Biology of the Tanner crab *Chionoecetes bairdi* in Alaska: A Report to the Alaska Board of Fisheries

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FORWARD

This report was written to provide the Alaska Board of Fisheries (BOF) with background material on the Tanner crab, *Chionoecetes bairdi* for its March 1999 meeting. A brief summary of the report is given in the executive summary, more complete explanation is given in the body of the text, and the reader who wants even more comprehensive information on the various aspects of *C. bairdi* biology may wish to consult the cited literature. Another report also prepared for the March 1999 meeting, “Shellfish Keywords,” contains a glossary of some of the terms used in this report. Terms defined in the “Shellfish Keywords” report appear in **bold** the first time they appear in this report.

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EXECUTIVE SUMMARY

There are four species of the genus *Chionoecetes* in Alaska: Tanner crab *C. bairdi*, snow crab *C. opilio*, grooved Tanner crab *C. tanneri* and triangle Tanner crab *C. angulatus*. All four have been fished commercially but Tanner crab has by far the longest fishing history, with the first landings in 1953. It is also the largest and most valuable per pound of the four species. This report focuses primarily on this species.

Tanner crab are widespread in the North Pacific Ocean, ranging from the Oregon coast north to Norton Sound and west to Hokkaido in Japan and the Russian coast of the Bering Sea. They occur mainly on soft bottoms in depths ranging from shallow nearshore waters to over 200 **fathoms**[1], although they are most abundant for most of the year in depths of 40–50 fathoms. Recent genetic studies of Tanner crab in Alaska have detected differences between crab in two areas of Southeast Alaska, the Gulf of Alaska, and portions of the eastern Bering Sea.

Female Tanner crab reach a **terminal molt** upon maturity, but for male Tanner crab, the degree to which molting continues after reaching maturity is still debated. It appears that mature male Tanner crab molt at reduced frequencies, but the molting rate varies with population size and environmental conditions. When a male Tanner crab matures, its **chela** become relatively large compared to an immature crab of the same **carapace width**. Maturity occurs at 6–7 years old, with a maximum life span of over 12 years. A Tanner crab **recruit**ed to legal size averages about 2.2 lbs and is estimated to be 7 to 9 years old.

Tanner crab mate once per year in the spring. After mating the female extrudes a clutch of about 200,000 eggs. The eggs are then incubated under the abdominal flap for 12–15 months. The eggs hatch and are released shortly before the female mates again. If no male is available, females may fertilize their eggs with retained sperm from previous matings for up to two years. After hatching, the larvae swim free for about two or more months, settle to the bottom. During their first year they undergo 6 molts, but the period between molts gradually lengthens as the crab get older. By age three, Tanner crab molt only once a year. Crab that have not molted in the current year are known as **old-shell** crab or **skip molts**.

Tanner crab eat a variety of foods: clams, polychaete worms, shrimp, and crab including other Tanner crab. The mortality rate on larger crab is around 30% per year, although it is much higher on crab larvae, small crab and molting crab. They are preyed upon primarily by Pacific cod, Pacific halibut, sculpins, skates, octopus, and sea otters. Predation can be significant. A three year study in the eastern Bering Sea estimated that Pacific cod removed up to 90% of one and two year old Tanner crab. Diseases of Tanner crab include bitter crab syndrome**,** which renders the meat of the crab unpalatable and results in the death of the crab. Another fatal disease is black mat syndrome, a fungal infection. Nemertean worms can infest the crab egg clutches and consume virtually the entire clutch.

[1] Terms in **bold** are further explained in the report to the BOF titled "Shellfish Keywords."

INTRODUCTION

"Tanner crab" were named after Lt. Commander Z. L. Tanner, commander of the Bureau of Fisheries steamer *Albatross*, whose explorations produced the early Pacific records of the genus *Chionoecetes*. Four different species of the genus are sometimes called "Tanner crab" in Alaska: *Chionoecetes bairdi* Tanner crab, *C. opilio* snow crab, *C. angulatus* traingle Tanner crab and *C. tanneri* grooved Tanner crab. Tanner crab and snow crab live in relatively shallow waters on the continental shelf, while triangle and grooved Tanner crab live in much deeper waters of the slope of the continental shelf.

