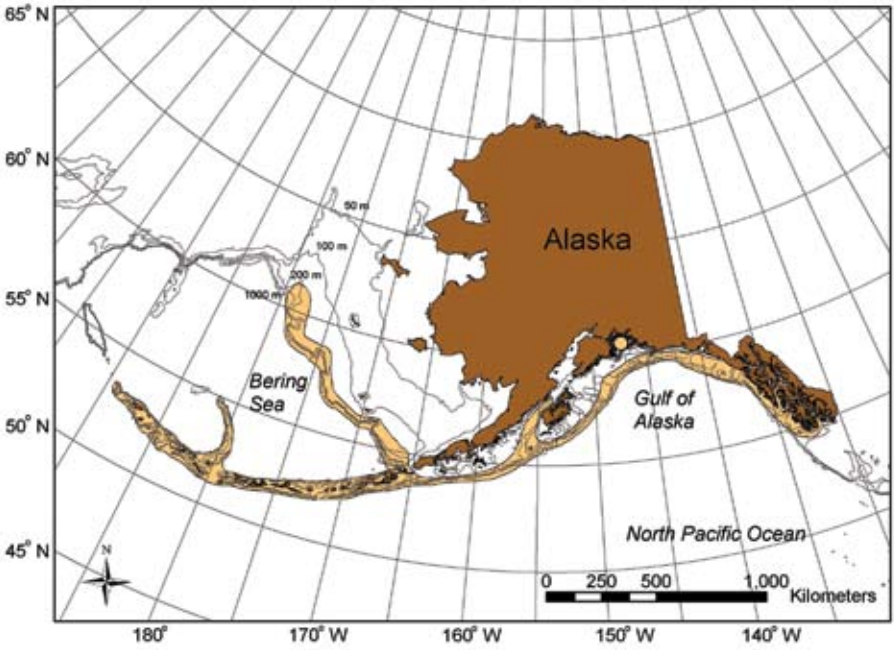


Figure 10. Distribution map of the golden king crab Lithodes aequispinus in Gulf of Alaska, Bering Sea, and Aleutian Islands waters. (C. Armistead)

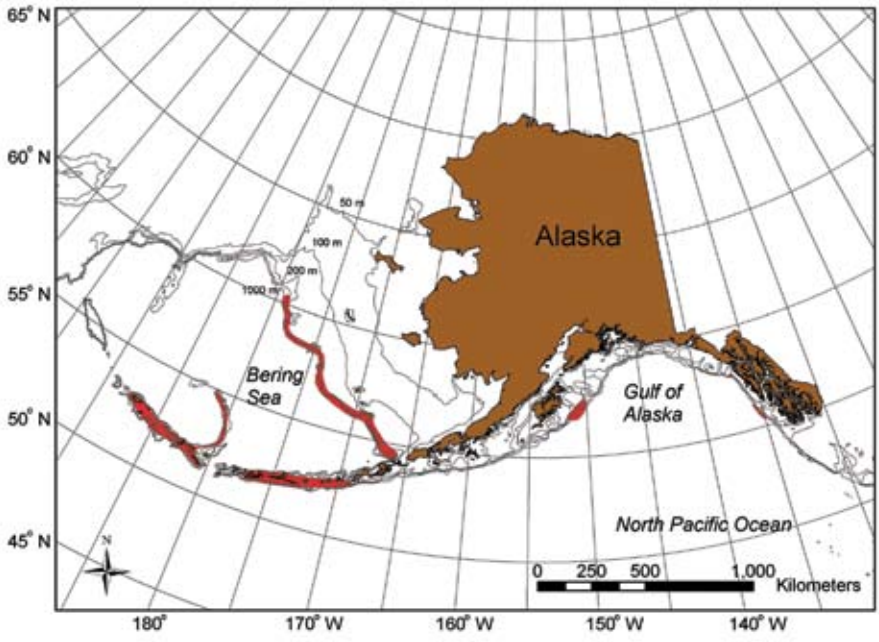


Figure 11. Distribution map of the scarlet king crab Lithodes couesi in Gulf of Alaska, Bering Sea, and Aleutian Islands waters. (C. Armistead)

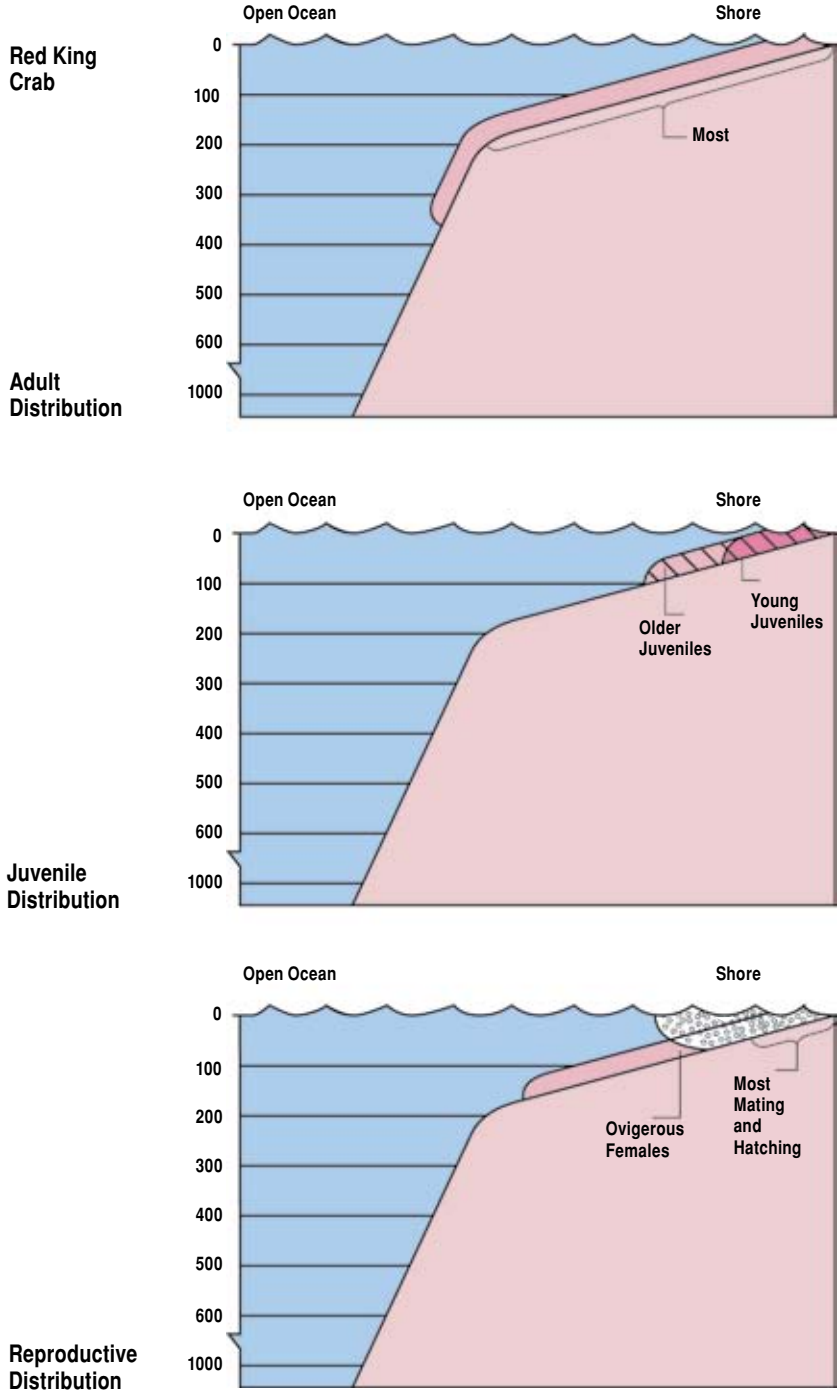


Figure 12a. Adult, juvenile, and reproductive distributions for red king crabs, in meters. (NOAA 1990)

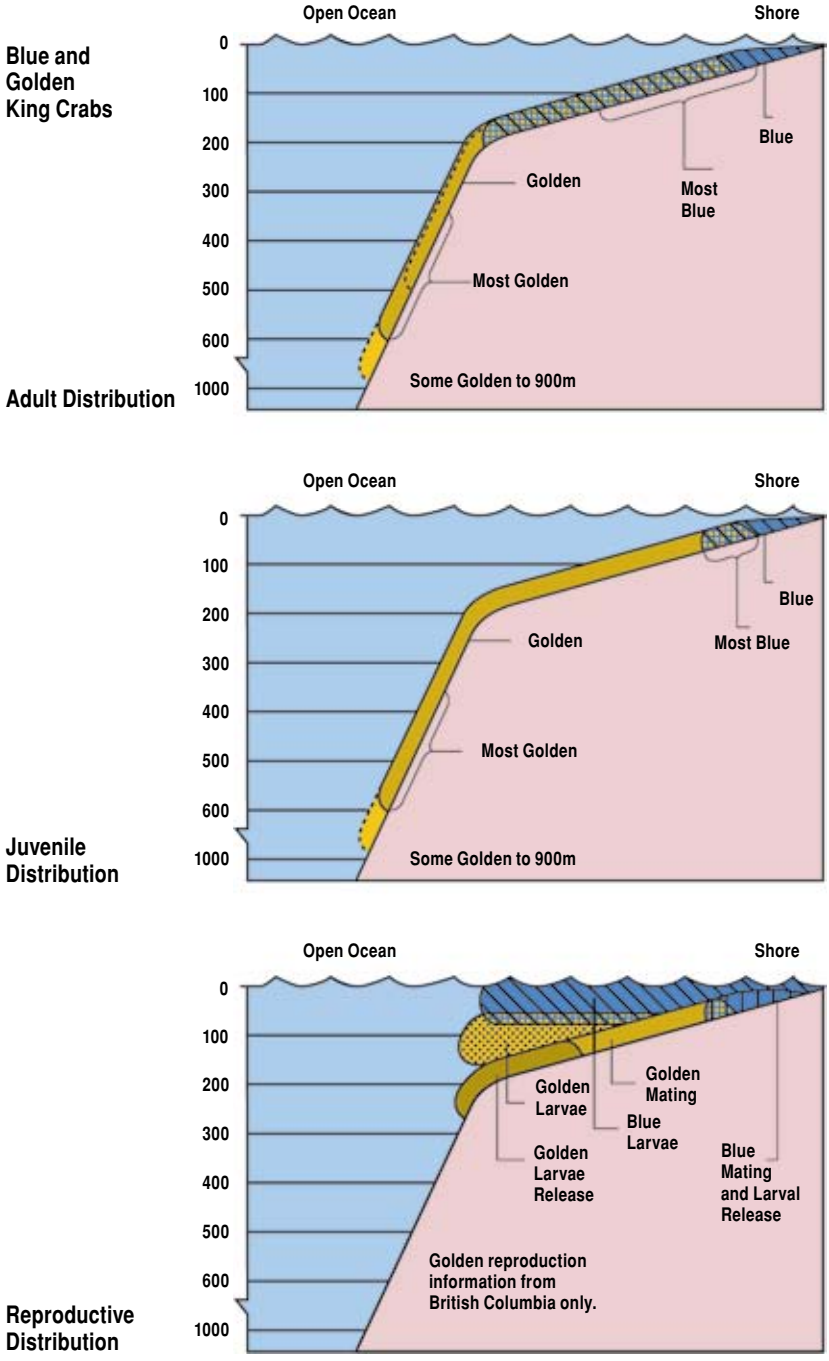


Figure 12b. Adult, juvenile, and reproductive distributions for blue and golden king crabs, in meters. (NOAA 1990)

4. External Anatomy

King crab bodies are composed of a cephalothorax (fused head and thorax) and an abdomen. Dorsally and laterally, the covering of the cephalothorax is referred to as the carapace. The carapace is dorso-ventrally flattened. The abdomen is reduced and reflexed under the carapace. Areas of the cephalothorax include the frontal, gastric, cardiac, and branchial regions (Fig. 13a). Mouth parts and antennae are located on the ventral side of the frontal region. Antennae are lateral to the eyes. The ventral branchial region bears the locomotor appendages (pereiopods). The first pereiopods are modified as the chelipeds. In adult males, the right cheliped is larger than the left and is used in defense, grasping, and holding. The second, third, and fourth pereiopods are walking legs (Fig. 13a). The legs are oriented posteriorly. The fifth pereiopods are rudimentary and tucked into the branchial chambers. In males, they are used to transfer sperm and in females they are used to aerate and clean egg clutches. In both sexes they are used to clean and aerate the gills. Walking legs are composed of seven segments from the proximal coxa to the distal dactyl (Fig. 13b). Two of these (basis and ischium) are fixed into a single segment (basi-ischium). Appendix 5 depicts claw, leg, and carapace abnormalities.

King crabs have the ability to autotomize limbs. Severance takes place at the breakage plane that runs across the basi-ischium (Fig. 14a). Internally there exists a double membranous fold that divides the segment into distal and proximal halves. When a limb is cast off, the plane of severance passes between the two membranes, leaving one membrane attached to the basal stub. The membrane constricts the perforations so that there is very little bleeding. New and intermediate autotomies are shown in Figs. 14b and 14c. An old autotomy will show a patchwork of light and dark areas where the "scabbing" has permanently healed over. In a crab that has autotomized a limb that will not regenerate, the membrane will eventually appear "bumpy or gnarly" (R.A. MacIntosh, NMFS, Kodiak, pers. comm.).

