2. Life History

The available information on the life history of *Chionoecetes* crabs is incomplete at best. What does exist is sometimes contradictory and area-specific. A general life history follows.

Chionoecetes embryos, which are about 0.5 to 1 mm in diameter, hatch from late winter through early summer and proceed through three planktonic stages. The prezoeae exit the egg mass beneath the female's abdomen and begin an upward migration in the water column. Laboratory studies indicate that prezoeae begin molting to the zoeae I stage in a matter of hours after hatching. The zoeae I molt to the zoeae II stage about one month later. The settling stage, referred to as the megalops, is achieved in one additional month. Megalops are about 6 to 7 mm in carapace length and are frequently found in surface waters. Estimates of megalops stage duration range from 1 to 10 months.

The megalops migrates to the ocean floor where it molts into the first instar at about 3.5 mm carapace width. The first instars are miniature versions of adults in appearance. During successive instars, many changes occur in size, relative dimensions of body parts, and habitat occupied. Duration of instar stages, or the intermolt period, increases with crab age. Estimates of growth per molt, in percent carapace width, range from 15 to 32% and decrease as crab size increases.

Female Tanner crabs are estimated to pass through 12 instars before they terminally molt at the 13th instar in about 5 years. Male Tanner crabs are estimated to mature in about 6 years with the largest males passing through as many as 18 instars (Donaldson et al. 1981). There is an ongoing, spirited debate concerning the existence of a terminal molt for males at morphometric maturity (Donaldson and Johnson 1988).

Bipartite breeding behavior has been described for both Tanner and snow crabs (Somerton 1982). Females capable of first sexual reproduction which have not previously spawned (termed pubescent) molt to maturity and spawn for the first time in shallow water with smaller males and earlier in the year (January to May). Females which have previously spawned once (termed primiparous) or more than once (termed multiparous) breed in deeper waters with larger males and later in the year (April to May). Multiparous Tanner females tend to form mating aggregations containing mounds or pods several meters high (Stevens et al. 1994). Large, old-shell males undertake seasonal migrations that bring them in contact with aggregated females.

Hatching and release of larvae occurs just prior to copulation and extrusion of the new clutch of embryos. Estimates for clutch size range from 24,000 to 318,000 eggs for Tanner crab in Prince William Sound (Hilsinger 1976), 20,000 to 140,000 eggs for snow crab off eastern Canada (Watson 1969), and 6,000 to 130,000 eggs for snow crab in Japanese waters (Ito 1963).

Reproductive behavior reported for Tanner and snow crabs is similar (Watson 1972, Adams 1982, Donaldson and Adams 1989). Adams described three phases of reproductive behavior. The precopulatory phase may last several weeks and involves detection of a receptive female by a male. Once he detects her, the male grasps the female at the base of the walking legs and holds her in front of himself, rostrum to rostrum, until the copulatory act.

If the female is pubescent, the male will continue to grasp and assist the female during her molt to maturity (terminal molt). After the female has completed her molt,

the male grasper releases the molted exoskeleton and immediately regrasps the soft-shell female. At this stage the female has the adult-shaped abdominal flap.

During the copulatory phase the male positions the female upside down and beneath himself, sternum to sternum, and transfers spermatophores into the female's gonopores. This phase may last less than one hour.

In the postcopulatory phase, the male continues to grasp the female, which is now upright, until the fertilized eggs or embryos are extruded and attached to the abdominal appendages, forming the egg (or embryo) mass. This occurs shortly after copulation. Grasping marks are left on the walking legs of females that are mated as primiparous and multiparous crabs. Grasping marks usually are not found on walking legs of a pubescent female because mating normally occurs when she is in a soft-shell condition.

Multiparous females are capable of fertilizing eggs in the absence of males by using sperm stored in their spermathecae from previous mating. Paul (1984) estimated that females could produce two fertilized clutches in succession using only stored sperm.

3. Distribution

Crabs of the genus *Chionoecetes* can be divided into two groups based on depth distribution. The shallower water (continental shelf) species are Tanner and snow crabs. The relatively deepwater (continental slope) species are the triangle Tanner crab, grooved Tanner crab, and Beni-zuwai crab.

Snow crabs have the widest distribution and are found in cold waters of the Japan Sea east of the Korean Peninsula, the Sea of Okhotsk, Bering Sea, and northwest Atlantic. According to results of National Marine Fisheries Service (NMFS) surveys, snow crabs are not found around the Aleutian Islands. They do not occur south of the Alaska Peninsula, but are found in the Beaufort Sea, occasionally as far east as Cape Parry (Squires 1969). In the northwest Atlantic they are reported from Greenland south to Casco Bay, Maine. Kon (1996) reported snow crabs at depths of 450 m in the Sea of Japan.

Tanner crabs are reported from subtidal areas to 437 m and occur in the Pacific Ocean from Oregon to Alaska, in the Bering Sea, and adjacent to the Aleutian Islands. Igarashi (1970) reported Tanner crabs off Hokkaido in the Sea of Okhotsk.