All these species have been commercially harvested in the state, but Tanner crab has by far the longest fishing history, having been commercially harvested since 1953. They are almost exclusively the *Chionoecetes* species harvested for subsistence and personal use. Commonly called "Tanner crab" state-wide, *Chionoecetes bairdi* will be referred to as such in this report. *Chionoecetes bairdi* have also been officially given the common name of Tanner crab by the American Fisheries Society (Williams et al. 1988). Figure 1 shows the principal ranges of the four species in Alaska.

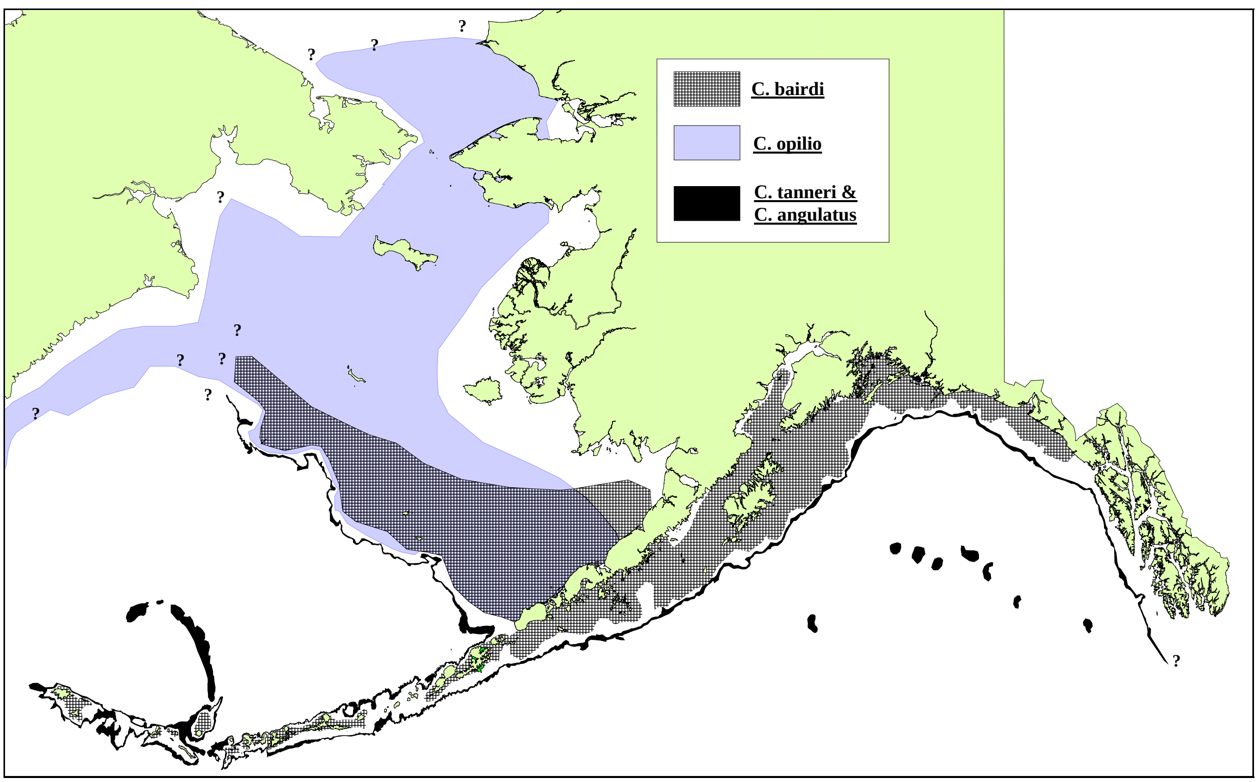


Figure 1. Principal ranges of four *Chionoecetes* species in Alaska.

Tanner crab are widespread in the north Pacific Ocean usually on muddy habitat, but sometimes also on sandy bottoms or on gravel in shallow waters. They typically occur in less than 100 fathoms. The species ranges from the Oregon coast, Gulf of Alaska, and the Bering Sea, as far north as Cape Navarin on the Russian coast (62^o N) and west to Hokkaido in Japan (Rathbun 1925; Slizkin 1990). It is the largest and fastest growing of the four *Chionoecetes* species with a maximum carapace width (CW) of over eight inches and maximum weight of about 6 pounds. Males may live over 12 years (Donaldson et al. 1981).