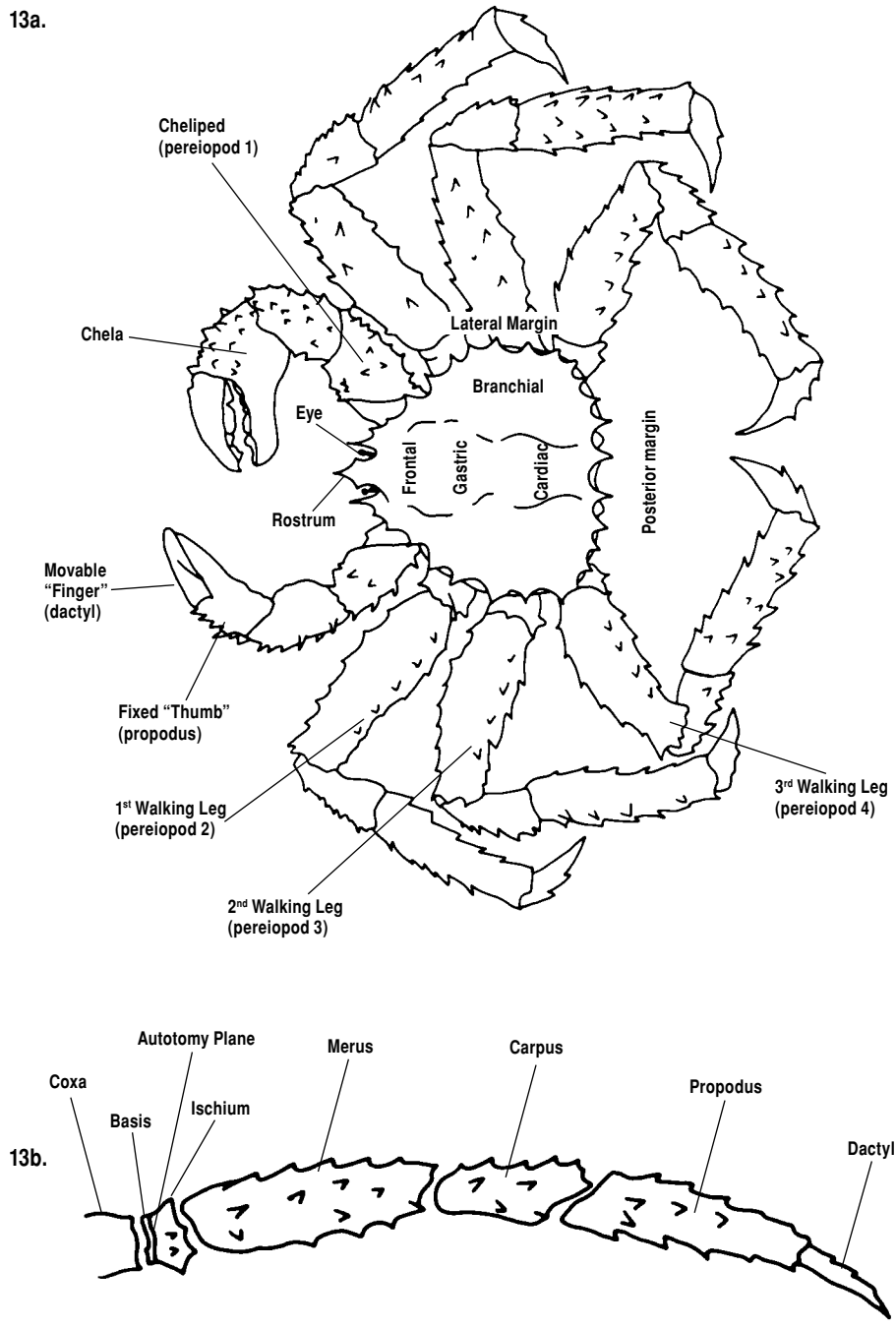


Figure 13. External dorsal anatomy of the exoskeleton showing carapace regions and pereiopods (a) and pereiopod structure (b) of a generalized male king crab (female chelae are symmetrical). (S. Byersdorfer)

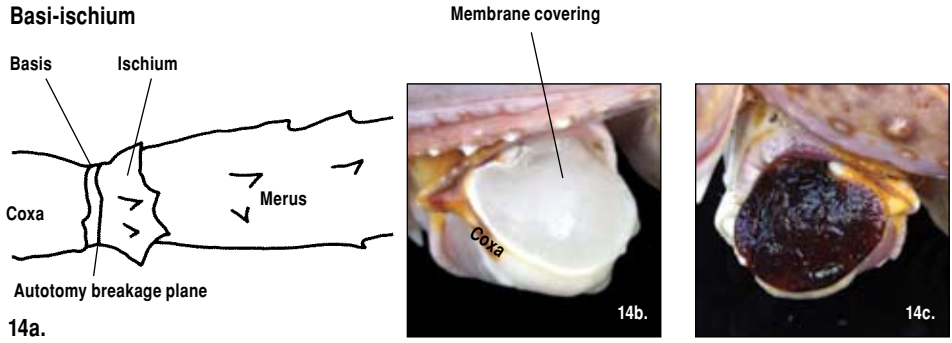
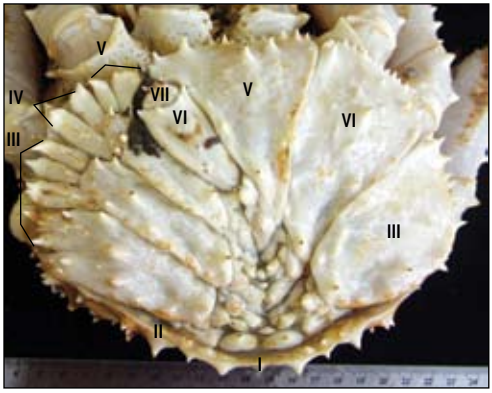


Figure 14. Leg showing autotomy plane (a), fresh autotomy, (b) and intermediate (healed) autotomy (c). (S. Byersdorfer)

The abdominal flap consists of seven major segments or calcareous plates and can be used to determine the sex of the crab and the maturity status of females (Fig. 15a). Male king crabs have symmetrical triangular-shaped abdominal flaps. Adult females have an oval-shaped abdominal flap that covers most of the ventral surface. The calcareous plates are larger on one side. Juvenile females have an oval abdominal flap that covers most of the ventral surface but leaves the coxa of the pereiopods exposed (Fig. 15a–c). The paired gonopores of females, through which eggs are extruded, are located on the ventral surface of the coxa of the third pereiopods or second walking legs (Fig. 15d). Females have five pleopods that are readily observable on their left side when the abdominal flap is opened. These structures are used for egg attachment (see chapter 7).

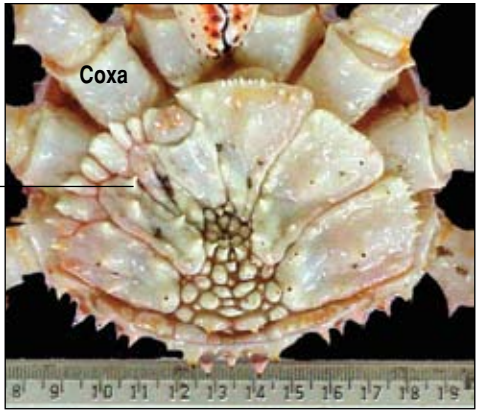
Determining the sex of very small crabs is difficult because the abdominal flap of the female is not fully developed. Sexing of small crabs can be accomplished by observing, with a magnifying lens, whether gonopores and/or pleopods are present (females) or absent (males).

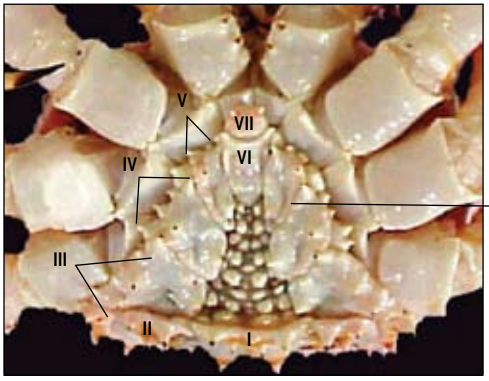
The paired antennae and mouth parts are depicted in Figs. 16a and 16b, respectively.



15a. Mature female crab with oval abdominal flap made up of seven major segments consisting of calcareous plates that cover most of the ventral surface.

15b. Juvenile female crab with oval abdominal flap that covers most of the ventral surface but leaves coxa exposed.

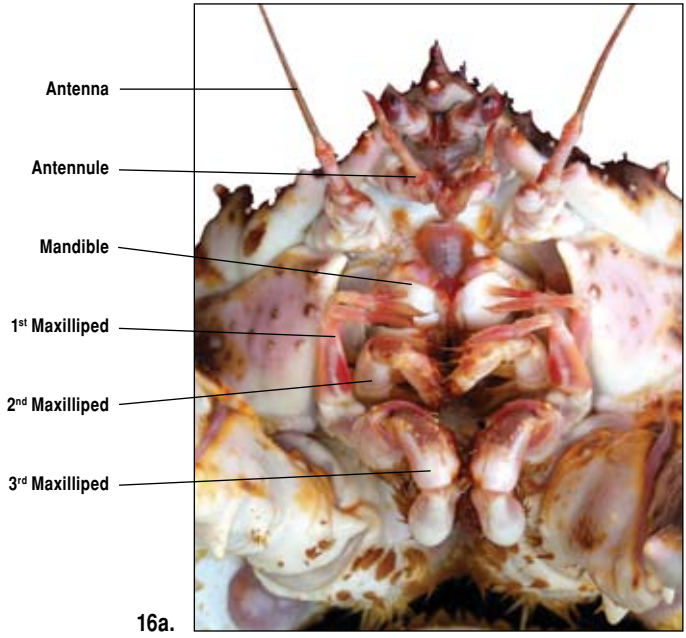




15c. Juvenile and mature male abdominal flaps are triangular in shape.

15d. Gonopore

Figure 15. Ventral views of red king crabs (dorsal view of abdominal flap) identifying sex and maturity status. (a) Mature female. (b) Juvenile female. (c) Juvenile and mature male. (d) Gonopore on 2nd walking leg of female. (S. Byersdorfer)



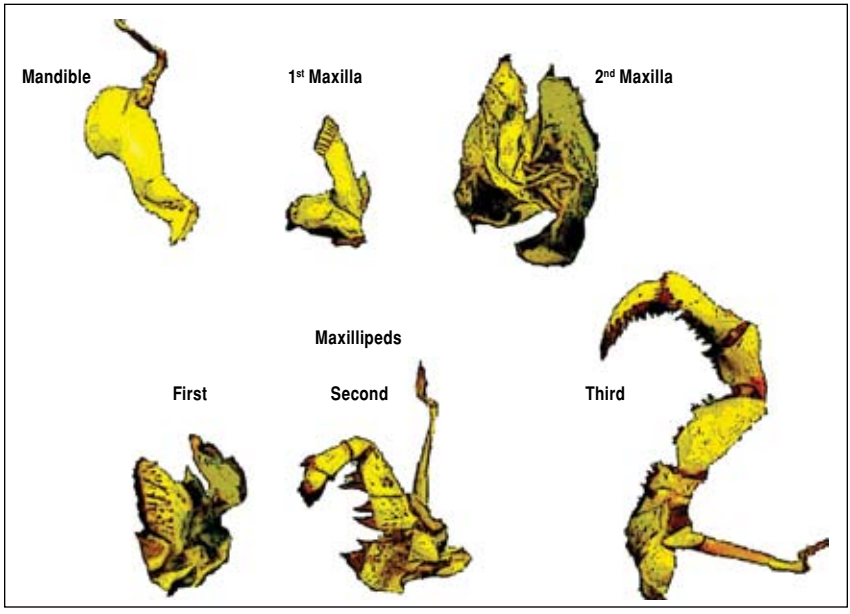


Figure 16. Mouth parts of a red king crab. (a) Anterior view of crab with placement of the antennae, antennule, mandible, 1st, 2nd, and 3rd maxillipeds identified (other mouth parts are posterior to the 1st maxilliped). (b) Mandible, maxillae, and maxillipeds, removed from crab. (S. Byersdorfer)

5. Internal Anatomy

The intent of this section is to facilitate the identification of major organs that may be examined by biologists working in the field and lab. It is not intended to be an exhaustive anatomical depiction. Anatomy descriptions are from Marukawa (1933). Anatomical structures of the alimentary/digestive system and the thoracic nerves are shown in Figs. 17 and 18, respectively.

The alimentary/digestive system consists of a mouth, esophagus, stomach, pyloric pouch, mid-gut, hindgut, and anus. The alimentary gland is the hepatopancreas. The alimentary system also includes a pair of intestinal and one abdominal caecum. King crab

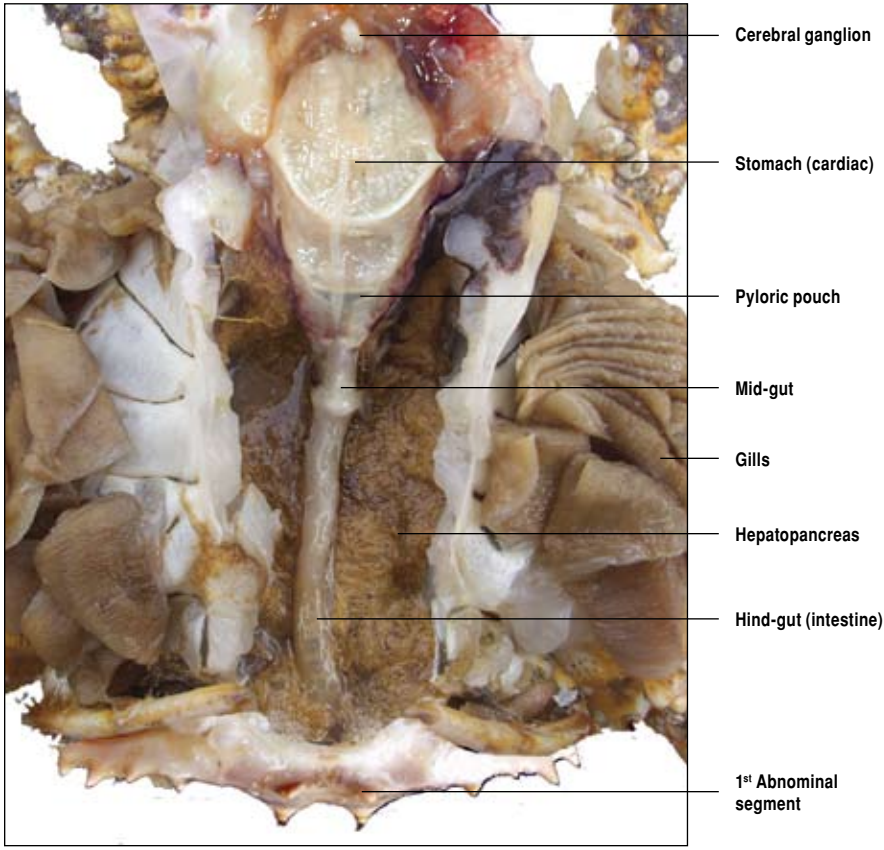


Figure 17. Dorsal view of adult male red king crab with carapace and heart removed showing the digestive system, cerebral ganglion, and gills. (S. Byersdorfer)

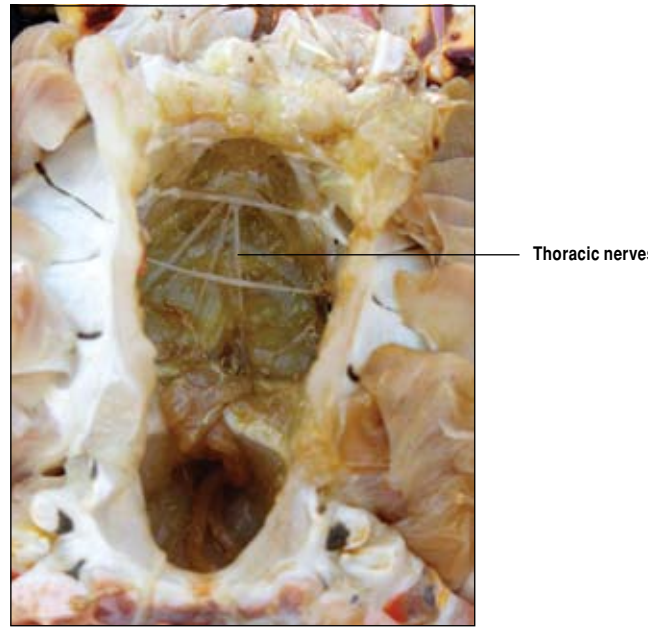


Figure 18. Dorsal view of adult male red king crab with carapace removed showing thoracic nerves. (S. Byersdorfer)

stomachs are masticatory and are divided into two sections, the cardiac and pyloric. The cardiac section is sac-like and larger than the pyloric. Food is shredded by the mandibles, enters the mouth, and passes down the esophagus and into the mid-gut where digestion begins. The gastric mill consisting of chitinous teeth in the stomach grinds food into tiny particles. Final digestion occurs in the hindgut. Waste material is excreted by the green gland and through the anus. The green gland is located at the posterior portion of the brain and along both sides of the stomach and the anterior portion of the heart. It appears as a greenish-spongelike mass. Excretions occur from the opening at the basal part of the antennae via a slender duct. The anus is located on the last segment of the abdominal flap.