Triangle Tanner crabs occur in the North Pacific from Oregon to Alaska, the Bering Sea, adjacent to the Aleutian Islands, and the Kamchatka Peninsula. They are reported from depths of 90 to 3,000 m (Garth 1958). Recent Aleutian Islands and Bering Sea fisheries for this species have averaged 878 and 948 m depths respectively.

Grooved Tanner crabs have a southern boundary in the Pacific Ocean off the California-Mexico border. Their distribution extends northward into the North Pacific, primarily adjacent to the Aleutian Islands, and in the Bering Sea with a reported depth distribution of 53 to 1,900 m (Garth 1958).

Beni-zuwai is restricted to the Sea of Japan and Okhotsk Sea. Yosho and Hayashi (1994) reported that the greatest abundance of this species was found at 1,000 m. Figures 12a-c show geographic locations mentioned in this book.

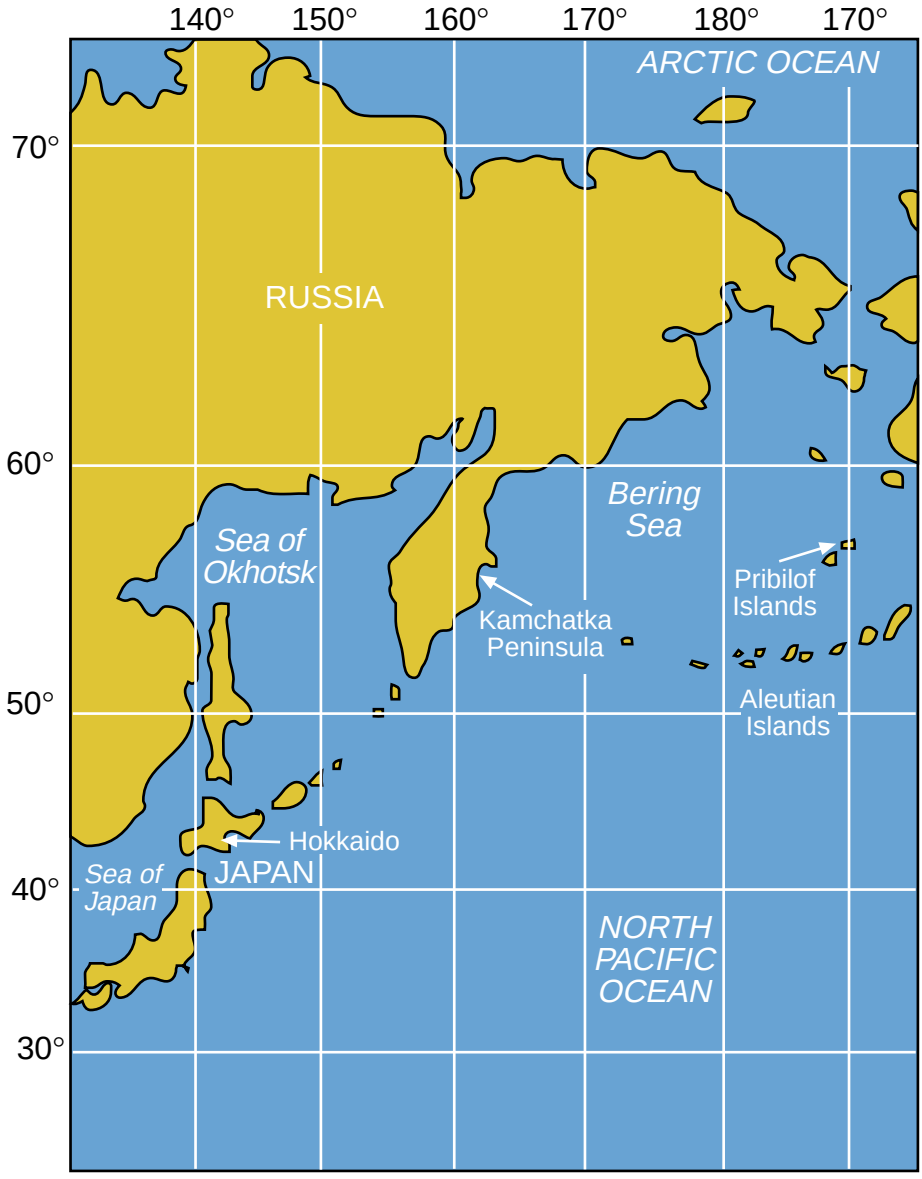


Figure 12a. Western North Pacific Ocean, with place names used to describe crab distribution in this book. (R. Quinones and D. Brenner)