The smallest of the Alaskan *Chionoecetes* species is snow crab, *C. opilio*. It is less valuable per pound than Tanner crab, but it currently represents the largest total pounds harvested in the state. They are found from Japan, into the Bering and Beaufort Seas (Squires 1969; Slizkin 1990). In the Bering Sea, snow crab are generally found in colder waters than Tanner crab although their ranges overlap. In these areas of overlap the two species may interbreed producing hybrids (Karinen and Hoopes 1971; Johnson 1976). Snow crab also occur in the Atlantic Ocean from Greenland southwest to Maine. A significant harvest occurs off the Atlantic coast of Canada. Recent studies have shown that the Atlantic and Pacific populations of snow crab are genetically very similar (Merkouris et al. 1998).

Triangle and grooved Tanner crab are of intermediate size and occur mostly in a narrow band of deep continental slope water and on sea mounts at depths of around 350–700 fathoms although grooved Tanner crab have been captured at depths greater that 1000 fathoms (Pereyra 1967).

EXTERNAL ANATOMY

Crab bodies consist of a fused head and thorax (cephalothorax) and an abdomen. The main dorsal covering of the cephalothorax is known as the carapace. The maximum width of the carapace is used to determine the legal status of the males, generally 5.5 inches including the spines (5 AAC 35.060 - ADF&G 1998, Figure 2), but 5.3 inches in Prince William Sound. The abdominal flap is attached to the posterior end of the carapace. Its shape allows the external identification of both the sex of the crab and the state of maturity in the females (Figure 3). Attached to the crab body are 4 walking legs (pereiopods numbers 2–5) and the first pereiopod to which the claw (chela, pronounced “key-la”) is attached (Figure 4). The claw-bearing pereiopod is also known as the cheliped.

LIFE HISTORY OF TANNER CRAB

A significant body of literature reviews the distribution, biology, and life history of Tanner crab (Hilsinger 1976; Donaldson and Hicks 1978; Somerton 1981a; Bowerman, et al. 1983; Bowerman and Melteff 1984; Paul and Paul 1992; Stevens et al. 1993; Paul and Paul 1995). Most research has been directed at populations around Kodiak and in the Bering Sea, with few life history studies being conducted in Southcentral and Southeast Alaska. Significant differences often exist in key life history parameters between different **stocks** and within the same stocks at different population levels or depths. For example,