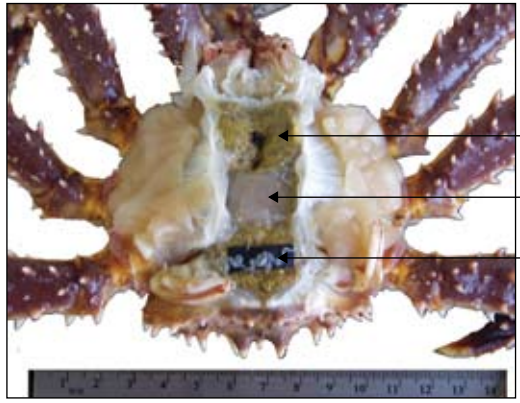
The nervous system is composed of two well-developed stalked eyes that are connected to the brain at the anterior terminus by the optic nerves. The brain is located immediately behind the eyes below the basal part of the rostrum and is rectangular in shape. Six well-developed nerves stem from the brain: the esophageal commissure, tegumentary, antennule, antennary, oculomotor, and optic. When the carapace is removed the brain can be found adhering to the frontal region.

The respiratory system is composed of gills, which are located in two branchial chambers, one on each side of the carapace. Each chamber contains 11 gills.

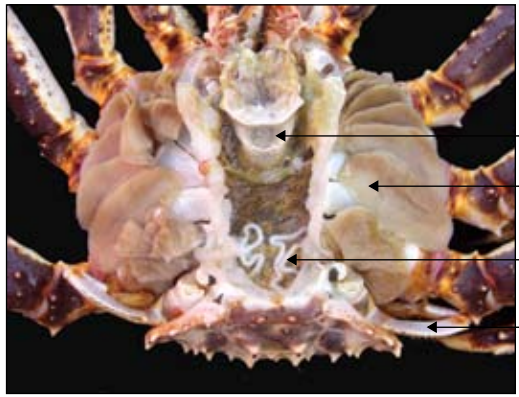
The circulatory system is composed of the heart, arteries, and pericardial cavity. Venous blood flows through the space (the hemocoel) between the various organs. In the gills, carbon dioxide, which has been picked up from the body tissues, is exchanged for oxygen. The branchial sinus leads the venous blood through the branchial lamellae, where it becomes oxygenated and returns via the branchial artery. The arterial blood then passes from the branchial vein and enters the pericardial sinus and flows out of the heart.

Both sexes have paired gonads. The testes are located primarily in the middle portion of the body; a small portion extends into the first and second abdominal segments (Marukawa 1933). The testes contain the seminiferous tubules where the spermatozoa are generated. The reproductive organs of the female consist of the ovaries and oviducts. The ovaries are located dorsal to the hepatopancreas. The oviducts connect to the ventral sides of the exopodites of pereiopods 3 (2nd walking legs).

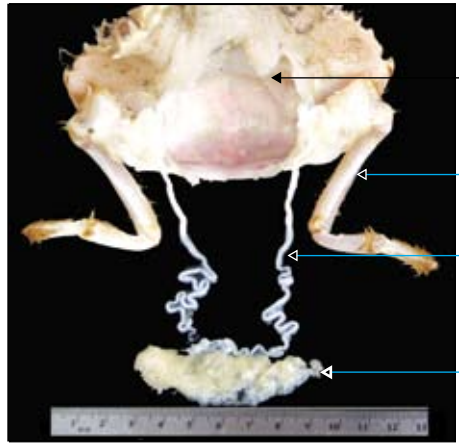
The major anatomical structures for a male red king crab when the carapace is first removed are shown in Fig. 19. Ovaries and egg clutches of juvenile and mature females are contrasted in Fig. 20.



19a.



19b.



19c.

Figure 19. Dorsal view of male red king crabs with the carapace removed. (a) Vas deferens typical of a juvenile male; also identified are the heart and hepatopancreas. (b) Vas deferens typical of sexually mature males (note darkened gills, characteristic of a very old shell male). (c) Abdominal flap of a mature male showing testis and vas deferens attached to the 5th walking leg. (S. Byersdorfer)

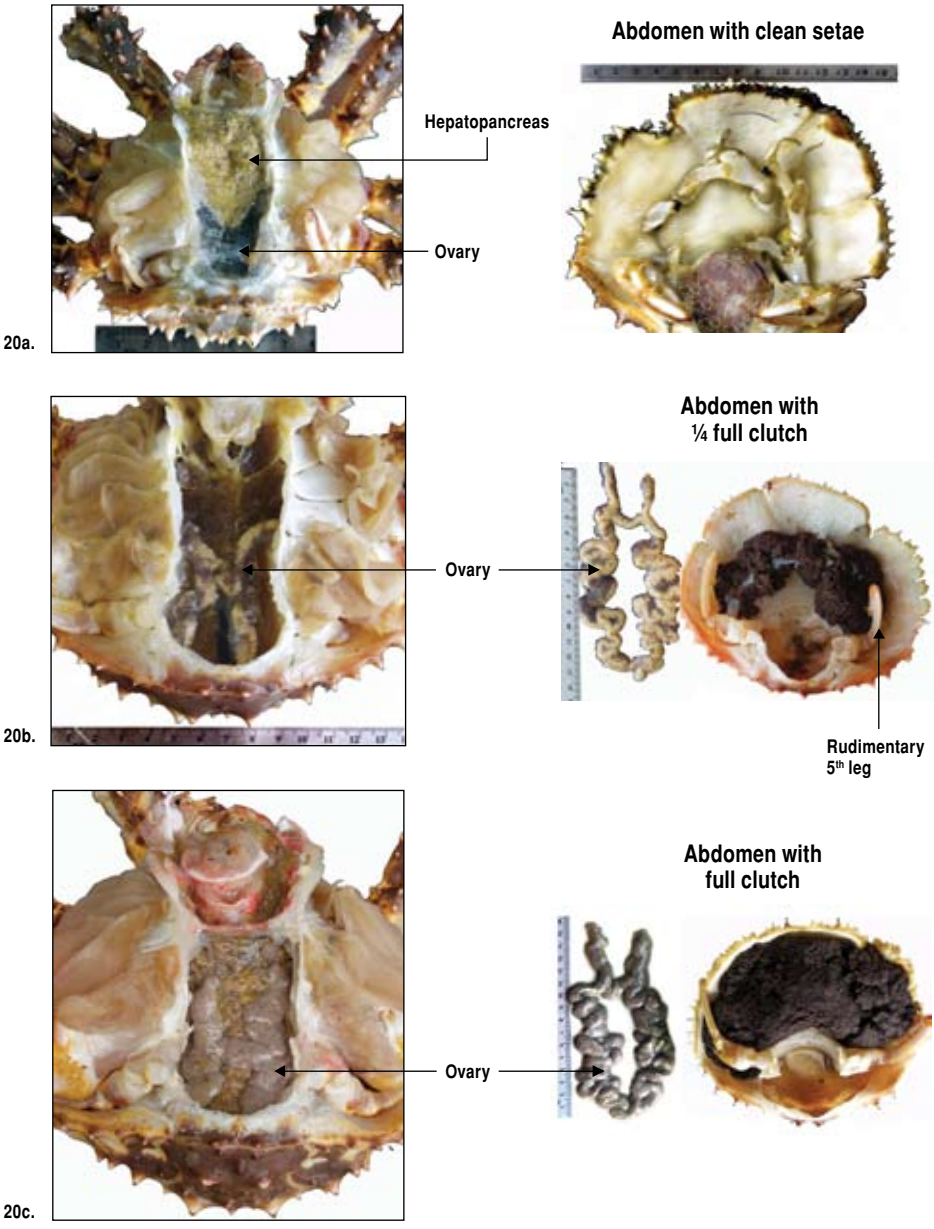
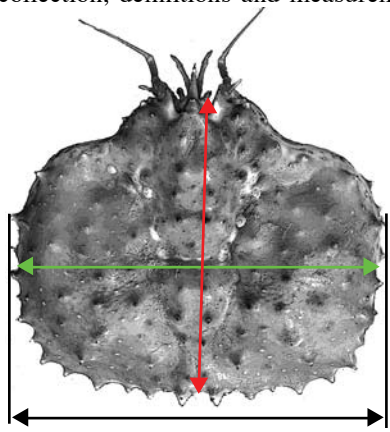


Figure 20. Dorsal view of female red king crabs with carapace removed. (a) Ovary in juvenile crab with clean setae. (b) Ovary in body cavity and removed from mature post-molt crab with ¼ full clutch. (c) Ovary in body cavity and removed from adult crab with full clutch. (S. Byersdorfer)

6. Morphometrics

A series of morphometric measurements in millimeters are routinely collected from king crabs. The carapace width measurement used by research biologists is different from the carapace width used to determine legal status for retention in Alaska fisheries. To allow standardization of data collection, definitions and measurements are depicted in Figs. 21a through 21d.



21a. Dorsal view of a king crab showing carapace measurements:

Carapace width (biological): The greatest straight-line distance across the carapace excluding spines.

Carapace width (legal): The greatest straight-line distance across the carapace including spines.

Carapace length (biological): The straight-line distance across the carapace from the posterior margin of the right eye orbit to the medial-posterior margin of the carapace.

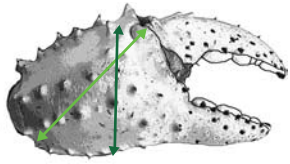


Figure 21b. Lateral view of the right chela of a male king crab showing the following measurements:

Chela height: Greatest height measured on right chela excluding spines.

Chela length: Length measured diagonally on right chela.

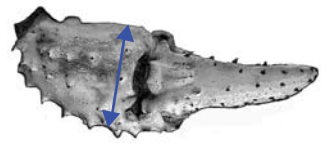


Figure 21c. Dorsal view of the right chela of a male king crab showing chela width.

Chela width: Greatest width of right chela excluding spines.

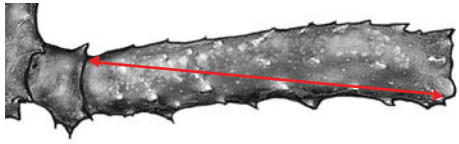


Figure 21d. Lateral view of the right merus of a male king crab showing merus length

Merus length: Length of merus usually taken on longest leg, i.e., third pereiopod (middle walking leg). (Measurement should be a diagonal line from upper proximal to lower distal notch.)

Figure 21. Morphometric measurements that are routinely collected from king crabs. (S. Byersdorfer)

7. Egg Condition, Clutch Fullness, and Reproductive Cycle

Egg Condition

Embryonic development stage and egg color are used in combination to assess "egg condition." Egg condition plus an estimate of clutch fullness is used to assess the reproductive status of a female king crab. As embryos develop inside eggs, eyespots become visible. Egg color, egg development time, and reproductive seasons vary between the four species. Egg color and development for red, blue, golden, and scarlet king crabs are shown in Figs. 22 and 23.

The variability between species must be noted when using female reproductive indices to measure a population's reproductive status (Table 1, Appendix 2). Egg condition categories and color variables used for the four species are:

- No eggs present
- Uneyed eggs present plus egg color
- Eyed eggs present plus egg color
- Hatching eggs
- Matted setae; dead eggs and empty egg cases

The information in Table 1 will aid in determining egg condition and development stage. A color chart is presented in Appendix 6 that can be used as a standard reference for describing colors.