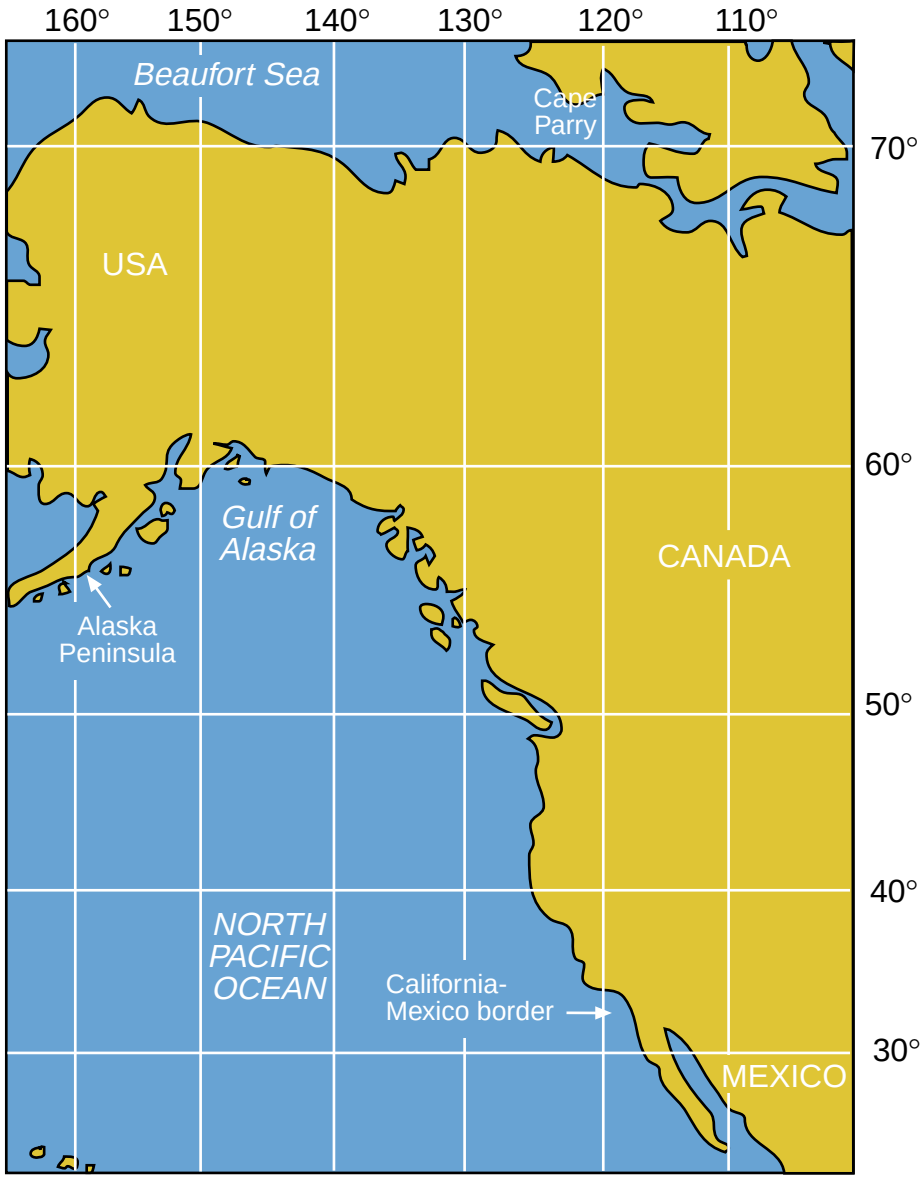


Figure 12b. Eastern North Pacific Ocean, with place names used to describe crab distribution in this book. (R. Quinones and D. Brenner)