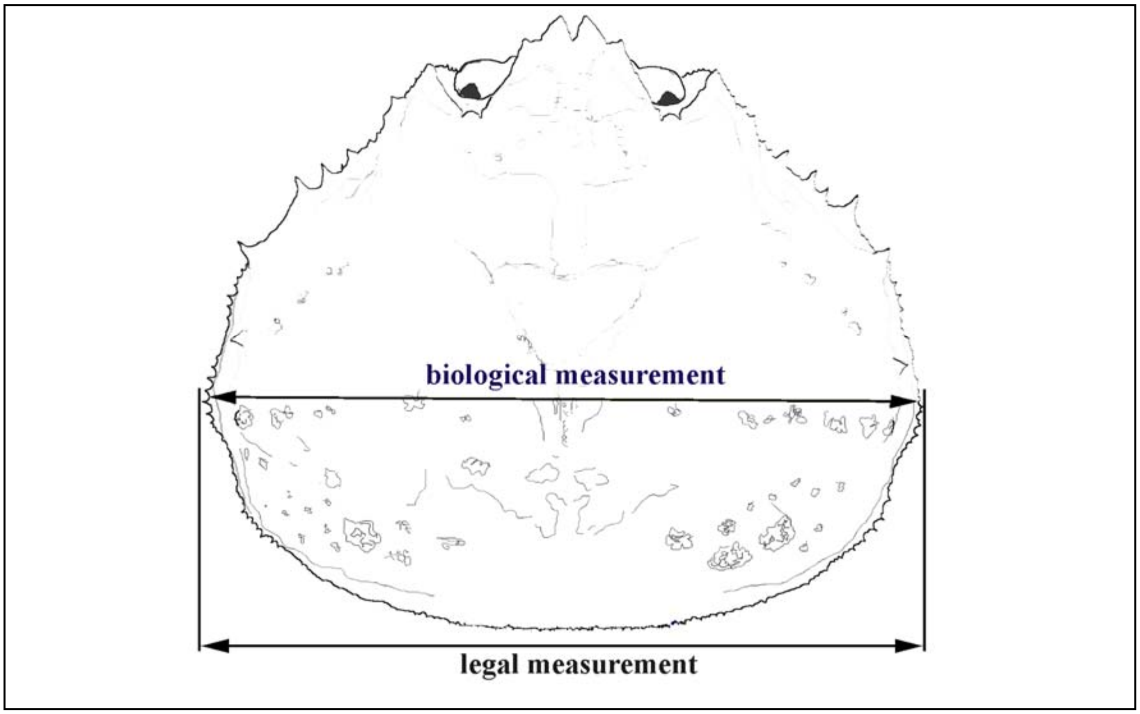


Figure 2. Carapace measurements made in Tanner crabs. Biological measurement is made inside the spines while the legal measurement is outside the spines.

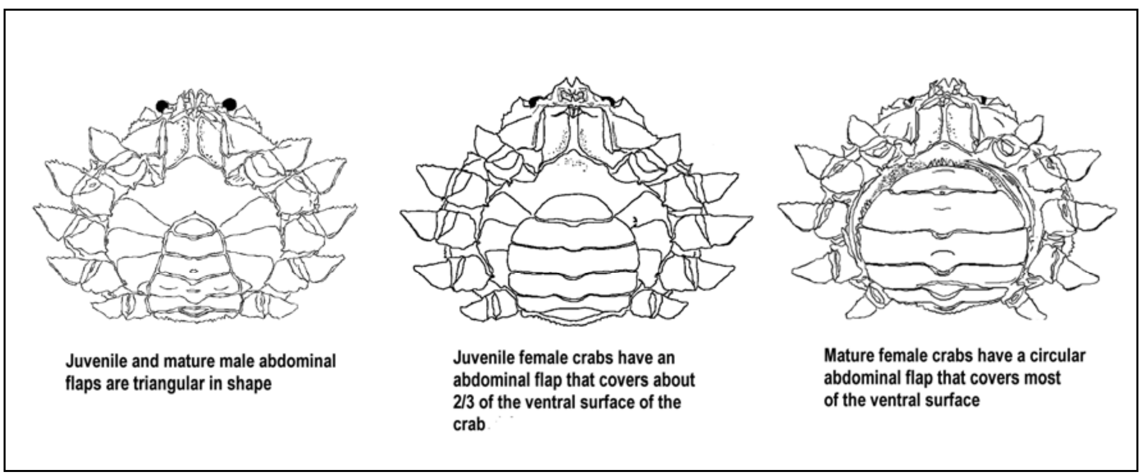


Figure 3. Abdominal flaps on male, juvenile female, and mature female Tanner crabs.

differences exist in the size at maturity of male Tanner crab of Bristol Bay and the Pribilof Islands (Somerton 1981b) although these differences may be explained by differences in depth rather than as the result of separate stocks. Differences also exist in the size of maturity for female Tanner crab in Bristol Bay over time, (J. Zheng, Alaska Department of Fish and Game, Juneau, personal communication). Therefore, caution must be used both in generalizing specific research results to Tanner crab statewide and over long time periods.

Reproductive Biology

Reproduction of Tanner crab has been extensively studied both in the laboratory and in the field (Donaldson et al. 1981; Paul 1984; Donaldson and Adams 1989; Stevens et al. 1993). The study of reproduction in Tanner crab is complicated by the fact that several issues regarding maturity are still unresolved. The literature is not consistent in the terms used for the various stages of female maturity, but will follow here those of Sainte-Marie (1993). In females, four distinct stages are generally recognized: 1. Immature females with undeveloped ovaries, 2. Pubescent females which have a small abdominal flap (Figure 3) but have ripe ovaries and will become fully mature with their next molt, 3. Primiparous females with their first egg clutch and a wide abdominal flap, and 4. Multiparous females that have had a prior egg clutches and have old or very old shells. It is agreed the primiparous females reach a terminal molt and do not molt again. Although the size at which female Tanner crab reach their maturity molt varies greatly, 80 mm seems to be a reasonable long-term average (Hilsinger 1976; J. Zheng, Alaska Department of Fish and Game, Juneau, personal communication).