Table 1. Reproductive indices for king crabs

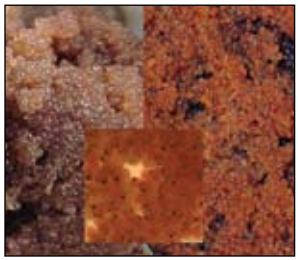
Red king crabs		**Reference**
Reproductive cycle	12 mo	Marukawa 1933, Stevens and Swiney unpubl. manuscr.
Seasonal breeding migration	Late winter/spring to shallow water	Marukawa 1933, Hayes and Montgomery 1963, Powell and Reynolds 1965, Bright 1967, Stone et al. 1992
Mating season	February–April	Powell et al. 1973, Stevens and Swiney unpubl. manuscr.
	March–September	Bright 1967
	January–July	Otto et al. 1990
Incubation period	300 days	Nakanishi 1987
	11 mo	Shirley et al. 1990
	11–12 mo	Stevens and Swiney unpubl. manuscr.
Spawn	Synchronized	Shirley and Shirley 1989
	Protracted	Stevens and Swiney unpubl. manuscr, Powell et al. 1973
Uneyed egg color	Blue-violet	Marukawa 1933, Bright 1967
	Purple, purple-brown, may be gray or tan if infertile	NMFS unpubl. data
Eyed egg color	Orange red	Marukawa 1933, Bright 1967
	Purple, brown, orange, purple-brown, pink	NMFS unpubl. data
Blue king crabs		
Reproductive cycle	24 mo	Sasakawa 1973, Somerton and MacIntosh 1985
Seasonal breeding migration	Egg-bearing females in shallow water during summer, deeper water during winter	Pereladov and Miljutin 2002
Mating season	Autumn	Sasakawa 1973
	February to April	Somerton and MacIntosh 1985
Incubation period	14–15 mo	Somerton and MacIntosh 1985
Spawn	Synchronized	Jensen and Armstrong 1989
Uneyed egg color	Purple	Jensen et al. 1985
	Purple, purple-brown, brown	NMFS unpubl. data
Eyed egg color	Purple, rose, orange	NMFS unpubl. data
Golden king crabs		
Reproductive cycle	20 mo	Paul and Paul 2001a
Seasonal breeding migration	Incubating females migrate deeper prior to larval release	Sloan 1985
Mating season	Asynchronous, any month	Paul and Paul 2001a
Incubation period	12 mo	Paul and Paul 2001a
Spawn	Not synchronized; extrude and hatch in any month	Sloan 1985, Paul and Paul 2001a
Uneyed egg color	Orange	NMFS unpubl. data
Eyed egg color	Yellow, tan, cream	NMFS unpubl. data
Scarlet king crabs		
Reproductive cycle	Unknown	
Seasonal breeding migration	Unknown	
Mating season	Unknown	
Incubation period	Unknown	
Spawn	Not synchronized; protracted spawning	Somerton 1981
Uneyed egg color	Orange	NMFS unpubl. data
Eyed egg color	Yellow	NMFS unpubl. data

22a. Purple clutch, uneyed eggs.

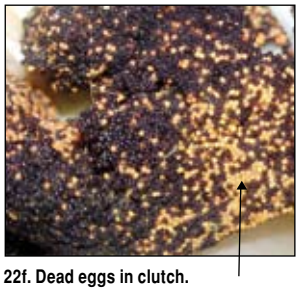
22b. Purple-brown clutch, uneyed eggs.

22c. Brown clutch, uneyed eggs.

22d. Tan infertile clutch, uneyed eggs.



22e. Opaque brown clutch (left); orange clutch (right) eyed eggs: inset 20x magnification.



22f. Dead eggs in clutch.

Figure 22. Live egg color categories used in the field for red (a–e) and blue king crabs (a–c,e). Dead eggs are depicted in f. (a–d,f. S. Byersdorfer. e. C. Armistead)

23a. Orange clutch, uneyed eggs.

23b. Yellow clutch, eyed eggs.

23c. Cream clutch, eyed eggs.

Figure 23. Live egg color categories used in the field for golden king crab (a–c) and scarlet king crab (a,b). (J. Anderson)

Clutch Fullness

Clutch fullness as estimated in the field is a subjective measure of fecundity. Clutch fullness is recorded as a visual estimation of the size of the clutch relative to an idealized "full" clutch (100% egg capacity).

Clutch fullness classification schemes vary between and within agencies. ADF&G observers record percentages to the nearest 20% (0, 20, 40, 60, 80, 100); ADF&G researchers record percentage ranges and pleopod condition (barren clean, barren matted, 0, 1–29, 30–59, 60–89, 90–100). NMFS researchers record a combination of fractions, ranges, and reproductive status (immature, mature with no eggs, trace to ⅛, ¼, ½, ¾, full). Johnson et al. (2002) examined the reliability of the field classification schemes used by ADF&G and NMFS researchers by comparing the estimates made by pairs of shellfish biologists. They reported no overall substantial agreement using either the ADF&G or NMFS relative clutch fullness intervals. NMFS intervals had weak moderate agreement; approximately half of the observer pairs showed moderate agreement.

In this guide, clutch fullness is described using the NMFS increment system. This is done to (1) provide consistency with the standard scheme recommended for *Chionoecetes* crabs (Jadamec et al. (1999), and (2) reflect the results of Johnson et al. (2002).

Clutch Fullness Categories

No eggs No eggs present, barren with clean pleopods, or barren with empty egg cases. (Fig. 24a).

Trace–⅛ 1 egg to ⅛ capacity of eggs. Eggs are not visible when the abdomen is closed (Fig. 24b).

¼ 25% capacity of eggs. Eggs are not visible when the abdomen is closed, and eggs do not completely cover the surface of the brood pouch (Fig. 24c).

½ 50% capacity of eggs. Eggs are just visible when the abdomen is closed (Fig. 24d).

¾ 75% capacity of eggs. Eggs are visible when the abdomen is closed (Fig. 24e).

Full 100% capacity of eggs. Thickness of visible egg mass is greatly enlarged (Fig. 24f).

Percent egg clutch fullness categories for the four species are illustrated in Fig. 24. These figures can be used to calibrate estimates of clutch fullness between observers.

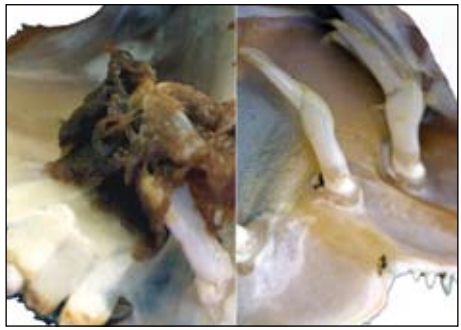
Reproductive Cycle

The annual reproductive cycle of red king crabs is synchronous and lasts about 12 months (Marukawa 1933, Stevens and Swiney unpubl. manuscr.). Red king crabs molt, mate, and extrude a new clutch of eggs within days of hatching the previous clutch. Therefore, estimates of clutch fullness, with notation of any predators and diseases (see chapter 9) can be used to judge the reproductive health of the population being studied. However, females can have clutches that appear normal to the unaided eye but contain only unfertilized eggs (Paul and Paul 1990).

Unlike red king crabs, the biennial spawning cycle of blue king crabs (Sasakawa 1973, Somerton and MacIntosh 1985) means that at any time of year, in a reproductively healthy population, a portion of the adult females will be carrying developing eggs and a portion will have only empty egg cases that they carry until the next molt. During this intermolt period, blue king crab ovaries develop slowly and take two years to produce fully mature oocytes compared to one year for red king crabs. In order to use observations of clutch fullness of blue king crab females as an indication of the reproductive health of the population, one must take into account their biennial cycle.

Red and blue king crab eggs hatch during the spring phytoplankton bloom (Jensen and Armstrong 1989). According to Paul et al. (1990), red king crabs hatch their eggs so that the larvae can feed on the spring plankton bloom. All ripe females molt and breed soon after hatching is completed. Golden king crab eggs held in captivity hatch in any month of the year (Adams and Paul 1999). Golden king crabs are found in all reproductive and molting stages throughout the year (Paul and Paul 2001a). Sloan (1985) described spawning of golden king crabs as continuous and aseasonal with similar proportions of egg-bearing individuals found at all times of year. In a lab study on golden king crabs, Paul and Paul (2001a) determined that on average the time between first and last egg hatch was 34 days, females molted about 192 days after the last egg hatched, eggs were extruded 2 days after molting, egg clutches were incubated for 362 days, and the time between successive egg clutches was 590 days.

Scarlet king crabs have not been well studied. Somerton (1981) reported that they exhibit aseasonal reproduction (Table 1, Appendix 2) and therefore pose the same challenge in estimating reproductive success as identified for golden king crabs. Improvements in estimating clutch size in the field for all species could possibly be obtained with standardized training, such as with videos (Johnson et al. 2002).



24a. (Left) Barren with empty egg cases. (Right) No eggs, barren with clean pleopods.

24b. Trace eggs to ⅛ full clutch.

24c. ¼ full clutch

24d. ½ full clutch

24e. ¾ full clutch

24f. Full clutch

Figure 24. Clutch fullness categories recommended for use in the field. (a) No eggs present (also displays clean pleopods and empty egg cases but still represents a 0% clutch). (b) Trace eggs to ⅛ full clutch. (c) ¼ full clutch. (d) ½ full clutch. (e) ¾ full clutch. (f) Full clutch. (S. Byersdorfer)

8. Shell-Age Classification

Shell-age classification reflects approximate time since the last molt. Consistent and accurate shell-aging is difficult to achieve due to the subjectiveness of assessing crab shell conditions in situ. Molting history and habitat type cause crab shells to age or show wear at different rates. Also, the length of time between molting events (inter-molt period) increases as a crab ages. Differences in molt schedules are also apparent between the shallow and deepwater species. Adult red and blue king crabs have fairly well defined molting seasons. Golden and scarlet king crabs molt year-round and therefore can exhibit a wide variety of shell ages at any time of year. Before attempting to age shells, it is helpful to review the available literature on molt season and geographic area/habitat type for the species in question.

When attempting to determine shell age, it is helpful to examine several areas on each crab. The amount of scratching on the ventral surface of the coxa, legs, and carapace; shell color; epifaunal growth; and spine and dactyl wear are all useful indicators of elapsed time since molting. The coxa, abdominal flap, and dactyls usually show wear first.

Females molt, breed with a male, and deposit a clutch of eggs in a short period of time. Red king crab embryos have an 11–12 month interval from ova deposition to hatch, blue king crabs 14–15 months, and golden king crab have a 12 month interval. Adult red king crab females have a 12 month molt cycle, adult blue king crab females 24 months, and adult golden king crab females 20 months (see Table 1, Appendix 2). Adult scarlet king crab females are assumed to be similar to golden king crab in this respect. Immediately after hatching and for variable periods of time, matted setae are apparent under the abdomen of females. Females with uneyed egg clutches are, by definition, new-shell. Since adult king crab females have variable molt cycles and matting on the setae may persist for some time after egg hatch depending on the species, females with matted setae may be either new or old-shell. The amount of shell wear and epifauna must be used in combination with the observation of matted setae to make a shell age determination for female blue king crab.

Categories and definitions vary somewhat by agency. No standard set of definitions has been agreed upon. The following categories are suggested as standards. These categories capture the important components of existing NMFS and ADF&G shell-aging schemes. The category names and definitions are also in alignment with those used for *Chionoecetes* crabs. Differences between species are emphasized when known. The term "skip molt" is somewhat of a misnomer as it implies that a crab "should" molt but for some reason "skips" a molt. Intermolt periods increase with age. The point of the term is to identify crabs that have not molted for one to two years. Their "normal" intermolt period might be 18 months. We use the term here because it is a commonly used term by agency biologists and fishermen.

Premolt and molting: 6 weeks prior to ecdysis up to and including ecdysis (all four species)

Premolt crabs are preparing to molt and can be detected up to approximately 6 weeks prior to ecdysis. The shell begins to decalcify and soften. The shell will change from very hard to soft; specifically the first abdominal somite and the ecdysial suture will change from firmly closed to easily opened. Pereiopod joints swell and are pink in color (Fig. 25). Dactyl tips, when broken, will separate cleanly from the soft integument of the developing shell. In the process of molting, the carapace will be elevated at the ecdysial suture forming an opening. The cephalothorax will be swollen and protruding from the ecdysial suture. Figure 26 shows a premolt red king crab with the old carapace removed.

Soft-shell: 0 to 2 weeks post ecdysis (all four species)

Crabs in this category have molted within the previous two weeks. Shells are very soft and flaccid, and will lose their shape when out of water. The exoskeleton is similar in texture to wet leather. Lack of careful handling will cause the shell to lose shape, making accurate morphometric measurements difficult. The duration of this shell condition is short. The exoskeleton begins to harden within 72 hours, allowing mobility, and is sufficiently hard in two weeks to be considered a new-shell pliable crab. Soft-shell crabs are rarely encountered in pots because a true soft-shell crab cannot climb into a crab pot. If a crab molts after entering a pot, it is in danger of being cannibalized by hardshell crabs. When the crab is encountered in a pot, the shed carapace is frequently present.

Recently molted or new-shell pliable: 2 to 8 weeks post ecdysis (all four species)

Recently molted or new-shell pliable crabs have a shiny ventral surface of the coxa and exoskeleton. There are few or no scratches, pits, or epibionts present. Dactyls and spines are sharp with no wear present. Legs are easily compressed when pinched because legs contain little muscle tissue at this time. To test for this category versus new-shell, place a thumb on the center of the dorsal side of the merus of the first or second walking leg and bend the leg around the thumb. If the merus is flexible and **does not** begin to crack, the crab is new-shell pliable. The exoskeleton is fragile and subject to damage when handled. If the carapace is removed, the gills will appear translucent to light-cream in color.

Paralithodes camtschaticus, red king crab

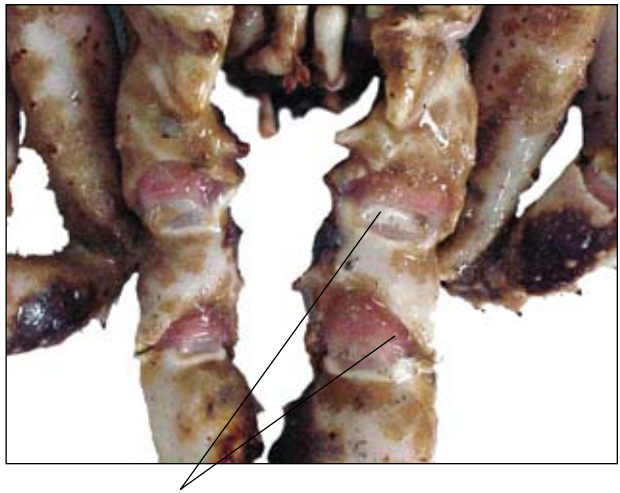


Figure 25. Swollen joints on red king crab preparing to molt. (C. Armistead)

26a. Dorsal

26b. Ventral

Figure 26. Dorsal and ventral views of a premolt red king crab with the old carapace removed. (C. Armistead)

New-shell:
2–12 Months post ecdysis for red and blue king crabs
2–20 months post ecdysis for golden and scarlet king crabs

Coxa and ventral surface of exoskeleton dull. Legs mostly full of muscle tissue, meri not easily compressed by pinching and will crack if bent as compared to a recently molted crab. Spines and dactyls may show slight wear. If the carapace is removed, the gills will be light cream in color. For female king crab, this category includes most ovigerous females. Blue king crabs may be ovigerous for up to 15 months. New-shell condition is depicted in Fig. 27.