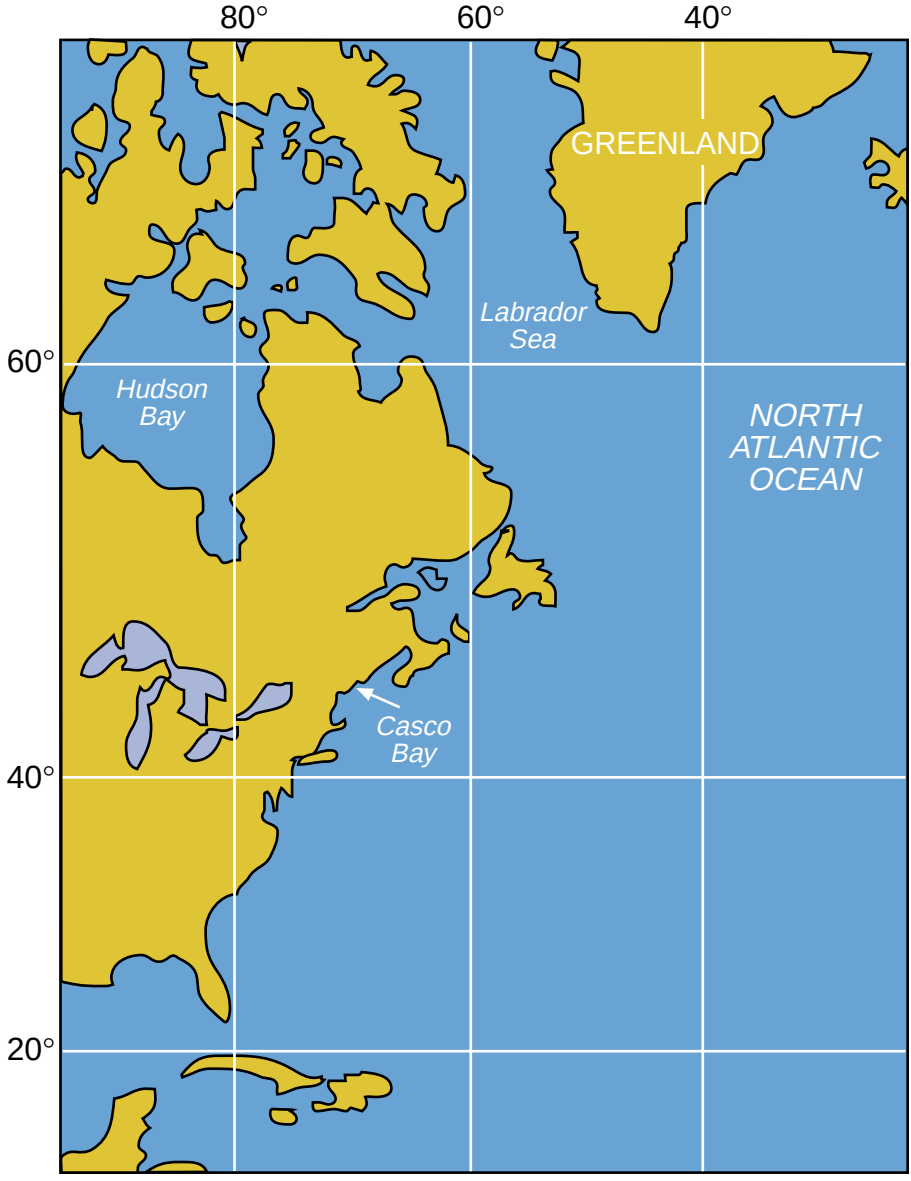


Figure 12c. Western North Atlantic Ocean, with place names used to describe crab distribution in this book. (R. Quinones and D. Brenner)

4. External Anatomy

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. Areas of the cephalothorax include frontal, gastric, branchial, and cardiac (Fig. 13). Mouthparts and antennae are located on the ventral side of the frontal region, while the ventral branchial region bears the locomotor appendages (pereiopods). The first pereiopods are modified as the chelipeds. The second through the fifth pereiopods are the walking legs (Fig. 14). The abdomen is composed of abdominal somites 1-6 plus the telson, which form the abdominal flap.

The shape of the abdominal flap can be used to determine the sex of the crab and the maturity status of females. Juvenile and adult males have a triangular shaped abdominal flap (Fig. 15a). Adult females have a circular abdominal flap that covers most of the ventral surface of the crab (Fig. 15b). Juvenile females have an abdominal flap that covers about two-thirds of the ventral surface (Fig. 15c). The abdominal flap of hermaphroditic individuals has a shape similar to juvenile females (Fig. 15d). Reproductive appendages including the pleopods (to which eggs are attached) of females and gonopods (sex organs of males) are located on the abdomen (Fig. 16a,b,c,d).

Determining the sex of very small crabs is difficult because the abdominal flap of the females may not be appreciably expanded. Sexing small crabs can also be accomplished by carefully lifting the abdominal flap and observing if gonopods are present (male) or absent (female). When sexing small crabs, a hand lens is recommended. As with juvenile females, hermaphroditic individuals are easily identified by checking under the abdominal flap and observing if gonopods (males), gonopores (females), and pleopods (females) are present (Fig. 16d).

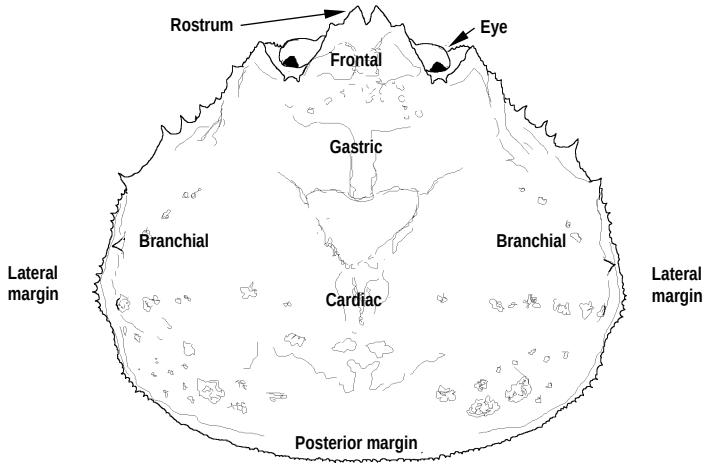


Figure 13. Major regions of the dorsal surface of a Chionoecetes *carapace. (L.S. Jadamec)*