Male Tanner crab go through at least three maturation stages. Immature crab have undeveloped gonads. Physiologically mature crab produce spermatophores, but still have a relatively small claw (morphometrically immature). These crab may be as small as 40 mm CW (Paul and Paul, 1989), but their small claw status apparently puts them at a disadvantage when mating in the wild (Stevens et al. 1993). Between 110 mm and 115 mm CW, male Tanner crab undergo a molt in which their claw grows relatively large (morphometrically mature). The debate continues whether these large-clawed crab molt again (Conan and Comeau 1986; Donaldson and Johnson 1988; Dawe et al. 1991). Data suggesting that large-clawed male snow crab, *C.opilio* do not molt again may not be applicable to Tanner crab. Recent analysis suggests that the rate at which large-clawed male Tanner crab molt varies widely by time and area from very low rates to perhaps 15% or more (Zheng and Kruse 1999, unpublished).

First discovered in Kodiak Island waters, there appears to be two distinct types of reproductive behavior (bipartite spawning). Primiparous females were found mating in shallow waters in isolated pairs while multiparous females mated in large aggregations in deeper waters (Stevens et al. 1993). Large mounds of 50–300 females were surrounded by a ring of mating pairs and unmated males. These mating aggregations were discovered by submarine in 1991 in 75 fathoms of water in Chiniak Bay off Kodiak Island (Stevens et al. 1994).

When female Tanner crab reach their terminal molt upon maturity, they produce an egg clutch annually without further molting. Observations of shell condition suggest that they may produce another four clutches of eggs before dying. Upon their maturity molt, females are sexually receptive for 21 days. Mating occurs sternum to sternum, with the male using his pleopods to insert spermatophores and seminal fluid into the female gonopores. This initial mating of the primiparous female occurs while the carapace is still soft, and extrusion of the egg clutch soon follows (Adams and Paul 1983). These females are attended and clasped by males in premating embraces lasting from 14 to 151 hours in the laboratory (Adams, 1982). During this period, the interactions of the male and female are intricate, involving a number of activities which were repeated in numerous mating events such as abdominal flapping, antennal flicking, and assisting in the female molt (Adams, 1982; Donaldson and Adams 1989).

Primiparous females mate in the soft-shell condition, whereas multiparous females are hard shelled and mate immediately after they have hatched their previous egg clutch. Egg hatch occurs slightly later in the year than the peak of the primiparous female molt and mating. In contrast to primiparous females in their soft-shell condition which are unable to resist the males and are grasped lightly, multiparous females are aggressively grasped on the meri (plural of **merus**) of their first walking legs by the male and later show grasping mark scars (Donaldson and Adams 1989). Multiparous females vigorously resist the mating activities. Donaldson and Adams (1989) thought this insured reproductive success because only those males with the most stamina mated. Although multiparous females can retain enough sperm from prior years' mating to fertilize two or three clutches of eggs without mating again, successive clutches are usually less full than those produced immediately after mating (Paul 1984). The receptive period of multiparous females may range from one to seven days (Paul and Adams, 1984), so the window of opportunity is fairly short.

Mating activity (clasping) occurs in late spring in the Gulf of Alaska, probably between late March and early June in Southeast Alaska, with newly mature females generally mating earlier in the season, beginning as early as November in some areas (Rich MacIntosh, National Marine Fisheries Service, Kodiak, personal communication). Multiparous females produce 24,000–318,000 embryos per brood (Hilsinger 1976), varying with body size (Adams and Paul, 1983).

Larval Biology

Hatching and release of larvae occurs just prior to mating and extrusion of the new clutch of embryos. The larvae proceed through three planktonic stages. The prezoea exit the egg mass beneath the females abdomen and begin an upward migration in the water column. Laboratory studies indicate that prezoea begin molting to the zoea I stage in a matter of minutes, usually less than 30 minutes, after hatching (Tom Shirley, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, personal communication). The zoea I molt to the zoea II stage about one month later (Incze et al. 1982). The settling stage, called megalopa, follows in about a month, although the length of each of the larval stages varies dependent upon water temperature and food supply (A. J. Paul, University of Alaska Fairbanks, Seward, personal communication). The prezoea and zoea 1 and 2 are described and illustrated by Haynes (1973, 1981), the megalopa by Jewett and Haight (1977), Figure 5. Megalopa are frequently found in surface waters before migrating to the ocean floor where they molt into the first benthic stage which resembles the miniature adult form.