Old-shell:
13–24 months post ecdysis for red and blue king crabs
21–36 months post ecdysis for golden and scarlet king crabs

Crabs that have skipped one molt cycle. Crabs in this category are referred to as "skip molts." Distal portion of the ventral coxa is partially or totally covered with brown scratching. Legs are full of muscle tissue, meri are not easily compressed when pinched. Epifauna is almost always present. If the carapace is removed, gills will be tan in color due to fouling by microorganisms. Old-shell red king crabs are depicted in Fig. 28.

Very old-shell:
24+ months post ecdysis for red and blue king crabs
> 36 months post ecdysis for golden and scarlet king crabs

Crabs that have skipped two consecutive molt cycles. Crabs in this category are referred to as "double skips." Distal portion of ventral coxa densely covered with dark scratching. Legs are full of muscle tissue, meri not easily compressed when pinched. Tips of dactyls are worn, rounded, and dark. Carapace is frequently covered with fouling organisms to a greater extent than with old-shell crabs. If the carapace is removed, gills will be dark gray or gray-black in color due to fouling by microorganisms. A very old-shell red king crab is depicted in Fig. 29. Figures 30, 31, and 32 compare new, old, and very old shells of male blue, female blue, and male golden king crabs, respectively.

***Paralithodes camtschaticus*, red king crab**

27a. Dorsal view of new-shell male red king crab.

27b,c. Ventral views of new-shell male red king crabs.

27d. Ventral view of new-shell female red king crab.

Figure 27. Dorsal and ventral views of new-shell male and ventral view of new-shell female red king crabs. (a,c,d. S. Byersdorfer. b. C. Armistead)

***Paralithodes camtschaticus*, red king crab**

28a. Dorsal view of an old-shell male red king crab.

28b,c. Ventral views of old-shell male red king crabs.

28d. Ventral view of old-shell female red king crab.

Figure 28. Dorsal and ventral views of old-shell male and ventral view of old-shell female red king crabs. (a,b,d. S. Byersdorfer. c. C. Armistead)

***Paralithodes camtschaticus*, red king crab**

29a. Dorsal view of a very old-shell male red king crab.

29b. Dorsal view of a very old-shell female red king crab.

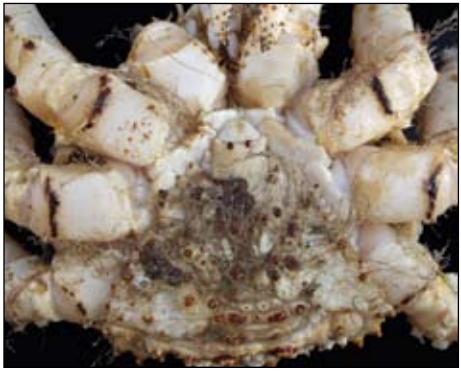
29c. Ventral view of a very old-shell male red king crab.

29d. Ventral view of a very old-shell female red king crab.

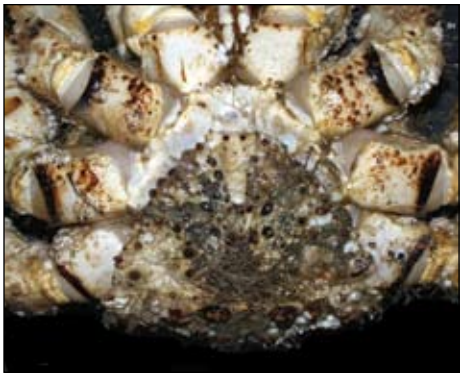
Figure 29. Dorsal and ventral views of very old-shell male and female red king crabs. (S. Byersdorfer)

***Paralithodes platypus*, blue king crab**

New-shell



Old-shell

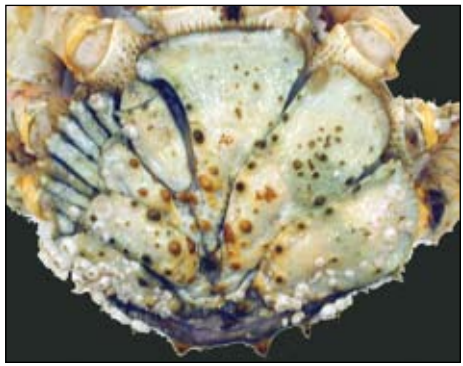


Very old-shell

Figure 30a. Shell ages of male blue king crab, ventral views. (S. Byersdorfer)

Figure 30b. Dactyls of male blue king crabs showing the wear and darkening due to aging. (Females also show similar wear and darkening patterns.) (S. Byersdorfer)

***Paralithodes platypus*, blue king crab**



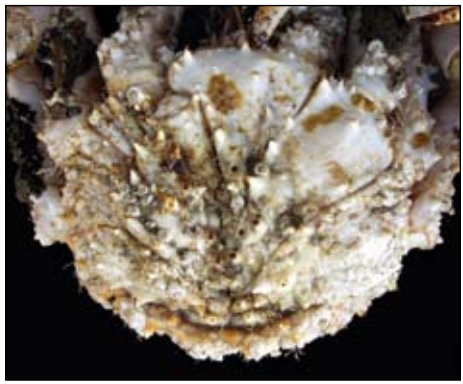


Figure 31a. Shell ages of new, old, and very old-shelled female blue king crab, ventral views. (S. Byersdorfer)

New-shell

Old-shell

Very old-shell

Figure 31b. Gills from new, old, and very old-shelled female blue king crabs. (Males also show darkening of gills due to aging.) (S. Byersdorfer)

***Lithodes aequispinus*, golden king crab**

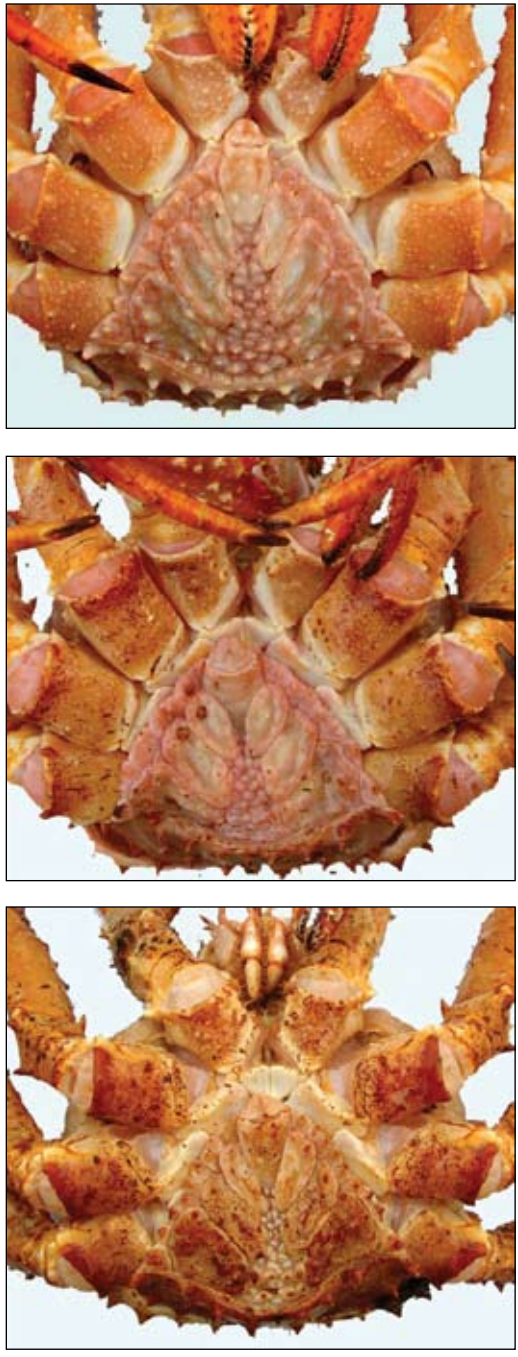


Figure 32. Shell ages of male golden king crabs, ventral views. (J. Anderson)

9. Parasites, Diseases, and Epibionts

Several major types of lithodid parasites are encountered in Alaska waters: rhizocephalan barnacle (*Briarosaccus callosus*), nemertean worms, turbellarians, amphipods, liparids (*Careproctus* spp.), and microsporidians. The following includes the main parasites that may be observed during the course of routine field work with red, blue, golden, and scarlet king crabs. Commonly observed bacterial infection, "torch," and epifaunal organisms are also described. For a more exhaustive list of diseases and parasites, most of which can be detected only in the laboratory, see Zaklan (2002).

Rhizocephalan Barnacle

The rhizocephalan barnacle *Briarosaccus callosus* has a nearly worldwide distribution and parasitizes many species of lithodid crabs. This parasite is highly specialized and invades the host's internal tissues to an extent the parasite produces immunosupressive agents that cloak its presence. Ultimately the parasite castrates and reduces growth of both male and female crabs. *B. callosus* has been found in red, blue, golden, and scarlet king crabs (Zaklan 2002). Most infections can be recognized by the externa of the parasite (Fig. 33a). Early infections in which neither an externa or scar from a previous externa are present may not be easily recognizable (Sparks and Morado 1985).

Nemertean Worms, Turbellarians, and Amphipods

Nemertean or ribbon worms *Carcinomertes regicides* and *Alaxinus oclairi* are egg predators and have been found in egg clutches of adult female red king crabs. Kuris et al. (1991) reported a widespread outbreak of *C. regicides* and three other undescribed nemertean egg predators in egg clutches of Alaska red king crabs. In addition, an amphipod *Ischyrocerus* sp. and a turbellarian were recognized. Nemerteans feed on eggs by piercing the membrane and sucking out the egg contents. Turbellarians were not observed to feed on intact eggs but moved in the direction of ruptured eggs and fed on the contents. Dissections of the amphipod *Ischyrocerus* sp. revealed crab egg membranes in their guts. They apparently feed by detaching eggs from the funiculi. Kuris et al. (1991) observed that egg predation by symbiotic nemertean worms can cause brood failure. In locations sampled from Southeast Alaska to Dutch Harbor during the 1983–1984 red king crab brood season, partial to nearly entire clutches were consumed. Otto et al. (1990) concluded that there was no evidence that nemerteans have ever occurred in the Bristol Bay and Norton Sound populations of red king crabs in densities associated with high embryo mortality in other areas of Alaska. *C. regicides* are 1–3 mm in length. When present, worms are readily seen by a gross examination of the egg clutch (Fig. 33b).

Turbellarians appear to be harmless commensals. They may obtain some nutrition by feeding on the egg remnants after nemertean predation. Otto et al. (1980) reported that one or more species of turbellarian flatworms were present in 37% of the sampled Bristol Bay red king crab egg clutches. The one species identified was *Ectocotyla hirudo*. The amphipod *Ischyrocerus* sp. did not appear to be abundant enough to be a major egg predator (Kuris et al. 1991).

Liparid Fish

Liparids (snailfish) of the genus *Careproctus* oviposit their eggs into the gill chambers of red and golden king crabs. The parasite egg mass interferes with the respiratory system of the host by compressing the gills, causing necrosis, and may lead to mortality (Somerton and Donaldson 1998). Liparid egg masses are found by lifting the sides of the carapace and peering into the branchial chambers (Fig. 33c).

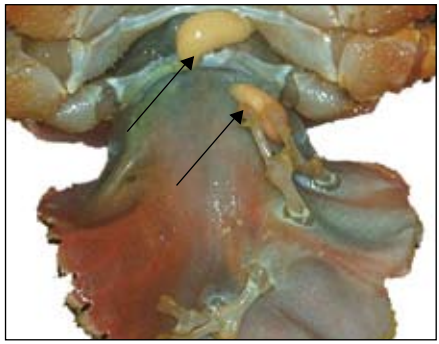
Cottage Cheese Disease

"Cottage cheese disease" is a microsporidian infection and is recognizable by the white, large curd cottage cheese–like appearance in the abdominal cavity of male and female crabs. According to Sparks and Morado (1985), the disease is most obvious when the carapace is removed, but can be recognized in heavily infected crabs by the whitish discoloration of the abdominal tissues as seen through the thin cuticle of the underside of the abdomen (Fig. 33d). Cottage cheese disease has been found in red, blue, and golden king crabs. Microsporidians from the genus *Thelophania* are responsible for the disease in red and blue king crabs. A microsporidian from the family Nosematidae is responsible for the disease in golden king crabs. Although this disease is confined to muscle, it is probably fatal because the cardiac muscle of the heart is heavily invaded and destroyed (Sparks and Morado 1985).

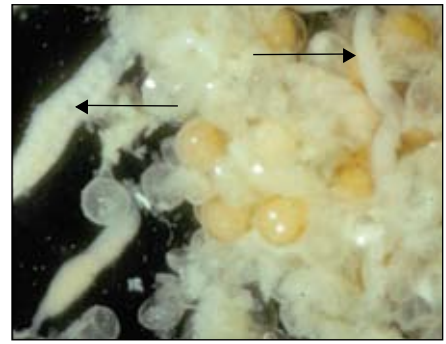
Chitinoclastic Bacteria or "Torch"

Torch is caused by a chitinoclastic bacterial infection of the exoskeleton during which chitin is consumed by the bacteria. The infection appears as dark spots or lesions of the exoskeleton. An infected host will appear to have had holes burned through the exoskeleton with a blow torch, hence the name "torch" (Fig. 33e).

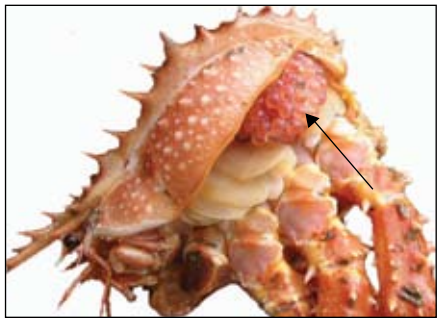
Other commonly occurring epifaunal organisms found on king crabs are shown in Fig. 34. Appendix 5 depicts king crab claw, leg, and carapace abnormalities that have been observed during routine field sampling.