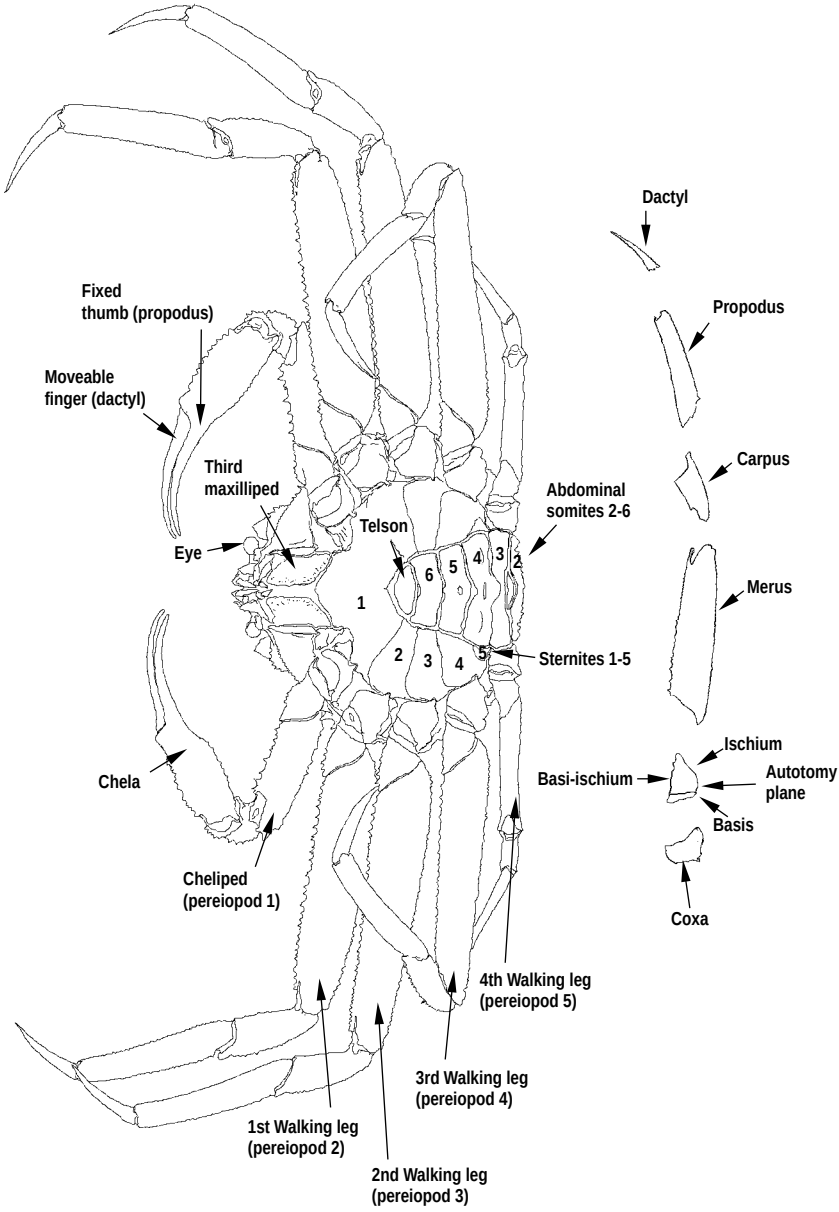
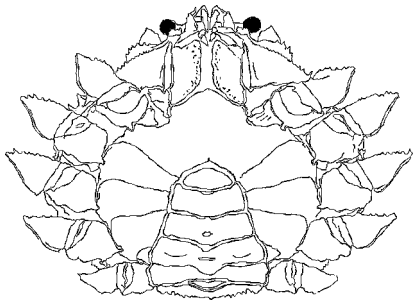
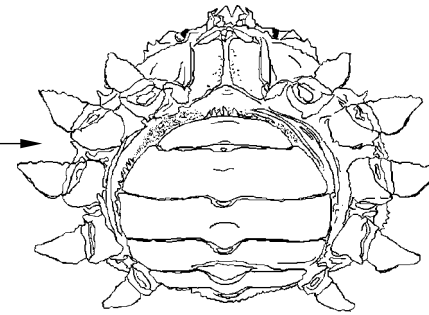


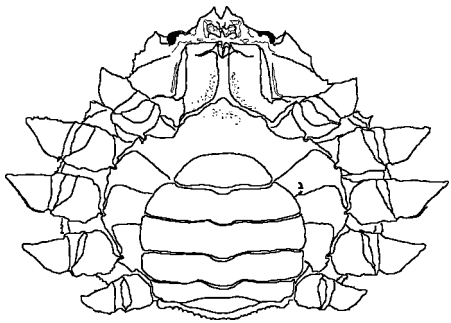
Figure 14. Ventral anatomy of a Chionoecetes *crab. (L.S. Jadamec)*



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

15b. Mature female crabs have a circular abdominal flap that covers most of the ventral surface.