Age and Growth

The study of growth in Tanner crab is complicated by the fact that all hard structures are shed during molting. No age rings are laid down and so age must be inferred from analysis of size frequencies. This technique is reasonably accurate at smaller sizes when combined with growth-per-molt information, but as crab get older, slow and fast growing members of a cohort overlap with other cohort groups, complicating the size frequency analysis. Growth per molt information can be gathered by holding crab and measuring them before and after molting. Figure 6 shows the width frequencies of male and female crab from Prince William Sound. It can be seen than both sexes have similar growth patterns until about 60 mm CW, the size at which females begin to cease molting and several year classes begin to accumulate. Males may molt several more times but distinct year classes are impossible to distinguish in these larger crab. Pioneering work in age and growth of Tanner crab was done in the Gulf of Alaska during the early 1970s (Donaldson et al. 1981). It should be remembered that considerable variability exists in Tanner crab growth between areas and within the same stock over time.

Each benthic stage of crab is known as an instar. In the northern Gulf of Alaska, the first instar is only about an 1/8 inch wide and lasts for about 2 months. The young crab molt six times in the first year, increasing about 30% in size per molt. The intermolt period gradually lengthens until by age three the crabs molt only once a year. Donaldson et al (1981) suggested that the maximum age of males could easily be over 12 years and for females more than 9 years.

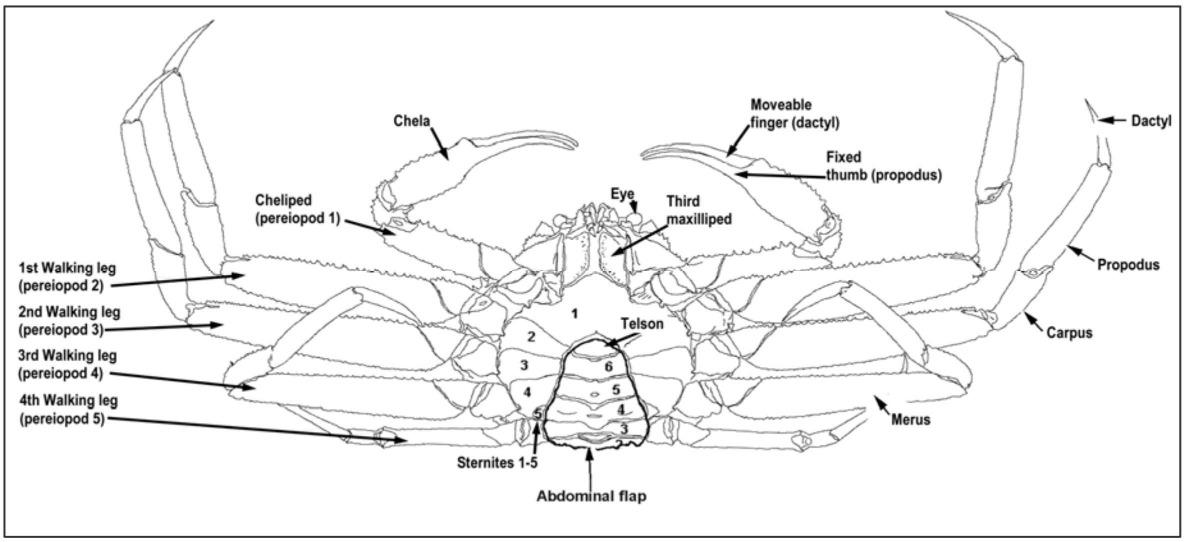
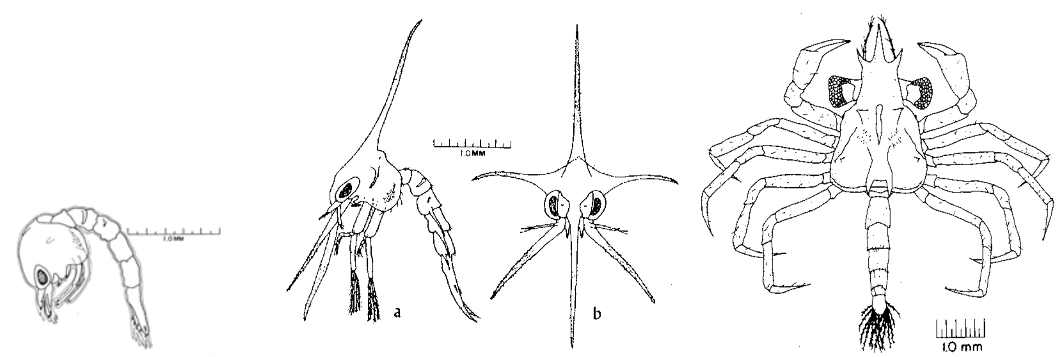


Figure 4. External ventral anatomy of the Tanner crab.