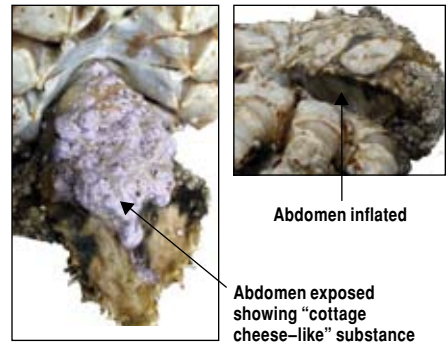
33a. ***B. callosus*** **on abdomen of female golden king crab.**



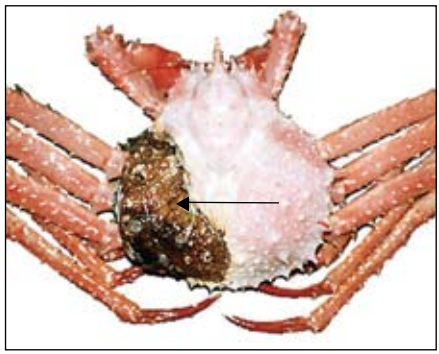
33b. **A nemertean brood symbiont** ***Carcinomertes*** **sp.**



33c. ***Careproctus*** **sp. eggs in golden king crab.**



33d. **Microsporidian infection producing "cottage cheese disease."**



33e. **Chitinoclastic bacteria or "torch" on a scarlet king crab.**

Figure 33. Major lithodid parasites and diseases. (a) rhizocephalan (Briarosaccus callosus). (b) Nemerteans (Carcinomertes sp.). (c) Liparids (Careproctus sp.). (d) Microsporidians. (e) Chitinoclastic bacteria. (a. S. Blackloke, b. F. Blau, c. R. Burt, d. S. Byersdorfer, e. M. LaCroix)

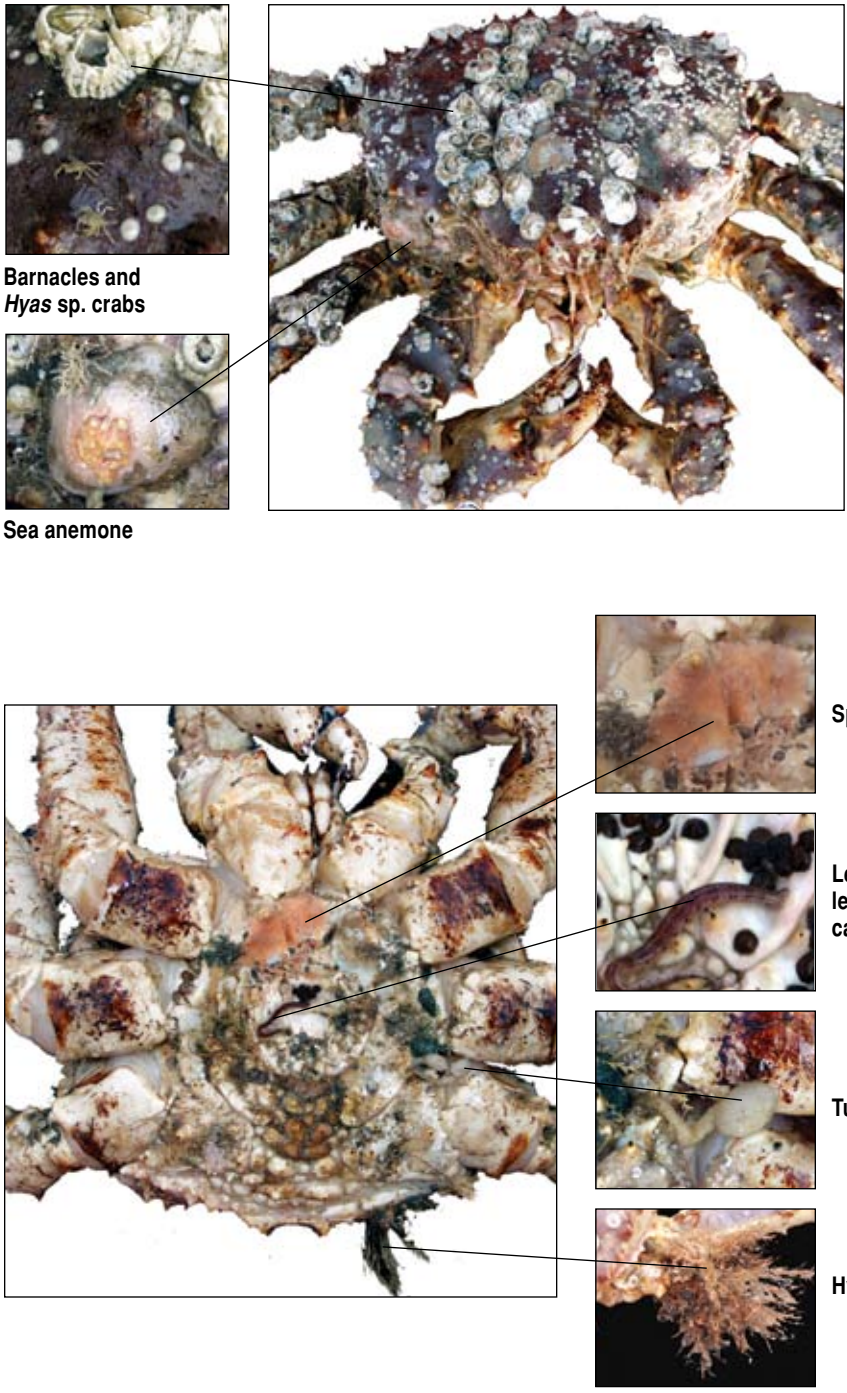


Figure 34. Epibionts commonly encountered on king crabs. (S. Byersdorfer)

10. Collecting Specimens

Field biologists often collect specimens of and from lithodid crabs. Among the specimens collected are live whole crabs, whole frozen crabs, dried carapaces (dorsal covering of cephalothorax), and tissues for genetic study.

All specimens collected are documented with information on the location of capture (latitude, longitude, depth, date, and collector), species, sex, shell age, carapace length (biological), specimen tissue type, and other information as requested by the lead investigator. The methods presented here are the standard collection methods used at this time.

Whole Live Crabs

- For best results, collect the specimens directly from point of capture and handle with care. Avoid injured or damaged specimens.
- Record the necessary biological information from the specimens.
- Place the specimens in a burlap bag with an information label written in pencil on waterproof paper.
- Seal the bag with a zip tie and sink the bag in the live tank of the vessel.
- Transporting or shipping live crabs: live crab specimens can be maintained for approximately four days out of water using these procedures:

  Place crabs upside-down in an insulated, ventilated container (wet lock box or plastic cooler).

  Line the container with wet burlap or other similar seawater-soaked material such as seaweed or newspaper. Do not soak the material in freshwater. Cover crabs with similar material. If the specimens are in burlap bags, do not re-bag them.

  When transporting or storing live crabs in uncirculated seawater, be aware that the smaller the volume of water, the faster the depletion of dissolved oxygen.

  To keep the specimens cool, place ice packs or sea ice under the crabs, or store the box in a refrigerated area. Do not freeze the crab.

  Return crabs to chilled recirculated seawater as soon as possible. When the crabs are returned to water, the air under the carapace should be evacuated by holding the crab upside down, under water, until the air bubbles cease. Then turn the crab right-side-up and allow it to sink to the bottom of the tank.

Whole Frozen Crabs

- For best results, collect specimens directly from point of capture and handle with care. Injured or damaged crabs may be acceptable; refer to instructions from the lead investigator. Record necessary biological information.
- Fold pereiopods at the distal merus joint and secure pereiopods together by wrapping each crab in pallet wrap or plastic wrap. Include shed legs with the specimen. If pallet wrap is not available, large rubber bands can be used to secure the specimen. A label stating capture location should accompany the specimen and be wrapped between the layers of pallet wrap, not directly against the specimen.
- Quick freeze the specimen in vitro with a blast or brine freezer. If only standard freezer equipment is available, place wrapped or banded crab in the freezer. Store in a box in the freezer after it is frozen.
- Do not allow the specimens to thaw and avoid direct handling of the specimens. Frozen specimens should be regarded as very fragile.

Carapace Dried

Collect carapace specimens from live crabs only. Late new-shell, premolt, and molting shell-age crabs are recommended for this type of collection because the carapace has begun to naturally separate from the epithelium and will require little or no cleaning. Conversely, recently molted and early new-shell crabs are the most labor intensive to collect. Old-shell crabs have variable shell characteristics because of the unknown molting cycle. To estimate the ease with which a carapace may be collected, lift the posterior portion of the carapace at the ecdysial suture. If the carapace is firmly attached and cannot be raised, assume that the carapace is firmly attached to the epithelium and will require extensive cleaning.

- For best results, collect crabs directly from the point of capture, and make sure specimens have no carapace damage. Record necessary biological information.
- Clean mud and detritus from the carapace surface. It is not necessary to remove epibionts; they fall off on their own when the carapace is dried. Insert a knife at the ecdysial suture and bisect the connective tissue located at the left and right of the cardiac region.
- Raise the carapace at the ecdysial suture 15 to 20 degrees. Twist the carapace left and then right and break the shell connection in the frontal region. You should be able to feel them pop or snap.
- Once it is free, lift the carapace all the way off, twisting it free of the frontal connective tissues.
- Scrape the connective tissue from the perimeter of the cardiac and frontal regions where it is found in discrete patches firmly stuck to the shell.
- Flush the carapace with seawater. Scraping with the flat end of angled forceps will free most of the epithelium from the shell.

- Finish cleaning the epithelium from the shell with a hard bristle toothbrush. Recommended modifications to the brush are heating the brush shaft near the head and bending it back slightly (10 degrees) and removing every other bristle cluster with a pair of needle-nose pliers. Be sure to clean the margin of the shell and the frontal region. Properly cleaned shells are free of odor when dried and do not have dried blackened tissue remaining.
- Rinse the carapace with water to remove residual hemolymph.
- Dry carapaces in a warm, dry room. Dried carapaces are fragile and should be handled with care.

Tissue Collections for Genetic Study

There are two methods for collection of tissues from crabs for electrophoretic studies. Each involves a different storage medium and different tissue collection. Liquid nitrogen is used to store the heart, hepatopancreas, and muscle tissue. Ethanol storage is used with the collection of entire egg clutches and pereiopods.

Liquid Nitrogen Tissue Collections

- The lead investigator will provide instructions for recording, storage, and safety, along with all the necessary supplies.
- Tissues are to be dissected in vitro, kept cool, and stored in liquid nitrogen promptly. Therefore, preparations should be made to facilitate collection of tissues, including the necessary space for temporarily storing cryovials on ice and for having the appropriate number of crab specimens queued up. Collect all necessary information from the set of crab specimens and label the vials before dissection.
- Remove the carapace by either bisecting the connective tissue with a clean knife as described above for carapace collection, or by prying open the frontal portion of the carapace at the epistomal margin with a thumb. If the carapace is also to be collected, ensure that the epistomal margin is not damaged. It should be noted that carapace cleaning should begin within 20 minutes of the crab's expiration to prevent shell discoloration. Tissue collections for genetic study require immediate attention, so store carapaces in seawater once they are removed until they can be properly cleaned. They may be identified for labeling later based on their morphometric measurements.
- Remove the heart with forceps and scalpel. Be careful not to contaminate the heart with hepatopancreas fluid. Set the heart aside or place it directly into the appropriate vial. If necessary, cut the heart into pieces that will fit into the vial. The vial should be more than ¾ full.
- Remove a portion of the hepatopancreas, enough to fill the cryovial ¾ full. Be careful not to contaminate the hepatopancreas with the digestive tract, reproductive organs, or other organs.

- Remove muscle tissue from the merus segment of the largest pereiopod present. There are several options for gaining access to the muscle tissue. One option is to break the merus just proximal to its distal end, then pull the muscle tissue out of the segment. To get enough tissue to fill the cryovial ¾ full, it may be necessary to remove the muscle tissue from more than one pereiopod or segment. Be careful not to contaminate the muscle tissue with epithelium, tendons, or fluids from the body cavity.
- Once all tissues have been stored in the appropriate vials and set on ice, clean the work area and dissect the next specimen.

Ethanol Tissue Collections

- The lead investigator will supply instructions for data, storage, and safety, along with all the necessary supplies.
- Tissues are to be collected in vitro and placed in ethanol directly. Specimens are stored in 100% ethanol at a ratio of 4:1, i.e., 4 ml of ethanol to 1 g of specimen. After 24 hours, the ethanol is replaced with fresh ethanol at the same ratio.
- Record information from the specimen and prepare a collection station.
- Remove the 2nd pereiopod at the autotomy plane. To remove the pereiopod, either suspend the specimen by the pereiopod until autotomy takes place or induce autotomy by applying pressure with a stout pointed object at the aperture on the ventral surface of the autotomy plane.

Mounting Hemolymph on Slides

- For detection of diseases carried in the hemolymph, the hemolymph is examined under a microscope. Samples are taken from live specimens, mounted on slides, dried, and stored.
- The lead investigator will supply biological data requirements and slide coding instructions.
- Label the frosted side of the slide.
- For crabs larger than 30 mm carapace length, extract a large drop of hemolymph with a disposable syringe from the articulating membrane between the dactyl and propodus of the chela, and place a drop of hemolymph on the slide near the end of the slide. For crabs smaller than 30 mm carapace length, pinch off a leg at the merus segment, and allow two drops of hemolymph to fall free, and catch the third drop on the slide near the end of the slide.
- Position a second slide on edge in the center of the slide containing the hemolymph, angled slightly toward the drop, and draw it toward the drop until it comes in contact with the drop. Then draw the drop toward the center of the slide with a slow smooth motion.
- Let excess hemolymph run off the slide and blot the edge of the slide dry if necessary.

- Place the slide in a warm, dry area until the slide has dried, then store the slide in a slide box. Two slides may be stored in each slot if the dried hemolymph is facing outward.
- Check slides periodically for fuzziness. If the slides become fuzzy, they have been contaminated with fungi and will require further drying. Fungi impede slide reading and can be prevented with proper drying.
- To ship slides use a slide box. Tape slide box shut and shake lightly to make sure there is no excessive rattling.

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Appendix 1. Other Lithodid Crabs

Other commonly occurring North Pacific/Bering Sea crabs in the family Lithodidae. (Photos taken from preserved specimens may not represent true colors.)

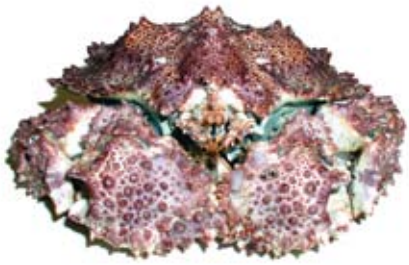
Cryptolithodes typicus
Butterfly crab (H. Morrison)

Size: Carapace width to 3.8 cm (1.5 in).

Range: From Amchitka Island, Alaska to central California.