15c. Juvenile female crabs have an abdominal flap that covers about $^{2}/_{3}$ of the ventral surface of the crab; fold back abdominal flap for sexing very small crabs.

15d. Hermaphroditic crabs have an abdominal flap similar in shape to juvenile females; fold back abdominal flap for identification.

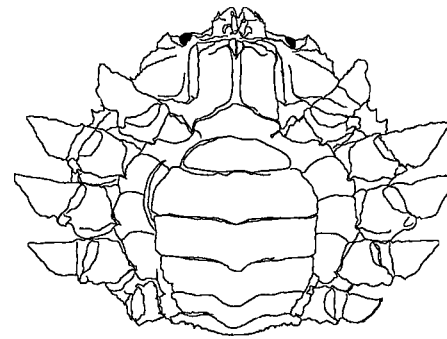


Figure 15. Ventral view of Chionoecetes *crabs (dorsal view of abdominal flap) identifying sex and maturity status: a. Juvenile or mature male. b. Mature female. c. Juvenile female. d. Hermaphrodite. (L.S. Jadamec)*

16a. Mature and juvenile male

Gonopods

Gonopores

Pleopods

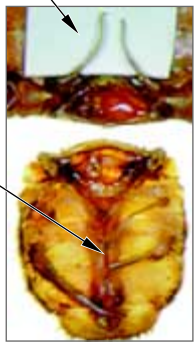
16b. Mature female

16c. Juvenile female

Gonopores

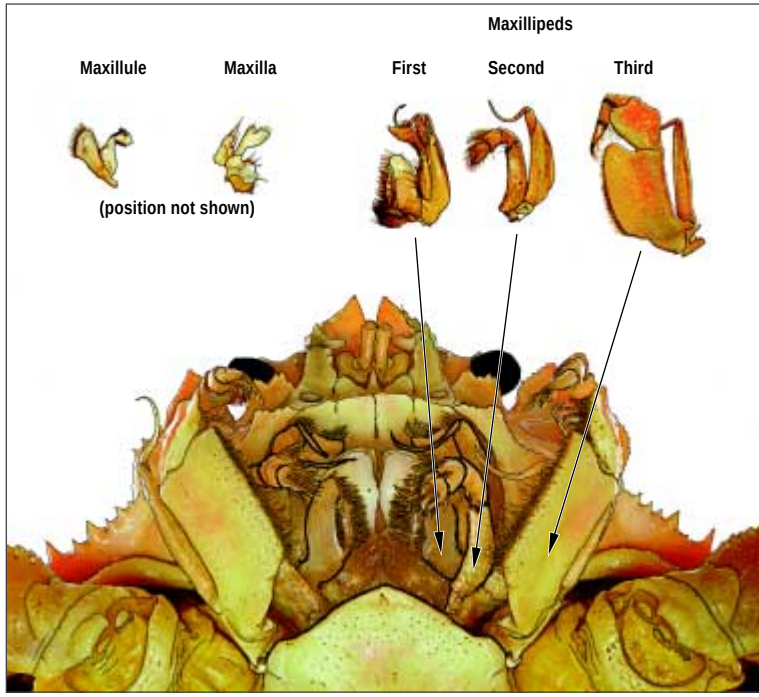
Gonopods

Pleopods

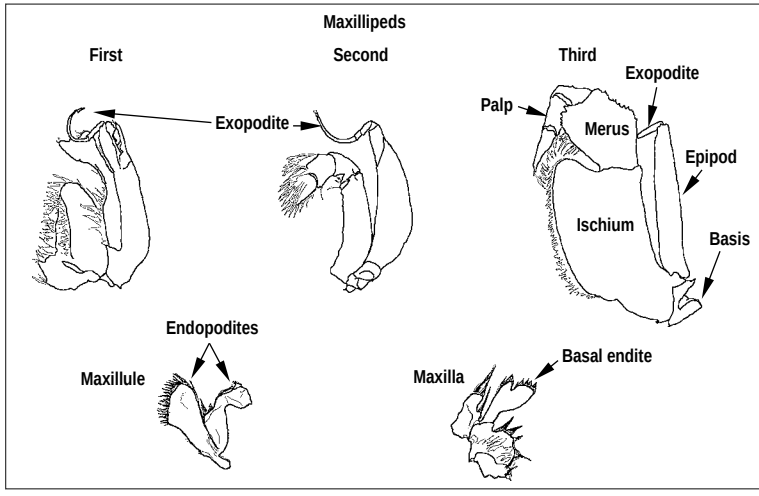


16d. Hermaphrodite

Figure 16. Ventral view of Chionoecetes *crabs with the abdominal flap open and reproductive appendages identified. (a. H. Pennington. b,d. L.S. Jadamec. c. E. Munk).*