Prezoea stage (Haynes 1973) **Stage I Zoea (Haynes 1973)** **Megalopa (Jewett and Haight 1977)**

Figure 5. Larval stages of the Tanner crab *Chionoecetes bairdi*.

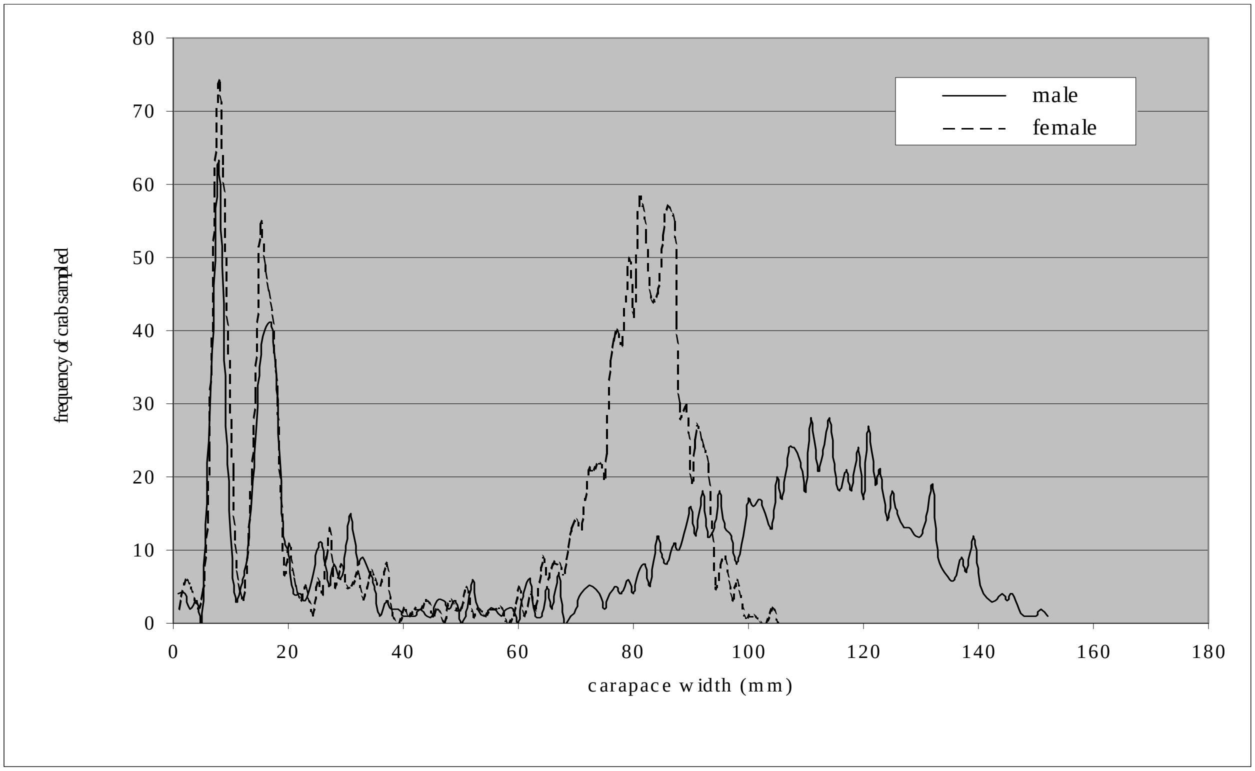


Figure 6. Length frequencies of Tanner crab in Prince William Sound, 1989.

Migration

Migratory movements of tagged crabs in the Kodiak area seem to follow two differing pathways (Donaldson 1980). Tagged crab in bays tend to move to, then remain in, offshore areas as they grow. Those tagged in offshore areas remain in offshore areas. For the most part, tagged crab did not move far from their release sites, mean distance between tagging and recapture locations was only 24.0 km (15 mi). On Kodiak Island, females mating in shallow waters were mostly new-shell primiparous while those mating in deeper waters were found to be old-shell multiparous. This also would indicate an offshore migration with age (Stevens et al. 1993). Observations of molting aggregations in Southeast Alaska suggest an upward movement by larger males into the lower littoral zone during the spring molt (K. Imamura, Alaska Department of Fish and Game, Juneau, personal communication).