Habitat: Low intertidal to 45 m on gravel slopes, rock, or shell debris.

Identification: Carapace has lateral extensions concealing legs from dorsal view. Color variable. Rostrum narrows at tip and claw surface rough. (Barr and Barr 1983)



Lopholithodes foraminatus
Brown box crab (S. Byersdorfer)

Size: Carapace length to 18.5 cm (7.4 in).

Range: Northeast Pacific; San Diego, California to Banks Island, B.C., Canada; north to Aleutian Islands and Bering Sea.

Habitat: Low intertidal to 547 m. Usually found below 18 m.

Identification: Predominately drab reddish-brown or tan. When chelipeds and legs are tucked in, a round hole, or foramen, is formed on each side of the crab by the joining indentations. (Barr and Barr 1983, Zaklan 2002)

Lopholithodes mandtii
Box crab (S. Byersdorfer)

Size: Carapace length up to 22.8 cm (9 in).

Range: From Kodiak Island, Alaska to central California.

Habitat: Shallow subtidal to 100 m. Usually found on steep bedrock areas.

Identification: Carapace heavy with 4 large, cone-shaped humps. Chelipeds are massive, with white teeth; legs are short and can be tucked under carapace. Coloration of adults is orange-brown with purple markings. (Barr and Barr 1983)

Appendix 1. (continued)

Paralomis multispina
Spiny paralomis (S. Byersdorfer)

Size: Carapace length 8 cm (3.2 in).

Range: North Pacific: Queen Charlotte Islands, B.C., Canada; Shumagin Islands, Alaska to San Diego, California; West Bering Sea: Kamchatka, Russia; off Hokkaido, Miyagi Prefecture, Chiba Prefecture, off Manauru and Enoshima, Sagami Bay, Japan.

Habitat: Depth range 600–1,665 m.

Identification: Carapace is about as wide as it is long. The scarlet carapace is thickly studded with blunt spines. The rostrum has a simple median spine with two basal spines. Under the rostrum proper there is a short conical spine. Male abdomen has several rows of leathery plates. Ambulatory legs are long, slender and thickly set with spines. (Hart 1982, Zaklan 2002)

Paralomis verrilli
Verill's paralomis (B. Stevens)

Size: Carapace length 10.2 cm (4 in).

Range: North Pacific: Bering Sea, Pribilof Islands; south to Cortez Bank, California; coast of Nemuro Hokkaido; Kumanonada, Japan.

Habitat: Depth range 850–2,379 m.

Identification: The scarlet carapace slightly longer than wide; large spines on elevated areas and lateral margins. Walking legs are somewhat flattened and margined, ventrally and dorsally, with rows of large spines with scattered small spines. (Hart 1982, Zaklan 2002)

Phyllolithodes papillosus
Flatspine triangle crab (S. Byersdorfer)

Size: Carapace length up to 9 cm (3.6 in).

Range: Northeast Pacific: Unalaska, Alaska to Monterey, California.

Habitat: Subtidally in shallow rocky areas up to 183 m.

Identification: Carapace triangular in outline with raised heart-shaped sculpturing. Claws, legs, and edge of carapace armed with long flattened projections. Color is grayish or brown with juveniles often white with purple or orange markings. (Barr and Barr 1983, Zaklan 2002)

Appendix 1. (continued)

Rhinolithodes wosnessenskii
Rhinoceros crab (S. Byersdorfer)

Size: Carapace length to 6 cm (2.5 in).

Range: Northeast Pacific: Kodiak Island, Alaska to northern California.

Habitat: Rock, gravel, or shell bottoms, 6–102 m.

Identification: Carapace triangular in shape with deep semicircular depression around a smooth knob. Remainder of carapace covered with tubercles. Carapace light brown with base of rostrum orange, depressed area orange and white. Legs have short, stout, and pointed spines with coarse tip hairs. (Hart 1982, Zaklan 2002)

Acantholithodes hispidus
Fuzzy crab (S. Byersdorfer)

Size: Carapace length to 7.6 cm (3.0 in).

Range: Common south, not found north of the Alaska Peninsula.

Habitat: Intertidal to 245 m.

Identification: Top surface of carapace with small spines, rostrum sharp, tail soft without plates. Carapace varying shades of brown with opaque white areas, spines dark red-brown, orange or white. (Hart 1982, Kessler 1985)

Hapalogaster grebnitzki
Soft crab (L. Watson)

Size: Carapace length to 2.3 cm (<1 inch).

Range: Eastern shores of Kamchatka, Sea of Okhotsk, Russian shores of Sea of Japan; Bering Sea north to Bering Strait; west coast of North America from Aleutians, Alaska south to Humboldt Bay, California.

Habitat: Intertidal to 90 m.

Identification: Carapace and claws covered with tufts of long brown hairs. Carapace red and orange; marginal spines with white tips. Abdomen soft and softly folded under body. Broad triangular rostrum, slender setae on the inner surface of the large claw, and bluish-black

Appendix 1. (continued)

Hapalogaster mertensii
Hairy crab (S. Byersdorfer)

coloration on the fingers of the claw. (Hart 1982, Zaklan 2002)

Size: Carapace length to 3.5 cm (1.4 in).

Range: Atka, Alaska to Puget Sound, Washington.

Habitat: Usually found under algae-covered rocks from low intertidal to 55 m.

Identification: Body covered with tufts of long brown hairs. The abdomen is soft and loosely folded under the body. Carapace brown and red with a few white spots. Claw fingers often reddish orange in color.

Remarks: Often replaced in the northern part of its range by *H. grebnitzkii*. (Hart 1982, Zaklan 2002)

Placetron wosnessenskii
Scaled crab (R. Burt)

Size: Carapace length to about 7.6 cm (3 in).

Range: Pribilof Islands, Alaska to Puget Sound, Washington.

Habitat: Found on hard surfaces with crevices to hide in and usually associated with large aggregations of plumose anemones.

Identification: Body covered with scale-like plates; claws nearly equal in size. Carapace medially red-brown and laterally gray with dark brown scales. Abdomen thin, flat, and not completely covered by calcareous plates. (Hart 1982, Barr and Barr 1983)

Appendix 2. Life History Traits

Life history traits for *P. camtschaticus, P. platypus, L. aequispinus,* and *L. couesi*. Modified from Zaklan 2002.

Species	Age (years) and size at reproductive maturity of males max. size (ms) in (mm)	Age (years) and size at reproductive maturity of females max. size (ms) in (mm)	Reproductive cycle	Brood size (eggs/clutch)	Egg diameter (mm)	Eclosion date	Number of zoeae (Z) and glaucothoe (G) stages	Size of zoeae (Z) and glaucothoe (G) (mm) [a]	Duration of zoeae and glaucothoe stages (days)
P. camtschaticus red king crab	age 8 (1) chelae allometry CL=103 (2) CL=120, presence of spermatophores at CL=70-99 (3) MS male: CL=227, CW=283 (4)	CW=85-100 (5) CL=83-95 (6) 86-119 (7) age 5 (8) chelae allometry CL=102 (2) CL=76-105 (9) CL=76-88 (10) MS: CL=195, CW=213 (4)	12 month cycle, annual spring migration and synchronized spawn (11) mate February to April shallow water (7) brood for 300 days (12)[b]	70,000-270,000 (5) 15,330-214,410 (13)	0.71-0.82 (5) 0.88-1.03 (14)	March to May (5)	4 Z, 1 G (5)	Z1 = 1.18 Z2 = 1.38 Z3 = 1.45 Z4 = 1.53 G = 1.8 G = 1.5 CW (15) G = 2.0 G = 1.7 CW (5)	Z1 = 14, Z2 = 8 (5) Z 1-4 = 47-84 (13) Z1 = 14, Z2 = 14 (16)
P. platypus blue king crab	Area dependent: sperm CL > 70 (19) CL = 77-108 (20) spermatophores in CL = 50-69 (3) MS male: CL 159 CW 170 (21)	Area dependent: CL = 80.6-96.3 (20) CL = 101-105 (9)	24 month cycle (22) biennial mating and broods for 14-15 months (23) 12 months (24) synchronized spawn (24)	3,000-160,000 (25)	1.18 x 0.98 (25) 1.2 x 1.0 (23)	March to May (24)	4 Z, 1 G (13)	Z1 = 1.2, 3.2 Z2 = 1.3, 3.4 Z3 = 1.6, 3.5 Z4 = 2.0, 4.5 (CL, TL) G = 1.8 CL (26)	Z1 = 12.4 Z2 = 12.3 Z3 = 12.5 Z4 = 14.3 G = 12.8 (26)
L. aequispinus golden king crab	CL = 114 based on chelae allometry (27) CL = 92-130 (28) functional CL = 107 (29) MS male: CW = 220 MS female = 192 (30)	CL = 105 (27) CL = 98-111 (28)	20 month cycle (29) asynchronous mating (28), (29), (31) July-Oct. (30) brood for 12 month (29)	9,500-30,100 (30)	2.1 (30) 2.4 (27) 2.07-2.52 (Zaklan, pers. obs.)	February-July (30) March (32) April-August (33)	4 Z and G (32) 3 Z skips Z3 or Z4 (33) 3 Z (34), (35)	Z1 = 7.3 TL Z2 = 7.5 TL Z3 = 7.6 TL Z4 = 6.8 TL G = 5.9 TL (32)	Z1 = 6.6 Z2 = 7-8.8 Z3 = 12 Z4 = 9.3 G = 41.3 Z1-4 and G = 67 (33) Z1-4 and G=75-148 (temperature dependent) (34)
L. couesi scarlet king crab	CL = 91.4 (36) MS male: CW = 113 CL = 115 MS female: CW = 103 CL = 105 (37)	CL = 80.2 (36)	Asynchronous or protracted spawning (36)	2,600-5,500 (36)	2.3 (36)				

R = rostrum; CL = carapace length; CW = carapace width; TL = total length; G = glaucothoa; Z = zoea; PZ = pre-zoea; C1 = first juvenile instar (= crab one); C2 = second juvenile instar (= crab two).
[a]Measurement of carapace length (CL) unless otherwise noted.
[b]See Table 1 for additional estimates of mating seasons and incubation period.

(1) Loher et al. 2001. (2) Somerton 1980. (3) Paul et al. 1991. (4) Powell and Nickerson 1965a. (5) Marukawa 1930. (6) Powell and Nickerson 1965b. (7) Powell et al. 1973. (8) McCaughran and Powell 1977. (9) Otto et al. 1980. (10) Paul 1992. (11) Marukawa 1933. (12) Nakanishi 1987. (13) Sato 1958. (14) Matsuura and Takeshita 1985. (15) Sato and Tanaka 1949. (16) Shirley and Shirley 1988. (17) Stevens 1990. (18) Donaldson et al. 1992. (19) Sasakawa 1971. (20) Somerton and MacIntosh 1983. (21) Sakai 1976. (22) Sasakawa 1973. (23) Somerton and MacIntosh 1985. (24) Jensen and Armstrong 1989. (25) Sasakawa 1975b. (26) Hoffman 1968. (27) Jewett et al. 1985. (28) Somerton and Otto 1986. (29) Paul and Paul 2001b. (30) Sloan 1985. (31) Hiramoto and Sato 1970. (32) Haynes 1982. (33) Shirley and Zhou 1997. (34) Paul and Paul 1999. (35) Adams and Paul 1999. (36) Somerton 1981. (37) Takeda 1974.

Appendix 3. Feeding, Movements, Associations, and Seasons

Feeding, movements, associations, and mating and molting seasons for *P. camtschaticus*, *P. platypus*, *L. aequispinus*, and *L. couesi*. Modified from NPFMC 1998.

Species	Life Stage/Activity	Duration of Life Stage (years)	Feeding Types: Lecithotrophic	Feeding Types: Planktotrophic	Feeding Types: Omnivore	Movements: Drift with Ocean Conditions	Movements: Reside in Nursery Areas	Movements: Inshore Molting/Mating Migration	Movements: Offshore Migration	Movements: Diel Migration	Movements: Nocturnally Active	Movements: Unknown	Associations: Solitary	Associations: Mating Aggregation	Associations: Defensive/Podding Aggregation	Associations: Spatial Aggregation	Associations: Unknown	Seasons/Months: Months Molting	Seasons/Months: Months Mating	Life Stage/Activity
P. camtschaticus red king crab	M	7-15+			●			●	●		●		●	●	●[a]	●		Dec-June	Jan-July	M
	LJ	4			●				●		●					●		year-round		LJ
	EJ	2			●		●				●		●			●		year-round		EJ
	L	0.2		●		●				●							●	March-July		L
	E	1								●										E
P. platypus blue king crab	M	8+			●			●	●		●		●	●		●		Jan-July	Jan-July	M
	LJ	4			●				●		●		●			●		year-round		LJ
	EJ	2		●	●		●				●		●			●		year-round		EJ
	L	0.2				●				●			●					March-June		L
	E	1-1.5																		E
L. aequispinus golden king crab	M	6+			●							●				●		year-round	year-round	M
	LJ	4.5			●							●				●		year-round		LJ
	EJ	2			●		●											year-round		EJ
	L	0.2		●								●					●	year-round		L
	E	1															●			E
L. couesi scarlet king crab	M				●							●					●			M
	LJ				●							●					●			LJ
	EJ				●		●													EJ
	L		●									●					●			L
	E																			E

M = mature, LJ = late juvenile, EJ = early juvenile, L = larvae, E = egg
[a]females only.

Appendix 4. Habitat Associations

Habitat associations for *P. camtschaticus, P. platypus, L. aequispinus,* and *L. couesi.* Modified from NPFMC 1998.