17a



17b

Figure 17. Photograph and illustrations of the mouth parts of a Chionoecetes *crab: a. Photograph with the placement of the maxillipeds identified; maxillule and maxilla are located posterior and dorsal of the first maxilliped. b. Illustrations of the maxillipeds, maxillule, and maxilla with the major segments identified. (Photo H. Pennington, illustrations L.S. Jadamec)*

5. Internal Anatomy

Vas Deferens

The paired vas deferens are positioned in the dorsal cephalothorax below the level of the heart, and connect the testes (located to the anterior of the vas deferens and dorsally of the stomach) to the gonopods at the base of the 5th pereiopod. Vas deferens are filled with white, oval-shaped spermatophores. When mature, the vas deferens occupy much of the posterior quadrants of the body cavity, and spermatophores are apparent (Fig. 18a). In senescent males the vas deferens are much reduced in size (Fig. 18b).

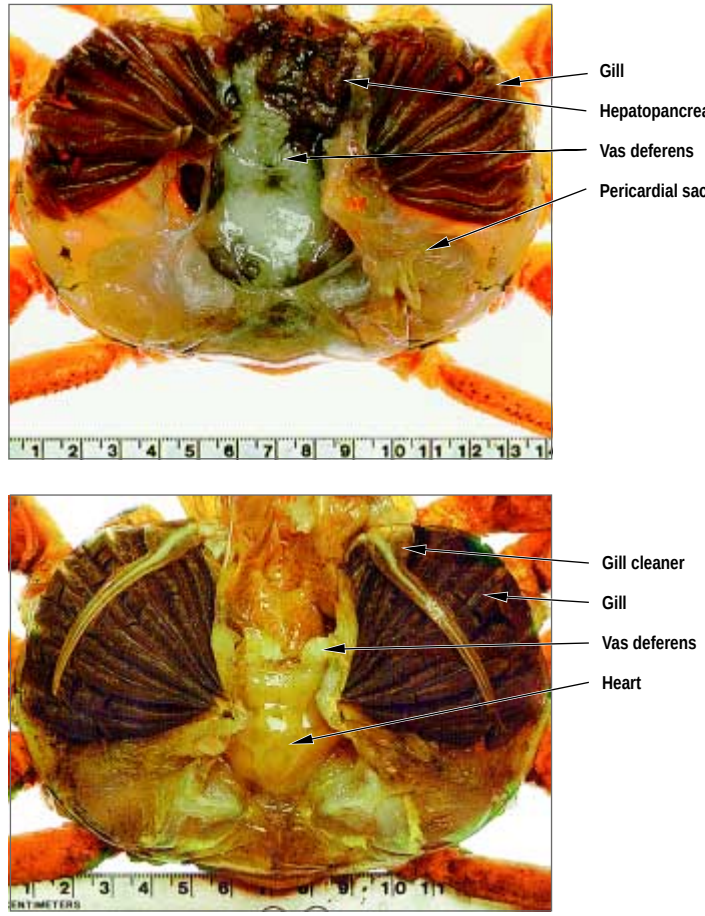
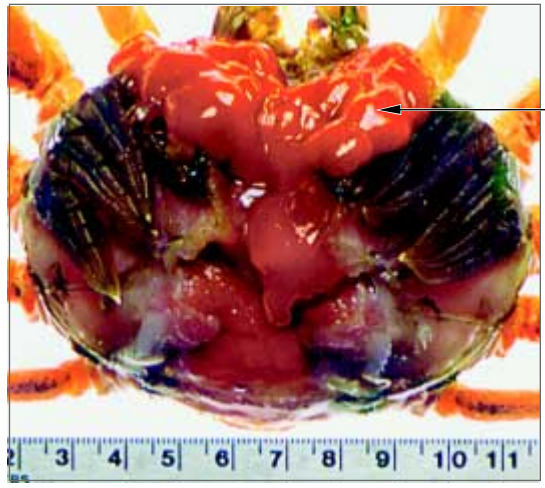


Figure 18. Dorsal view of adult male Chionoecetes *crab with the carapace removed: a. Full vas deferens typical of sexually mature males prior to mating. b. Atrophied vas deferens typical of senescent males. (H. Pennington)*

Ovary

Ovaries are positioned in the dorsal cephalothorax and are shaped as an elongated “H”. The right and left lobes are connected at the level of the heart. When mature, the posterior lobes extend into the abdomen and the anterior lobes extend to the level of the eyestalks. Paired white or translucent oviducts (tubes) leave the ovary at its ventral surface, pass ventrally through the cephalothorax, and lead to the gonopores (see Fig. 16b).