Feeding and Food

The principal food items in the diet of Tanner crab are clams, other crab (including smaller Tanner crab), barnacles, shrimps, polychaetes, ophiuroids, and fish (Paul et al. 1979; Tarverdieva 1981; Jewett and Feder 1982, 1983). As cited by Jewett and Feder (1982, 1983), Tanner crab are significant predators of smaller members of their species. Food species and relative importance of specific food sources may be dependent on local availability and abundance of prey and differ from those found around Kodiak by Jewett and Feder (1982).

Jewett and Feder (1983) examined food consumption rates. Small crab (41–99 mm CW) generally fed to capacity more often than did larger crab (120–179 mm CW). This was expected as smaller crab experience greater molting frequency and require a greater energy demand. Food consumption was also noted to be greater for new-shell crab in comparison to old-shell crab. Presumably this is because tissue growth occurs immediately after molting and metabolic reserves are accumulating in preparation for the next molt (Lockwood 1967).

SOURCES OF MORTALITY

Predation

Primary predators of Tanner crab are demersal fish, such as Pacific cod *Gadus macrocephalus*, tom cod *Microgadus proximus*, skates (Livingston and deReynier 1996), and Pacific halibut *Hippoglossus stenolepis*, and also larger Tanner crab (Jewett and Feder, 1982), and octopus. In parts of their range where they occur in depths less than 40 fathoms, sea otter are also an important predator.

Predation may be quite significant. Predation mortality of Tanner crab by Pacific cod was estimated to be about 84%, 95%, and 94% of the population of age 1 crab during 1981, 1984, and 1985 respectively (Livingston 1989). More long-term work is needed to determine if predation on young crab is a controlling factor of mature crab populations (Livingston and deReynier 1996).

Parasites and Disease

Tanner crab can be attacked by a blood parasite that causes “bitter crab disease.” Caused by a single celled dinoflagellate of the genus *Hematodinium* (Meyers et al. 1987 and 1990; Imamura and Woodby 1993), this organism is of similar size to the crab blood cells and by late stages in the disease virtually all the crab blood cells are replaced by the parasite. The parasite gives the crab shell an ivory or pinkish–ivory color and imparts an astringent, bitter taste to the crabmeat, hence the disease has been termed bitter crab disease or bitter crab syndrome. Up to 40% of crab in early stages of infection exhibit no external symptoms but its presence can be detected by microscopic examination of the crab blood (Urban 1997). A similar species described by Newman and Johnson (1975), infects blue and cancrid crabs on the east coast of North America. In the Bering Sea, a similar parasite has also been identified in snow crab.

In 1985 Dr. T. Meyers (ADF&G Pathology Lab, Juneau) first formally identified the disease problem from samples collected by ADF&G fisheries biologist, C. Botelho after processors began reporting bitter, off-taste or unpalatable crabmeat in Tanner crab taken in certain areas in Southeast Alaska. Subsequent studies revealed a widespread range for the disease (Pearson and Meyers 1992). While the exact method for transmission of the disease is not known, it is thought that disposing of infected crab bodies by processors may contribute to spreading the disease to uninfected areas. Eight years of blood sampling in Alitak Bay on Kodiak Island has shown a continuing prevalence rate of 7–8% (Urban 1997), but some areas of the Lynn Canal in Southeast Alaska have shown much higher rates (Meyers et al. 1987, 1990).

Another lethal Tanner crab disease is black mat syndrome. Black tar-like incrustations on the crab shell are fruiting bodies while the fungal hyphae invade deep into the body of the crab. The disease prevents molting (Sparks 1982) and is eventually lethal to the crab.

Nemertean worms (Phylum nemertea) of the genus *Carcinonemertes* have been found to infest the egg clutches of Tanner, king and Dungeness crab (Wickham and Kuris 1989). Predation on the eggs can be severe, destroying virtually the entire egg clutch. The infestation in Tanner crab is highest in those crabs off Kodiak Island and Cook Inlet. At some survey stations, prevalence can reach up to 70% (ADF&G Trawl Survey Database).

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