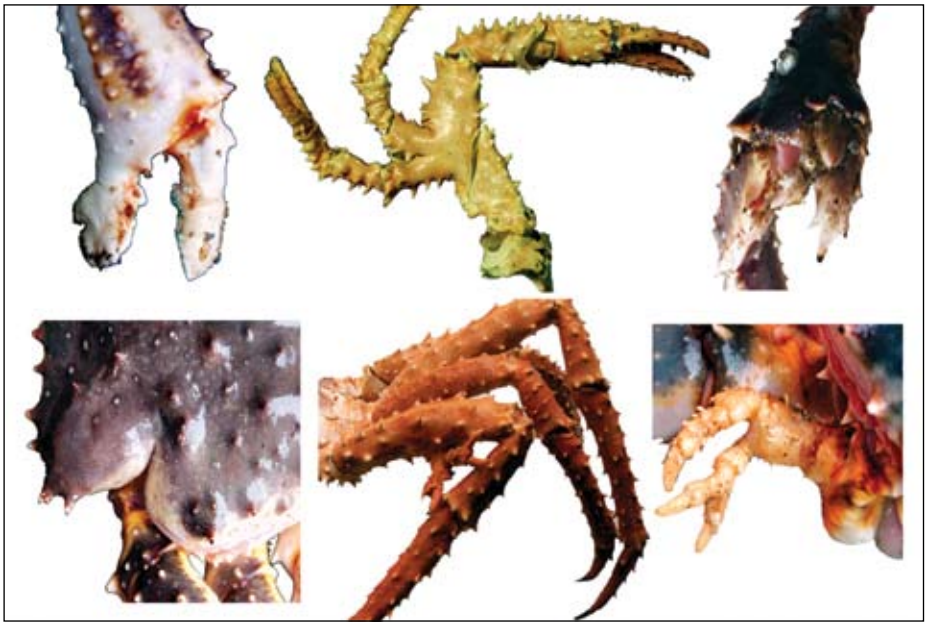
Species	Life Stage/Activity	Pelagic Domain: Estuarine	Pelagic Domain: Inshore Water (0-3 miles)	Pelagic Domain: Offshore Water (3+ miles)	Pelagic Domain: Surface Water	Pelagic Domain: Midwater	Pelagic Domain: Near Bottom	Pelagic Domain: Epipelagic (<200m)	Pelagic Domain: Mesopelagic (200-1000m)	Benthic Domain: Bottom Depth Range (m)	Benthic Domain, Shelf: Intertidal	Benthic Domain, Shelf: Subtidal (<30)	Benthic Domain, Shelf: Middle (30-100m)	Benthic Domain, Shelf: Outer (100-200m)	Benthic Domain, Slope: Upper (Break-500m)	Benthic Domain, Slope: Intermediate (500-1000m)	Benthic Domain, Slope: Lower (>500m)	Benthic Domain, Canyon: Upper and Middle (100-500m)	Benthic Domain, Canyon: Lower (>500m)
P. camtschaticus red king crab	M									3-300		•	•	•	•				
	LJ									0-200	•	•	•		•				
	EJ									0-50	•	•	•	•	•				
	L	•	•	•	•	•	•			0-100									
	E									0-200	•	•	•	•	•				
P. platypus blue king crab	M									0-200		•	•	•					
	LJ									0-200		•	•	•					
	EJ									<50	•	•	•						
	L	•	•	•	•	•	•	•		0-100									
	E									0-100		•	•						
L. aequispinus golden king crab	M									100-1000				•	•	•	•	•	•
	LJ									>1000							•		•
	EJ									>1000							•		•
	L								•										
	E									100-1000				•	•	•	•	•	•
L. couesi scarlet king crab	M									300+					•	•	•	•	•
	LJ																		
	EJ																		
	L																		
	E									300+					•	•	•	•	•

Species	Life Stage/Activity	Structure: Bars	Structure: Banks	Structure: Sinks	Structure: Slumps/Rockfalls/Debris Field	Structure: Channels	Structure: Ledges	Structure: Pinnacles	Structure: Reefs	Structure: Vertical Walls	Structure: Man-made	Substrate: Organic Debris	Substrate: Mud/Clay/Silt	Substrate: Sand/Granule	Substrate: Gravel	Substrate: Pebble	Substrate: Cobble	Substrate: Boulder	Substrate: Bedrock
P. camtschaticus red king crab	M	•	•	•	•	•	•		•			•	•	•	•	•	•		
	LJ	•	•	•	•	•	•		•			•	•	•	•	•	•		
	EJ																		
	L																		
	E	•	•	•	•	•	•		•			•	•	•	•	•	•		
P. platypus blue king crab	M	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	
	LJ	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	
	EJ	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	
	L																		
	E	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	
L. aequispinus golden king crab	M		•		•	•	•	•	•	•				•	•	•	•	•	•
	LJ		•		•	•	•	•	•	•				•	•	•	•	•	•
	EJ																		
	L																		
	E		•		•	•	•	•	•	•				•	•	•	•	•	•
L. couesi scarlet king crab	M																		
	LJ																		
	EJ																		
	L																		
	E																		

Species	Life Stage/Activity	Community: Algal Cover	Community: Anemones	Community: Echinoderms	Community: Corals (soft)	Community: Mollusca	Community: Drift Algae/Kelp	Community: Kelp Forest	Community: Polychaetes	Community: Sea Onions	Community: Tunicates	Ocean: Temperature (Celsius)	Ocean: Salinity (ppt)	Life Stage/Activity
P. camtschaticus red king crab	M		•	•	•	•	•	•	•	•	•	<6	>25	M
	LJ	•	•	•	•	•	•	•	•	•	•			LJ
	EJ												>20	EJ
	L											<12	>20	L
	E		•	•	•	•	•	•	•	•	•	<6	>25	E
P. platypus blue king crab	M		•	•	•	•	•	•	•	•	•	<6	>25	M
	LJ		•	•	•	•	•	•	•	•	•			LJ
	EJ		•	•	•	•	•	•	•	•	•			EJ
	L													L
	E		•	•	•	•	•	•	•	•	•			E
L. aequispinus golden king crab	M		•	•	•	•			•			<5	>30	M
	LJ		•	•	•	•			•			<5	>30	LJ
	EJ											<5	>30	EJ
	L											<5	>30	L
	E		•	•	•	•			•			<5	>30	E
L. couesi scarlet king crab	M											<4	>33	M
	LJ													LJ
	EJ													EJ
	L													L
	E											<4	>33	E

M = mature, LJ = late juvenile, EJ = early juvenile, L = larval, E = egg

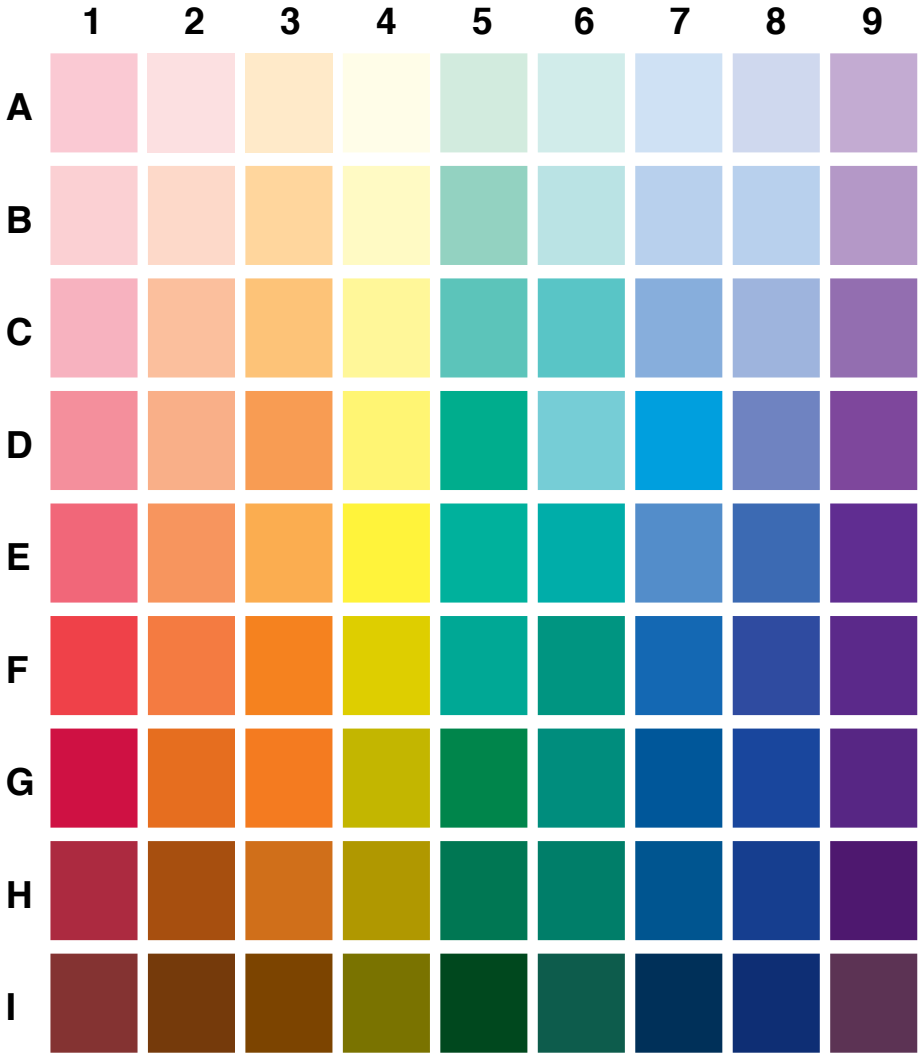
Appendix 5. Exoskeletal



Claw, leg, and carapace abnormalities found on king crabs. (S. Byersdorfer)

Appendix 6. Color Chart

This color chart (from Jadamec et al. 1999) can serve as a standard reference for collecting and analysis of data. A biologist collecting data should match crab color to a color on the chart and record the color code. Field biologists who are collecting information on egg color can match and document egg color to the chart and alphanumeric code (e.g., “H9”).



Glossary

Abdominal flap: Formed by the abdomen, which is folded under the thorax. In females, the abdomen is modified into a brood pouch to hold eggs.

Antenna (plural = antennae): First pair of anterior jointed sensory appendages with one flagellum.

Antennule (plural = antennules): Second pair of anterior jointed sensory appendages with two flagella.

Autotomy: Self amputation or shedding of damaged or trapped legs.

Branchial: Relating to the gills.

Calcareous: Composed of calcium carbonate.

Carapace: The dorsal covering of the cephalothorax; divided into frontal, gastric, branchial, and cardiac regions.

Carapace length biological: The straight-line distance across the carapace from the posterior margin of the right eye orbit to the medial-posterior margin of the carapace.

Carapace width biological: The greatest straight-line distance across the carapace excluding spines as measured in biological data collection.

Carapace width legal: The greatest straight-line distance across the carapace including spines as measured for determining legal size.

Carpus: The "wrist" of a crustacean limb; the third segment in from the dactyl end.

Cephalothorax: Fused head and tail.

Chela (plural = chelae): The pincer or claw.

Cheliped: A modified leg that contains the pincers or claws; the first pereiopod of crabs.

Chitin: A characteristic organic component of the arthropod exoskeleton.

Clutch: The cluster of eggs extruded by the female and located under the abdomen.

Dactyl: The terminal segment of a pereiopod.

Decapod: Any crustacean of the order Decapoda having 5 pairs of thoracic legs. Decapods include crabs, lobsters, and shrimps. From Greek deca = 10, poda = feet.

Dorsal: Referring to the back or upper surface of the body.

Ecdysis: Shedding or casting off the exoskeleton.

Eclosion: The act of hatching from the egg.

Embryo: A fertilized ovum consisting of an embryo surrounded by nutrient material with a protective coating.

Epibionts: Animal and plant material of other species attached to a host species.

Epithelium: Inner lining of the shell and covering of the muscle tissue.

Exoskeleton: External skeleton of crustaceans composed mostly of chitin.

Glaucothoa (plural = glaucothoe): Transition body stage between larval and benthic forms.

Gonopods: Male sexual organs located under the abdominal flap.

Gonopores: Paired egg extrusion openings located on the coxa of females' second walking legs.

Hemolymph: The fluid in the body cavity and tissues that functions as blood.

Hepatopancreas: Digestive gland that secretes digestive fluid.

Mandible: The most anterior of three pairs of mouth parts, used to bite and crush food.

Maxilliped: A thoracic appendage that functions as a mouth part.

Merus (plural = meri): The fourth segment from the dactyl end of the crustacean limb, usually the longest of the segments.

Molting: Shedding of the shell, with the succession of a new shell.

Morphometrics: The science of measuring forms and structures of plants and animals.

Multiparous female crab: A female that has produced more than one clutch of eggs and embryos.

New-shell: A crab with a shell that is approximately 2–12 months (red and blue), or 2–20 months (golden and scarlet) post ecdysis, with sharp dactyl, few or no scratches, and little or no growth or epifauna.

Old-shell: A crab with a shell approximately 13–24 months (red and blue), or 21–36 months (golden and scarlet) post ecdysis, characterized as having a darker coloration and significant scratching, wear, and abrasions as compared to a new-shell.

Oocyte: A maturing ovarian germ cell.

Oviduct: A tube that serves for passage of eggs from the ovary to the gonopore.

Ovum (plural = ova): A mature but unfertilized ovarian germ cell.

Ovary: The female gonad that produces ova and hormones that regulate female secondary sex characteristics.

Pereiopods: Chelipeds and walking legs 1–3.

Pleopods: Paired appendages associated with the abdomen, used by crabs for brooding eggs.

Primiparous female: A female that has produced only one clutch of eggs and embryos.

Propodus: The next-to-last segment of a crustacean appendage; forms the "hand" of the clawed appendage.

Pubescent female: A female that is capable of first sexual reproduction or having offspring. Pubescent females have full ovaries and will molt to maturity at their next molt, OR they have completed the molt to maturity but have not produced their first eggs and embryos.

Recently molted: A crab that has a shell approximately 2–8 weeks post ecdysis. Shells are very soft and may lose their shape when out of water.

Rostrum: A forward elongation of the carapace between the eyes.

Scaphocerite: A flattened plate on the second joint of the antenna.

Scaphognathite: Appendage in exhalent opening that pumps water.

Senescent: Growing old, aging. Senescent crabs have atrophied sex organs and very old shells.

Setae: Bristle-like structures.

Shell: Outer chitinous covering of a crab.

Shell-age: An estimate of the elapsed time since the last molt.

Soft-shell: A crab that is newly molted, 0–2 weeks post ecdysis. Shells are very soft and may lose their shape when out of water.

Spawn: To deposit eggs.

Spermatophores: Capsules containing numbers of spermatozoa produced by the male.

Thorax: In crustaceans, the middle portion of the body between the head and the abdomen.

Vas deferens: A tubular organ for spermatophore transfer and storage that also secretes seminal fluid.

Ventral: Referring to the underside of the body.

Very old-shell: A crab that has a shell greater than 24 months (red and blue) and greater than 36 months (golden and scarlet) post ecdysis. The difference between old-shell and very old-shell is that very old-shell has more wear and fouling than old-shell.

Walking legs: Pereiopods 2–4.

Zoea (plural = zoeae): Larval stage of a crustacean.

Index

A

B

C

M

N

O

P

R

S

T

V

W

Z