19a



19b

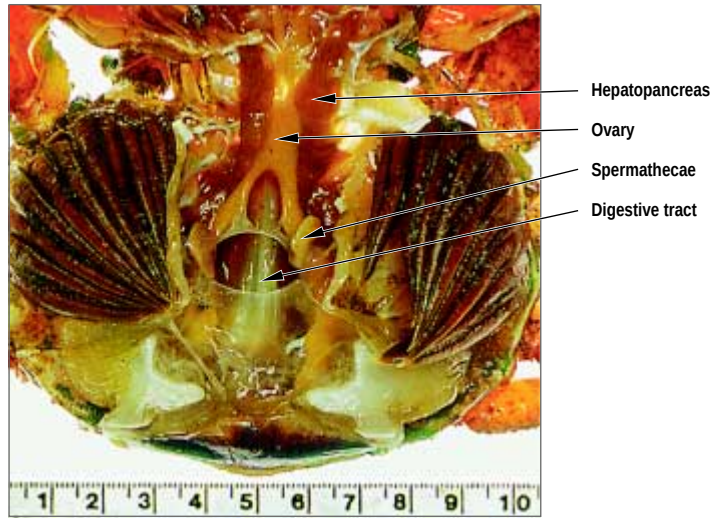


Figure 19. (This and facing page) Dorsal view of female Chionoecetes *crabs. a. An ovary after egg extrusion. b. A full ovary prior to egg extrusion. c. Very old-shell senescent crab. (a. E. Munk. b. D. Mercy. c. H. Pennington)*

Ovary Stages

In early development of a pubescent female's ovary and immediately after egg extrusion, the size of the ovary is much reduced relative to a fully developed, full ovary (Fig. 19a). The presence of developing oocytes imparts an orange color to the ovary. A fully developed ovary with oocytes can appear to occupy much of the body cavity (Fig. 19b) and is bright orange. Senescent female crabs are typically very old shell with atrophied ovaries (Fig. 19c).

Pubescent Ovary

Initially, the ovary is a white, thread-like structure that will increase in size as the ovary fills with white (undeveloped) oocytes. Once the ovary has become conspicuous, i.e., partially filled with oocytes, it will resemble an ovary (primiparous or multiparous) immediately after egg extrusion (see below).

Primiparous and Multiparous Ovary

Immediately after egg extrusion, the color and size of the ovary will range from white and much reduced (Fig. 19a) to dull orange and partially full depending on the quantity of oocytes remaining in the ovary. Prior to egg extrusion the ovary occupies much of the body cavity and has a bright orange color (Fig. 19b).

Senescent Ovary

This atrophied ovary is white-yellow or translucent and much reduced in size (Fig. 19c). It is no longer producing oocytes.

Spermathecae

Spermathecae are paired organs attached to the gonopore and oviduct. They are located medially on the right and left side under the ovary. In pubescent females the spermathecae are translucent and empty (not shown). In primiparous females the spermathecae are often partially full and white or translucent when empty (Fig. 20a,b). Primiparous female spermathecae are seldom full or turgid. Multiparous crab spermathecae are often full and turgid because sperm and ejaculate from successive matings may be present. They may also contain very little ejaculate if females have used stored sperm to fertilize clutches. Over time, multiparous crab spermathecae develop a dark band at the distal end (Fig. 20c,d). A senescent female's spermathecae appear empty without dark banding (Fig. 20e).

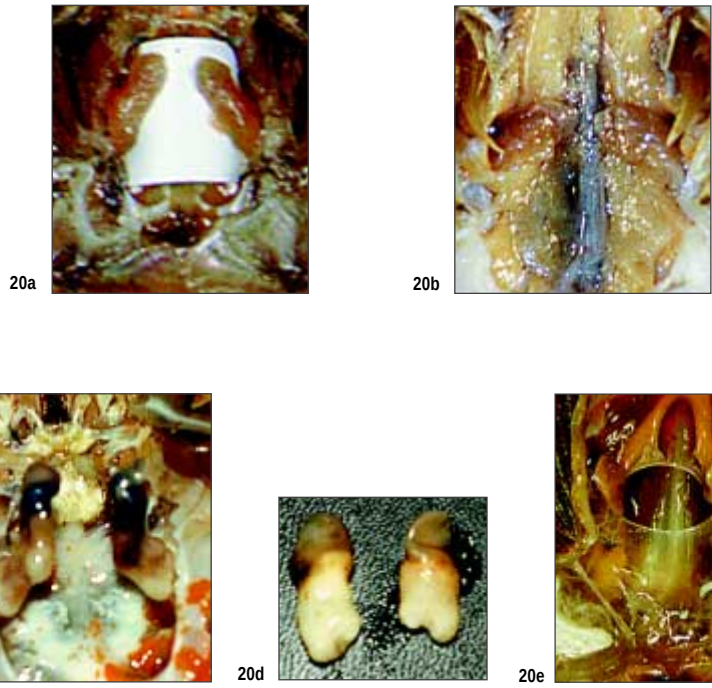


Figure 20. Spermathecae of female Chionoecetes *crab: a. Turgid spermathecae without dark banding. b. Partially full spermathecae without dark banding. c. Turgid spermathecae with dark banding. d. Removed spermathecae. e. Empty spermathecae without dark banding. (a. D. Mercy. b. L.S. Jadamec. c,d. W.E. Donaldson. e. H. Pennington)*